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STATE ACID RAIN RESEARCH AND SCREENING SYSTEM  
VERSION 1.0 USER'S MANUAL

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## NOTICE

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## ABSTRACT

The Environmental Protection Agency has overseen the development of a compliance planning system that has been delivered to over 40 state regulatory commissions. STARRSS (the STate Acid Rain Research and Screening System) is a PC-based integrated information and modelling system that was developed to assist commissions and utilities in their evaluation of acid rain compliance plans. STARRSS gives analysts the ability to:

- ▶ Evaluate the costs and risks of specific compliance plans
- ▶ Develop compliance plans through one of three STARRSS optimization methodologies.

As a decision support tool, STARRSS uses a multiple-scenario, risk-assessment approach. The model can use three different user-specified forecasts for most input data items. Through a Monte Carlo process, STARRSS simulates hundreds of scenarios for a particular compliance strategy, selecting one of these three values during each scenario, based on user-specified probabilities. Therefore, a strategy is exposed to the full uncertainty of future events, such as varying allowance prices, fuel prices, construction costs, or generating unit operating characteristics. These multiple simulations yield a distribution of cost estimates that represent the range of possible costs for a compliance strategy. Working with this distribution, the user can see the level of economic or business risk inherent in a particular compliance strategy.

Although STARRSS ranks the plans based on the expected value of compliance costs, this is not meant to imply that the least-cost plan is the best. The risks that STARRSS quantifies must also be taken into consideration. The level of risk that a utility is willing to bear is a major factor in the decision to adopt an emissions reduction option. The central objective of the STARRSS system is not to identify the best compliance strategy for decision-makers, but to provide a decision-support screening tool that will help organizations identify good strategies (low cost, combined with acceptable levels of risk) that deserve further detailed analysis.

STARRSS requires databases representing utility systems for use as input files. To facilitate the process of database development and refinement, RCG/Hagler Bailly has developed databases to model all of the major utilities affected under the CAAA. These databases contain publicly-available information for all of the generating unit data and allowance allocation data required of STARRSS. Relevant databases have been included with each STARRSS delivery to serve as a starting point for further database development. State public utility commissions have received databases for all utilities within their jurisdiction, including multi-state holding companies and power pools.

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## 1.0 INTRODUCTION

The acid rain provisions included in Title IV of the 1990 Clean Air Act Amendments (CAAA) mandate that many electric utilities substantially curtail their sulfur dioxide (SO<sub>2</sub>) emissions by 1995 -- with even more stringent environmental limits taking effect in the year 2000.<sup>1</sup> These affected utilities must file compliance plans with the U.S. EPA and state public utility commissions to indicate how they intend to reduce their SO<sub>2</sub> emissions to allowable levels. As they review these compliance plans, state regulators will play a critical role in determining the success of the CAAA. Whether they are asked to formally pre-approve compliance plans or not, commissions will have considerable influence over utilities' compliance decisions. Therefore, in determining what constitutes a "good" compliance plan, commissions will have to address the following questions:

- ▶ Is the utility's preferred plan the least-cost solution?
- ▶ What other compliance strategies should the utility be considering?
- ▶ Are the utility's assumptions about control costs reasonable?
- ▶ Has the utility performed a thorough analysis of how changes in technology costs and fuel/allowance market prices may affect different compliance strategies?
- ▶ How risky is the utility's preferred plan?
- ▶ Can this risk be mitigated, and how much would such mitigation cost?
- ▶ Should the utility be a buyer or a seller in the SO<sub>2</sub> allowance market -- and to what extent?
- ▶ What is the value of flexibility (in terms of being able to change strategies if future circumstances warrant)?
- ▶ What is the value of implementing a diverse set of compliance options versus a strategy which focuses on a single compliance option?

STARRSS (the S**T**ate A**C**id R**A**in R**E**search and S**C**reening S**S**ystem) is an integrated database and modelling system that is designed to assist the U.S. EPA and state regulatory commissions in answering these questions.

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<sup>1</sup> An excellent presentation of the details and issues surrounding Title IV of the CAAA can be found in reference 1 (Appendix E).

STARRSS is a screening tool that is based on scenario analysis and risk management techniques. Designed to run quickly on a personal computer (an IBM PC AT or IBM-compatible PC with an 80286 processor or better), STARRSS focuses on the comprehensive analysis of many compliance strategies. Of particular interest is how these strategies are affected by uncertainty and market volatility. Therefore, as a screening system, STARRSS has been designed for breadth rather than depth. STARRSS was developed to identify compliance strategies that deserve further, more-detailed analysis.

Considering the immediacy of the needs for such a system, (Phase I compliance plans are due in 1993), the development schedule for STARRSS has been divided into two stages. Version 1 is a simplified version that was made available in mid-1992. A Version 2 of the program will incorporate more sophisticated algorithms such as full production cost modelling and specific year-by-year analysis capabilities.

Version 1 STARRSS offers users three distinct capabilities:

- 1) The ability to research or verify the costs and operating impacts for compliance options at affected generating units;
- 2) The ability to evaluate and compare the costs and risks associated with specific compliance strategies; and
- 3) The ability to develop, evaluate and compare a set of suggested compliance strategies that are generated by an "optimization" process.

The term "optimization" is used loosely in the context of STARRSS. True compliance planning optimization would entail much greater data requirements and computing power than is needed for the STARRSS level of screening analysis. In addition, an optimization algorithm will only determine the "best" strategy based on pre-specified input assumptions. Considering the uncertainties that surround compliance planning, no one strategy can be declared "optimal." Also, since political and regulatory pressures can influence the adoption of various compliance strategies, true optimization based on one set of economic assumptions would be myopic.

## TERMINOLOGY

An affected unit refers to any of the almost 2000 generating units that will be given emissions allowances during Phase I or Phase II of the acid rain program. Many units in the country do not emit SO<sub>2</sub> or are too small to be targeted by the CAAA and are therefore "unaffected units."

A compliance option is an individual course of action that the owner of an affected unit can take (e.g., scrubbing or fuel-switching at a particular unit, pursuing a qualified conservation program, purchasing allowances).

A compliance strategy is a collection of compliance options that will bring the utility into compliance with the CAAA regulations.

The STARRSS optimization approach selects a set of top plans from a list of potentially billions of compliance strategies. STARRSS then evaluates these top plans under a range of economic and operational uncertainties (such as changing fuel prices, allowance prices, and generating unit operations). Instead of developing a deterministic value for the total cost of a particular compliance strategy (i.e., one in which all input assumptions are fixed), STARRSS presents a distribution of compliance costs for each strategy and an associated expected value. The expected value is the average of the cost distribution; it provides a comprehensive consideration of all of the different possible economic outcomes and their likelihood of occurring. The cost distribution also provides the user with an estimation of the level of risk associated with a strategy.

For example, a STARRSS analysis of Strategy A may have an expected value of \$2 billion, plus or minus \$0.5 billion. In other words, considering potential fluctuations in the fuel and allowance markets and other parameters, Strategy A is likely to cost between \$1.5 billion and \$2.5 billion. Strategy B has a cost of \$2.1 billion, plus or minus \$0.1 billion. If one simply chose the optimal strategy based on a comparison of the plans' expected value for compliance costs, then one would pick Strategy A as the best plan. However, Strategy B is less risky, because has less variance in its total costs. A utility or state commission may want to choose Strategy B, realizing that the likely economic exposure is capped at \$2.2 billion, whereas there may be a substantial probability that Strategy A could cost as much as \$2.5 billion.

STARRSS give users the flexibility to compare the likely outcome for a variety of strategies.

## STARRSS' PRIMARY OBJECTIVE

The central objective of the STARRSS system is not to identify the best compliance strategy for decision-makers, but to provide a decision-support screening tool that will help organizations identify good strategies (i.e., low cost, combined with acceptable levels of risk) that deserve further detailed analysis.

### A Word of Caution

Compliance planning is a very complex task. Although every effort has been made to make STARRSS as "user-friendly" as possible, the system is rather data-intensive, by necessity. Compliance planning requires a great deal of information. However, while experimenting and becoming acquainted with the system, the user might want to define compliance options with just a few pieces of information. Specifically, the user might want to defer the entering of multiple-forecast estimates (High, Medium, and Low) for any data items; instead, the user should only input a Medium estimate at first.

### 1.1 HOW TO USE THIS MANUAL

This STARRSS User's Manual is organized in the following fashion:

**Chapter 2** discusses the **installation** of the system.

**Chapter 3** helps the user in "**Getting Started**" and understanding STARRSS. This section discusses keyboard conventions (i.e., how to move around the STARRSS menu system, how to work within the STARRSS screens, etc.) as well as the program's multiple-scenario Monte Carlo approach to compliance planning.

**Chapter 4** discusses the basics of using STARRSS databases (loading, saving, quitting from STARRSS, etc.).

**Chapters 5 and 6** describe all of the STARRSS inputs on an input screen by input screen basis. Chapter 5 discusses system-level information, and Chapter 6 describes unit-level information.

**Chapter 7** shows how to execute the program.

**Chapter 8** shows the **reporting and graphical** features in STARRSS. It also discusses various auxiliary files that can be produced during a STARRSS execution and exported to other programs (e.g., Lotus 1-2-3, Harvard Graphics, SAS).

**Chapter 9** explains **how STARRSS works**, describing how STARRSS uses the input data and how the output results are calculated.

**Chapter 10** discusses what is contained in the **delivered databases**. The references for all information are clearly documented, as are any calculations that were performed to generate input information. Chapter 10 includes a complete listing of all of the **"illustrative" data values** (such as forecasted allowance prices) that are in the database(s). **It is especially critical that the user change these values**, because they have been input into STARRSS merely to provide reasonable numbers while the user is learning how to run the system. As is the case for all information in the delivered database(s), but especially for these illustrative values, **neither EPA nor RCG/Hagler, Bailly recommend the use of these numbers**.

**Chapter 11** provides a background presentation of the various compliance options that are available to utilities, primarily focusing on a **description of pollution control technologies** (their operating characteristics, ranges of costs, etc.). **Chapter 11 does not represent a balanced or exhaustive list of possible compliance options**.

#### **Recommended Reading for New STARRSS Users**

<b>RECOMMENDED READING</b>		
<b>Installer:</b>	<b>Chapter 2</b>	<b>(Installing STARRSS)</b>
<b>User:</b>	<b>Chapter 3</b>	<b>(Getting Started/Understanding STARRSS)</b>
	<b>Chapter 4</b>	<b>(Files)</b>
	<b>Chapter 9</b>	<b>(How STARRSS Works)</b>
	<b>Chapter 7</b>	<b>(Execution)</b>

Chapter 2 (Installation) is an essential starting point for installing STARRSS onto a user's PC. **A basic level of understanding of PCs and DOS (IBM's Disk Operating System) is assumed.** If the user is not familiar with PCs, he or she should seek out the assistance of the system operator.

Once STARRSS is installed, the user should at least read Chapter 3 (Getting Started/Understanding STARRSS); the information contained in this chapter will provide the user with the basic knowledge of how to move around the system and input/modify data values. Chapter 4 will show the user how to load and save databases. **The user cannot do anything in STARRSS without loading a database first.**

Chapter 9 (How STARRSS Works) provides the reader with an understanding of how STARRSS calculates all of the costs and impacts of a compliance strategy. Chapter 7 (Execution) is required for understanding how to run the program.

STARRSS has been designed to be as "user-friendly" as possible. The system has an on-line Help facility (accessed by pressing the F1 key). However, **there is no substitute for reading all of Chapters 5 and 6 (the chapters that describe input data) prior to invoking STARRSS.**

Chapter 10 (Customized Databases) should be the next stop, since the user should be aware of how the information in the delivered database(s) was developed. The dangers of using the "illustrative" data cannot be overemphasized. As soon as the user feels comfortable with STARRSS, he or she should change the illustrative data values to those that are endorsed by his or her organization.

Chapter 11 (Compliance Option Descriptions) is a good resource for those who want a cursory description of pollution control technologies and other compliance options. Particularly since it identifies the strengths and weaknesses of different options, Chapter 11 can provide users with a strong background in various qualitative aspects of compliance planning as well as the quantitative issues.

Chapter 8 (Reports) is a convenient reference resource for explaining specific output report elements.

Lastly, several appendices (for listing data requirements, explaining warning messages, troubleshooting) have been included in this manual.

In reading through various chapters, the user will encounter some redundant statements. This redundancy is intentional. The STARRSS User's Manual has been organized to make each section as self-contained as possible. This should make it easier to use as a reference resource.



## 2.0 HOW TO INSTALL STARRSS

STARRSS is a PC-based modelling system. It is designed to run on an IBM or IBM-compatible personal computer (PC) with an 80286 processor or better. STARRSS is executed from the standard PC DOS operating system. **If the user is not familiar with PCs and/or PC DOS commands, he or she should seek the assistance of the computer system operator.**

### 2.1 SYSTEM REQUIREMENTS

REQUIRED HARDWARE
IBM PC AT or IBM-compatible with an 80286 processor or better
500,000 bytes of available core memory (RAM)

Although most PCs have at least 512,000 bytes of RAM, often some of that core memory is used by DOS and other computer system features (e.g., electronic mail, network communications). These other features may have to be temporarily removed from the PC's core memory in order to provide STARRSS with the necessary memory. This can be done by copying and editing the PC's CONFIG.SYS file; the user should consult his or her computer system manager for details.

Technically, STARRSS may not require the full 500,000 bytes of core memory. The program itself is only 342,000 bytes, but it also needs room to pull in databases and perform calculations. The amount of additional memory that these activities may require will depend on the size of the database and the nature of the study. Therefore the 500,000-byte requirement is not hard and fast. **If the user's PC has less than 500,000 bytes of available memory, the system's installation and testing can still proceed.** However, the user should remain aware of the potential for PC-memory-related problems and should monitor the system's memory requirements. The details about this process can be found in Chapter 4 (see Section 4.4, Memory Available).

#### SPECIAL NOTE

**Do not invoke STARRSS from within other programs (e.g., Windows, Lotus 1-2-3). Because of the memory constraints, STARRSS should be invoked from DOS only.**

## Expanded/Extended Memory

Some PCs have "expanded" or "extended" memory. STARRSS Version 1 cannot use either one; however, STARRSS Version 2 will be able to use one or both of these capabilities.

RECOMMENDED HARDWARE
<ul style="list-style-type: none"><li>▶ Hard disk<sup>1</sup> (with <u>at least</u> 1 Megabyte of disk space reserved for STARRSS, databases and output files)</li><li>▶ Color monitor: not essential, but a significant plus when viewing STARRSS' graphs</li><li>▶ Math coprocessor: not essential for Version 1, but will make a tremendous difference in execution speed with Version 2</li></ul>



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<sup>1</sup> Although the program can be run from a floppy disk, it will run much faster if it is run from a hard disk.

## 2.2 THE STARRSS DELIVERY

STARRSS is provided on a single high-density (1.2 Megabyte) floppy diskette, found in the front flap of this User's Manual. The diskette contains several files that are described in Table 2-1 below.

**Table 2-1. Files on Delivery Diskette**

Filename	Description
INSTALL.BAT	Installation Batch File
STARRSS.EXE	The STARRSS program
<utility>.SDB	Assorted Delivered Databases
<assorted>.BGI	Assorted Graphics Interface Files
STARRSS.HLP	STARRSS Help File
FILES.LST	List of STARRSS Files (delivery files, as well as those produced during STARRSS execution)

## 2.3 INSTALLATION (HARD DISK SYSTEM)

The following is a synopsis of the STARRSS installation process.

Installation Instructions - Hard Disk System	
▶	Check available disk space on hard disk ( <i>Must have at least 1 Megabyte free</i> )
▶	Place diskette in floppy disk drive
▶	Change directory to the floppy disk drive ( <i>type "a:"</i> )
▶	Type "install" to run the installation program
▶	Remove delivery diskette from floppy disk drive and store it in a safe place
▶	Change directory to the hard disk drive ( <i>type "c:"</i> )
▶	Change location to STARRSS directory ( <i>type "cd starrss"</i> )
▶	Type "starrss" to start the program

The user should make sure that there is at least 1 Megabyte (i.e., 1 million bytes) of available space on the hard disk (usually referenced as the "C" drive<sup>2</sup>). STARRSS itself does not need this much memory; the installation and execution of the system will probably work fine with half of that. However, without a **minimum** of 1 Megabyte of available space on the hard disk, the user is likely to be plagued by situations where a STARRSS run is terminated because of insufficient memory, especially when generating several sets of output reports from different runs.

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<sup>2</sup> All instructions in this user documentation will assume this convention; if the user's PC is configured differently, the "C:\\" should merely be replaced with the appropriate letter or pathname in all documented instructions. References as to what the user should type are always in **bold** characters.

To check the available disk space, type "dir" at the C:> prompt. At the bottom of the listing of files and directories, DOS will display the number of bytes of available disk space. After verifying that enough memory is available, the user places the delivered diskette in the floppy disk drive, change the directory to the floppy disk drive, and type the following:

## **A:>install**

This will invoke an installation program that will set up everything in a C:\STARRSS directory, by default. **If the user wants STARRSS to reside in a different directory**, he or she must include the disk drive (or pathname) of this location on the same line where he or she types "install" (e.g., A:>install c:\acidrain). In this case, the installation program will create that directory and install STARRSS there.

If the user does not specify anything on the install command line, the installation program will create a main directory called C:\STARRSS and a BGI subdirectory called C:\STARRSS\BGI. It will copy the STARRSS program, delivered databases, and "HELP" file, and will list of all STARRSS files (FILES.LST) into the main directory. All of the STARRSS output will be written in this directory, unless the user specifies otherwise (see *Reporting Parameters*, page 112). The BGI subdirectory will contain a set of graphic interface files which are needed for STARRSS' graphics capabilities.

**If the directory specified by the user (either directly or by default) already exists, the installation program will overwrite some of it.** Specifically, the installation program will overwrite the STARRSS program itself, the BGI files, and the HELP file. If it finds any existing STARRSS databases in the directory, it will stop the installation process. None of the databases on the delivery diskette will be copied to the directory. The user will then be returned to DOS and will be free to list and copy any of the specific databases from the delivered diskette through the standard DOS commands. If the user is starting out with a "fresh" PC, there should be no complications.

Once the installation program is finished, the user should change the directory back to the hard disk drive (e.g., type "c:"). The delivery diskette should be removed from the floppy disk drive and stored in a safe place.

## **2.4 INSTALLATION (FLOPPY DISK SYSTEM)**

It is recommended that STARRSS be run on a PC that has a hard disk. However, if this cannot be arranged, STARRSS can be run from a floppy disk, but it is **much** slower.

If there is no hard disk available, then there is nothing to install. However, the PC **must** be capable of reading high-density floppy diskettes. STARRSS will not fit on a low-density (sometimes called double density) diskette.

Before executing STARRSS from a floppy disk system, the user/installer should make a backup copy of the delivered diskette and store that diskette in a safe place. If the user does not know how to copy diskettes, the system manager should be consulted. In order to run STARRSS, the "write-protect" tab/label must not be on the diskette. In other words, STARRSS needs to be able to write reports to the diskette.

To start the program, the user merely has to insert the STARRSS diskette in the floppy disk drive and type "STARRSS":

**A:>starrss**

If the PC cannot read the diskette, check to make sure that the PC can indeed read high-density diskettes.

## **2.5 RUNNING STARRSS**

Once the installation process is complete, the user is ready to invoke (start) STARRSS by going to the STARRSS directory and typing "starrss."

RUNNING THE PROGRAM	
<b>C:&gt;cd starrss</b>	(...to move to the appropriate directory)
<b>C:\STARRSS&gt;starrss</b>	(...to start the program)

This will bring up the STARRSS "banner" screen. If it does not, check to make sure that a file named "starrss.exe" is in the current directory. If not, then: (1) the user may not be in the correct directory, or (2) the program installation process was not successful and must be repeated.

Details concerning the operation of the system are continued in Chapter 3.

### 3.0 GETTING STARTED

STARRSS is a full-screen, menu-driven modelling tool. Table 3-1 lists some general rules that apply to moving around this menu-based system.

Table 3-1. Rules of the Road	
WHAT TO DO...	... AND HOW TO DO IT
To go to a specific screen	Move the highlighted cursor to the name of the screen (which is listed on a submenu) and press <Enter>
To move around any particular screen	Use the <b>Cursor Arrow</b> keys (up, down, right, and left)
To input or change a data value on an input screen	Place the cursor on the data field and type in the new value <sup>1</sup> and press <Enter>
To exit any screen	Press the <Escape> key
To move between "connected" screens (what is meant by "connected" will be seen shortly)	Use <Page Up> and <Page Down>
To request HELP!	Press the F1 key

At the bottom of each screen, the user will find a line of abbreviated reminders and instructions about special features (i.e., use of the PC's **Function Keys**) that are specific to that screen. Some of the **Function Keys** (i.e., F1 through F10) allow the user to locate information, jump to other screens, etc. Those specific **Function Keys** will be discussed during the description of those screens.

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<sup>1</sup> This new value will be automatically stored in the STARRSS database that resides in the PC's core memory; however, the database should be saved (see discussion in Chapter 4) if the user wishes to incorporate this data change into the STARRSS database that is in the PC's permanent disk storage.

**FIRST THINGS FIRST: STARTING THE PROGRAM**

To invoke STARRSS, go to the directory where the program is located and type "**starrss.**" If the installation program was used, then STARRSS will probably be in the C:\STARRSS directory, and the user should type the following:

C:>**cd starrss**                                (...to move to the appropriate directory)

C:\STARRSS>**starrss**                                (...to start the program)

**C:>cd starrss** (...to move to the appropriate directory)

**C:\STARRSS>starrss** (...to start the program)

After the banner screen, the user will see the *Main Menu*, displayed below as Table 3-2:

### Table 3-2. Main Menu

Files	System-Level Info	Unit-Level Info	Execute	Reports
L Load	S Save	M Memory Available	D Temporarily exit to DOS	
Q Quit				

F1 Help | ENTER make selection |

Along the top part of the screen, the user will see five submenu categories from which to select. Each category is described in detail in the following five chapters.



- ▶ ***Files*** Addresses file management issues: loading (retrieving) databases, saving databases, etc.  
[see Chapter 4]
- ▶ ***System-Level Info*** Accesses input data that is not unit-specific: conservation programs, allowance prices, system marginal costs, discount rates, tax rates, etc.  
[see Chapter 5]
- ▶ ***Unit-Level Info*** Accesses input data that is unit-specific: capacities, heat rates, allowance allocations, compliance option costs and impacts (for scrubbing, fuel-switching, repowering, etc.)  
[see Chapter 6]
- ▶ ***Execute*** Accesses screens for running STARRSS (Phase I or Phase II, Evaluations or Optimizations)  
[see Chapter 7]
- ▶ ***Reports*** Accesses output reports and graphs  
[see Chapter 8]

### What's a Submenu?

A submenu is a "box" of selections that is viewed and accessed by placing the highlighted cursor on one of the five STARRSS categories. The user can move the cursor back and forth between these categories using the left and right cursor arrow keys. As the cursor is moved from one category to another, a "submenu" is displayed under each category.

A STARRSS "organizational chart" is depicted in Figure 3-1; it provides an overview of all of the STARRSS selections. Each selection represents (and provides access to) a screen or set of screens that contain the program's inputs, outputs, or execution commands.

**Before going to any of the submenu selections in STARRSS, the user must load a database. The user cannot do anything in STARRSS before loading a database.**

**Figure 3-1. STARRSS Organizational Chart**

**Files**

L	Load
S	Save
M	Memory available
D	Temporarily Exit to DOS
Q	Quit

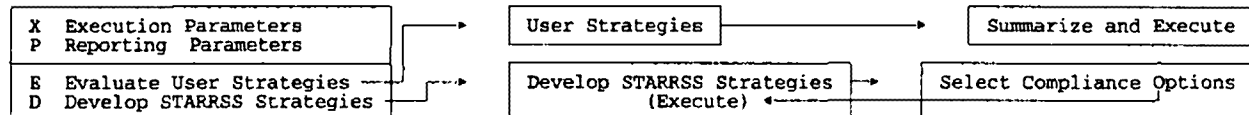
**System-Level Info**

B	Base Case Conservation/Renewables
I	Incremental Conservation/Renewables
E	Marginal Energy Costs
C	Marginal Capacity Costs
P	Allowance Purchase Prices
S	Allowance Sale Prices
A	Allowance Parameters
T	Tax Rate, Escalation Rates and Cost of Capital
F	Probabilities Associated with Forecasts

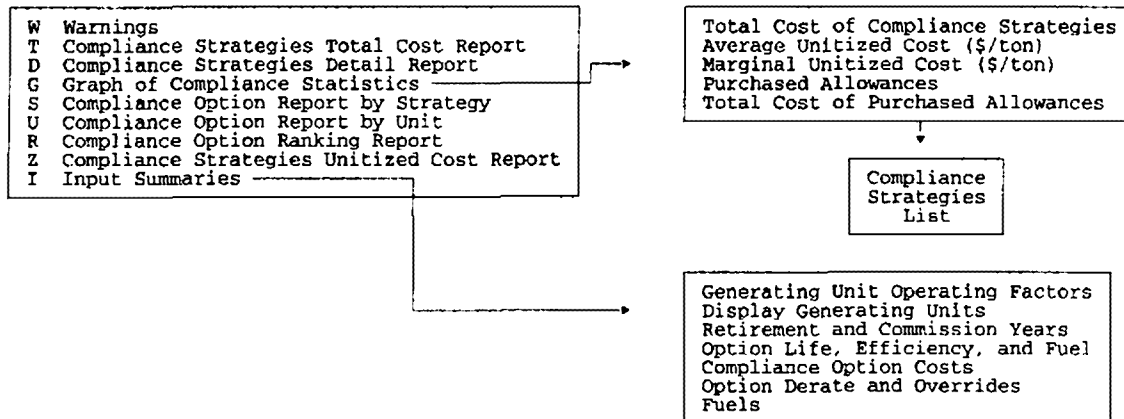
**Unit-Level Info**

A	Display/Edit Affected Units
O	Affected Unit Operating Factors
E	Edit/Define Compliance Options
N	Display Compliance Option Names
F	Fuel Inputs
R	Generating Unit Redundance
L	Compliance Option Linking
V	View Compliance Options

**Execute**



**Reports**



## Choosing Selections

In front of each selection in the STARRSS submenus, the user will find a letter. The user can choose a selection by either of two methods: 1) type the letter of the desired selection, or 2) position the cursor over the selection and press <Enter>.

### A HELPFUL Note: Information Bar and Help Facility

As mentioned earlier, at the bottom of each STARRSS screen, the user will notice a line of information that provides assistance instructions. One of the two instructions on the *Main Menu* informs the user that STARRSS has a Help facility. **By typing F1 from any STARRSS screen, the user can access this Help facility.** Help will display several paragraphs of information pertaining to the screen from which it was "called." The other notation at the bottom of the *Main Menu* ("ENTER make selection") merely reminds the user to press <Enter> to select from the submenu.

Before exploring all of the STARRSS screens in the subsequent chapters, it is essential that the user becomes acquainted with the program's general methodology. The remainder of this chapter presents information on:

- (1) the multiple forecasts used in STARRSS,
- (2) the system of user-specified probability distributions,
- (3) the data entry process, and
- (4) the program's Monte Carlo simulation approach.

### 3.1 MULTIPLE FORECASTS IN STARRSS

One of the most important and valuable aspects of STARRSS is its multiple forecast/scenario approach to compliance planning. As mentioned in Chapter 1, STARRSS allows a user to evaluate and determine the cost of compliance plans under a large variety of different economic and operational circumstances. By using several values for each data item, STARRSS can reveal how the cost of a compliance strategy would vary under different assumptions for fuel costs, unit operations, allowance prices, etc. STARRSS can run hundreds of different simulations and expose a specific compliance strategy to many different combinations of events. Therefore, to provide STARRSS with the necessary range of information, virtually all of the program's data inputs are entered in the form of three distinct forecasts. The user will see references to Low, Medium, and High forecasts on almost all of the data screens.

There are actually four pieces of information that are required to represent these triple forecasts; three of those entries are the different forecasts themselves (Low, Medium, and High), and the last is a *Probability Pointer*, which designates a probability distribution for the three forecasted values.

#### Use of *Probability Pointers*

The user must provide STARRSS with an estimate of the likelihood (in the form of a percentage) that each particular forecast will come about. These percentages must add up to 100%. The percentages will be used by STARRSS in the development of different, specific scenarios. For example, a user might expect allowance prices to start out at \$400/allowance in the first year of an analysis, but could also see prices starting as low as \$300/allowance or as high as \$500/allowance. The user would then enter these three values for the different forecasts and designate specific percentages that would be associated with each of the three forecasts. These percentages would represent the expected "probability of occurrence" for each of the forecasts. For instance, the user might specify a 30%-50%-20% probability distribution for the Low, Medium, and High forecasts, respectively. This would cause STARRSS to use the \$300 allowance price in 30% of its scenarios, \$400/allowance in 50% of the cases, and the \$500 price in the remaining 20% of the scenarios. A STARRSS input convention was adopted to make data entry less cumbersome and to keep the input screens less cluttered. Instead of having the user input six numbers for each data item (three for the forecasts and three for the probabilities associated with the forecasts), the user can "reference" a probability distribution with a single number: the *Probability Pointer*. A *Probability Pointer* is a number between 0 and 99. The distribution itself is defined on a separate screen (see page 20). A *Probability Pointer* merely "points" to this information. Thus, to represent the above example, the user would enter the following four pieces of information on the allowance price screen: \$300 for the Low forecast, \$400 for the Medium forecast, \$500 for the High forecast, and a *Probability Pointer* of, say, 17 -- where the 17th probability distribution was input (on a different screen) as a 30%-50%-20% distribution. As mentioned above, each probability distribution must sum to 100%.

The terms Low, Medium, and High (for the forecasts) do not constrict the actual data values in any way; the terms are nothing more than labels. There is no requirement that the High value be greater than the Medium, or the Medium greater than the Low. For all intents and purposes, STARRSS views the three forecasts as Forecast #1, #2, and #3.

As will be discussed in detail below (see page 32), dependence between different data forecasts can be modelled in STARRSS. For example, one might believe that low-sulfur fuel prices and allowance prices will move in tandem (i.e., when fuel prices are high, allowance prices will be high, and when fuel prices

are low, allowance prices also will be low). This dependence can be represented by having both sets of forecasts point to the same probability pointer. Another more advanced feature (probability pointer linking) can also be used; this process "links" two or more probability distributions (see page 21).

**The user is not required to input multiple forecasts for any data item.**

If the user does not wish to use the multiple-scenario capabilities in STARRSS or does not have multiple estimates for a particular data item, a single value may be specified in the Medium forecast. Simply leave the *Probability Pointer* set to its default value of zero. The *Probability Pointer* #0 has been internally fixed as a 0%-100%-0% distribution; therefore, for data items that have the *Probability Pointer* so designated, STARRSS will only use the Medium forecast in all of its scenarios.

### 3.2 THE PROBABILITY POINTERS SCREEN

**Table 3-3. Probabilities Associated with Forecasts screen**

Probabilities Associated with Forecasts -- Screen 1 of 7				
Probabilities in each row must sum to 100%				
Probability Pointer	Link Number	LOW	MEDIUM	HIGH
0	0	0.0	100.0	0.0
1	0	25.0	50.0	25.0
2	0	10.0	50.0	40.0
3	1	30.0	50.0	20.0
4	4	40.0	40.0	20.0
5	4	5.0	90.0	5.0
6	5	15.0	65.0	20.0
7	6	50.0	30.0	20.0
8	7	20.0	30.0	50.0
9	7	10.0	20.0	70.0
10	8	15.0	70.0	15.0
11	8	25.0	50.0	25.0
12	4	33.0	34.0	33.0
13	4	10.0	80.0	10.0
14	4	40.0	40.0	20.0

Enter number

F1 Help | | ESC menu

The *Probability Pointers* screen (shown in Table 3-3 above) is crucial to the STARRSS scenario analysis process. As described above, the data items on this screen will determine the likelihood of occurrence of the Low, Medium, or High forecast of any given data item during a STARRSS scenario. Along with probability distributions, the inputs to this screen will also define dependency relationships between forecasts. To ensure the best use of the STARRSS scenario analysis process, the user will need to consider carefully the probabilities he or she would like to associate with different data items, as well as which data items should be strictly dependent, which should be loosely dependent, and which should be independent. Strict dependence is accomplished by giving two data items the same *Probability Pointer*. This would ensure that whenever STARRSS selects the Low forecast for one data item, for example, the second data item would also have its Low forecast selected. The mechanics of this process are explained below.

The *Probability Pointers* screen can be found under the *System-Level Info* submenu; the selection is titled "*Probabilities Associated with Forecasts*" and will be discussed more in Chapter 5 (see page 63).

The 100 *Probability Pointers* in STARRSS (numbered 0 through 99) are listed on seven screens (accessed by <Page Up> and <Page Down>); however, the user is by no means required to use all one hundred pointers. In most STARRSS applications, the user will not need any more than a dozen or so pointers. As can be seen in Table 3-3, the *Probability Pointer* reference numbers are listed down the left-hand side of the screen. The numbers in this column are fixed (i.e., the cursor will not move into that column, and therefore the user cannot change them) and they are in ascending order. The associated probability distributions are on the right-hand side of the screen. These are the values that the user must input or modify (the delivered databases will have the same 0%-100%-0% probability distribution described for each *Probability Pointer*). **Each row of probabilities must sum to 100%.** If this is not the case, STARRSS will not let the user exit this screen. Instead, upon pressing the <Escape> key, the user

will see a "pop-up" window that reports which *Probability Pointer* has a set of probabilities that do not add up to 100%.

As mentioned earlier, *Probability Pointer* #0 has a permanently fixed probability distribution of 0%-100%-0%. Therefore, anytime that the user does not wish to define multiple forecasts for a data item, he or she may simply input a Medium forecast and leave the *Probability Pointer* set to zero. STARRSS will then overlook any information placed in the Low and High forecast fields, using the Medium value in all simulations.

Between the *Probability Pointer* and its probability distribution is another data item that the user can change: the *Link Number*. The *Link Number* "links" two or more probability distributions. This is a more advanced form of the probability dependence issue that was alluded to earlier. Strict dependence between two data items (for example, low-sulfur coal prices and allowance prices) can be modelled by simply designating the same *Probability Pointer* for both data items. For instance, assume that the user designated a particular low-sulfur coal price forecast as being \$1.20, \$1.40, and \$1.60/MMBTU for the Low, Medium, and High forecasts, respectively. Likewise, assume that allowance prices of \$300, \$400, and \$500 were similarly defined and that both data items were given a *Probability Pointer* of 3. From Table 3-3, the user can see that the probability distribution for this pointer is 30%-50%-20%. By giving both of these data items the same *Probability Pointer*, the user has ensured that when STARRSS selects the \$1.20/MMBTU coal price for one of its scenarios, it will also select the \$300 allowance price every time. STARRSS will never select \$1.20/MMBTU and the \$400 or \$500 allowance prices at the same time.

To model "loose" dependence between data items, the user can "link" *Probability Pointers*. To understand the linking of *Probability Pointers*, the mechanics of the STARRSS scenario development/forecast selection process is explained in the following section.

### 3.3 THE DATA ENTRY PROCESS

The STARRSS data entry process is fairly straightforward. The *Allowance Purchase Prices* screen (found under the *System-Level Info* category<sup>2</sup>) will be used as an example.

To get to this screen from the *Main Menu*, the user should place the cursor on the *System-Level Info* category; the user will see a list of input data screens. These screens contain information that pertains to the entire utility system or to the utility's compliance planning situation in general (e.g., data on conservation programs, allowance prices, tax rates). Table 3-4 below shows the *System-Level Info* submenu.

**Table 3-4. System-Level Info submenu**

Files	System-Level Info	Unit-Level Info	Execute	Reports
	<div><div>B Base Case Conservation/Renewables</div><div>I Incremental Conservation/Renewables</div><div>E Marginal Energy Costs</div><div>C Marginal Capacity Costs</div><div>P Allowance Purchase Prices</div><div>S Allowance Sale Prices</div><div>A Allowance Parameters</div><div>T Tax Rate, Escalation Rates and Cost of Capital</div><div>F Probabilities Associated with Forecasts</div></div>			
F1 Help   ENTER make selection				

The submenu lists all of the input screens that are under this category. The user can select or access any of these screens by typing the specific letter that is to the left of the selection or by using the up and down **Cursor Arrow** keys to place the cursor on the desired selection and pressing <Enter>. Exiting a screen is done by pressing the <Escape> key; this will return the user to the *Main Menu*.

#### **General Data Entry Example: *Allowance Purchase Prices* screen**

The *Allowance Purchase Prices* screen (accessed from the *Main Menu* by pressing "P") allows the user to define year-by-year forecasts for the expected price of allowances. An example of the *Allowance Purchase Price* screen can be seen in Table 3-5 below.

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<sup>2</sup> As was seen earlier, STARRSS is organized in a "top down" hierarchy, in that the five top-level categories have submenus that display the list of possible selections that can be made under each category. Most of these selections provide access to screens or other menus.



**Table 3-5. Allowance Purchase Prices screen**

```

===== Allowance Purchase Prices -- Screen 1 of 3 =====
Market for BUYING Allowances                               Units:  $/allowance
Probability Pointer:   3
Forecasts              LOW                                MEDIUM                                HIGH
Purchase Price
Premium (%):          1.10                                1.00                                1.00

Year      Price      Growth      Price      Growth      Price      Growth
1992      300.0      3.50      400.0      4.00      500.0      4.00
1993
1994
1995
1996
1997
1998
1999
2000
2001

                                Enter number

F1 Help      |      Ctrl-F fill      |      ESC menu
  
```

The screen's layout is duplicated on many different input screens throughout STARRSS. Starting about halfway down the screen, the annual price forecasts are arranged vertically and are grouped into Low, Medium and High forecasts across the screen. The screen displays the first ten years of the forecast, as depicted by the column of years on the left-hand side of the screen. The user can view/access later years of the forecasts by pressing <Page Down>.

### A Note About Nominal versus Constant Dollars

The user can enter price data in terms of either nominal or constant dollars. Nominal dollars reflect the total cost of an item in any particular year in question and therefore include the effect of inflation. Constant/real dollars do not include inflationary assumptions.

However, **the user must be careful to remain consistent** throughout the STARRSS data system. For example, if the user chooses to input data items in constant/real terms, all escalation rates and cost of capital rates must be in real terms (i.e., with inflation taken out) and all price/cost forecasts must be in terms of a single year's dollar (usually the study base year).

At the top of the *Allowance Purchase Price* screen, the user can see a reference to (1) how many screens this particular selection has, and (2) which of those screens the user is in. In this case, the user is in Screen 1 of 3. Screen 2 of 3 has the years 2002 to 2011; Screen 3 of 3 has the years 2012 to 2019. The time frame of the forecast (and hence, the number of screens required to represent the allowance price forecasts and other annual data items) is determined by the number of years represented in the STARRSS database. This is controlled by the database's *Base Year* and *End Year* (two user-specified data items that are discussed in Chapter 5; see page 59).

For any of the three price forecasts, the user need not input every year's value. STARRSS has specific conventions that make data entry faster and easier.

### Carry-Forward Conventions and Growth Rates

The user will note in Table 3-5 above that there are two columns for data entry under each forecast: a field for prices and a field for growth rates. The use of growth rates is a flexible and fast approach to entering data. As one option, the user can simply type in numbers in the price field. Any fields in the column that are left blank will "carry-forward" the value from the previous year. Thus, if the user entered 300.0 in 1992 and nothing else, that would designate an allowance price forecast that was flat (at \$300/allowance for each year of the study). Of course, if the user wished to vary this estimate year by year, different values could be entered for each year.

The second column of entries specifies growth rates. Using the growth rates data field can simplify data entry considerably. For example, if the user designated "3.50" for the 1992 growth rate, the 1993 allowance price would be 3.5% greater than the 1992 price **unless a value had already been input for the 1993 price**. The user may change forecast values or growth rates for any year of the study. The growth rate will escalate the current year's value into the next year's value and will continue this pattern from year to year until (1) a new growth rate is specified, or (2) a new data value is specified for the allowance price. In the latter case, the new price will "prevail" in that year and all subsequent years (unless there are entries in later years).

For all STARRSS screens, the carry-forward and growth rate processes can be summarized with the following:

- 1) If any annual field is left blank, STARRSS will carry-forward the previous year's information; this applies to data values and growth rates;
- 2) If a growth rate is specified, STARRSS will use it to escalate the current year's value up to the next year's value, **provided that the field for the next year's value is blank**;
- 3) A "carried-forward" growth rate is automatically reset to 0% in the year that a user-specified value is entered.

In reference to this last point, imagine that the user entered \$312.0 in 1994 for the Low forecast of allowance prices in Table 3-5 above. Since the low forecast starts out with \$300.0 at a 3.5% growth rate in 1992, the values that STARRSS would use would be:

1992	\$300.00
1993	\$310.50
1994 - on	\$312.00

Without another growth rate specified for 1994 (or any later year), STARRSS would assume that the low forecast was meant to stay at \$312.0 for all subsequent years.

The user is encouraged to use the carry-forward and growth rate features as much as possible. **If values are directly input for each year, the size (i.e., memory requirements) of the STARRSS database will increase.** The more fields that can be left blank, the smaller the STARRSS database will be, reducing the possibility of problems with insufficient memory.

#### **Fill function**

Along the bottom of all STARRSS screens is a line of instructional/assistance information. At the bottom of this particular screen (Table 3-5), the user will see the term "Ctrl-F fill." By holding down the Control (Ctrl) key and striking "F," the user will cause STARRSS to fill in all of the blank fields on the screen with the appropriate numbers. This way, the user can quickly check that all values are carrying forward and/or escalating as intended. The user can page down through subsequent screens to observe the carry forward/escalation effects in later years of the study.

The filled values are merely temporary; the fill function does not permanently input this information into a screen. When the user strikes any other key, the screen will be cleared of all filled values. When STARRSS is executed, the system will automatically fill in all of the forecasted data items for use in its calculations. Again, whenever possible, the user should try to use a few long-term growth rates to describe annual data in STARRSS for all of the years of a study rather than filling all of the annual values in the data screens by hand. This will save the user time and will conserve computer memory.

Incidentally, when the Fill function is executed, STARRSS will calculate and display all of the implicit growth rates, whether they were directly entered by the user or were implied by specific data value entries. In other words, if the user input allowance prices of \$500, \$550, and \$600 for one of the forecasts for the years 1992 through 1994, then STARRSS would display 10%<sup>3</sup> and 9.09%<sup>4</sup> as the growth rates for 1992 and 1993, respectively.

### Moving Around STARRSS - Using Selection Lists (F2)

In exploring and using STARRSS, the user will encounter input data screens that are unit-specific, fuel-specific, etc. In other words, each unit or fuel has its own specific screen of information. For example, in working with information about generating units, one of the screens that the user will utilize is the *Affected Unit Operating Factors* screen. This screen has multiple pages of information for each unit. Upon selecting this screen, the user will be placed in the first screen for the first unit in the database. The user can use the <Page Up> and <Page Down> keys to move between the multiple screens for this particular generating unit. However, in order to move to another generating unit's operating information, the user must do one of two things, both of which are listed on the instruction bar at the bottom of the screen and involve the use of the computer's function keys.

One option is to **place the cursor on the *Unit Name* field and press F2 (Select)**. A pop-up window will appear which will display the database's internal list of generating units. By moving the cursor to the desired unit name and pressing <Enter>, STARRSS will display all of that unit's current operational information on the screen.

Data Items that have Selection Lists	How to Use Selection Lists
Generating Units Fuel Contracts Conservation/Renewable Programs Unit-specific Compliance Options Compliance Option Links User-Specified Compliance Strategies	<p><b>Place the cursor on the <i>Name</i> field (e.g., Generating Unit Name, Fuel Name).</b></p> <p><b>Press F2.</b> A pop-up window will display the Selection List.</p> <p><b>Place the cursor on the desired selection.</b></p> <p><b>Press &lt;Enter&gt;.</b></p>

Another option is to press F8 to move forward through STARRSS' internal list of generating units. This is the same list that is displayed in the F2 selection process above, but in this case, the list is not displayed. Each time the user strikes F8, STARRSS will advance to the next unit in the database's list, displaying all of that unit's current information on the screen. By pressing F7, the user can move

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<sup>3</sup> 10% =  $(550-500)/500$

<sup>4</sup> 9.09% =  $(600-550)/550$

backward through this list and access information for previous units. The user should be careful to note the instruction bar at the bottom of each screen; some screens have two different data items with internal lists. In these cases, the next/previous capability may be activated with the F9/F10 keys as well as the F7/F8 keys (see the *Edit/Define Compliance Options* screen on page 82 for an example).

The general data entry features of carry-forward conventions, growth rates, "filling," and Selection Lists can be seen on many screens throughout STARRSS. With this knowledge of data entry conventions and a general understanding of the STARRSS multiple forecast approach, the user should be well-equipped to work with the program. The next five chapters of the User's Manual address each of the five categories on the *Main Menu*, starting with the *Files* category in Chapter 4.

### 3.4 THE STARRSS MONTE CARLO APPROACH

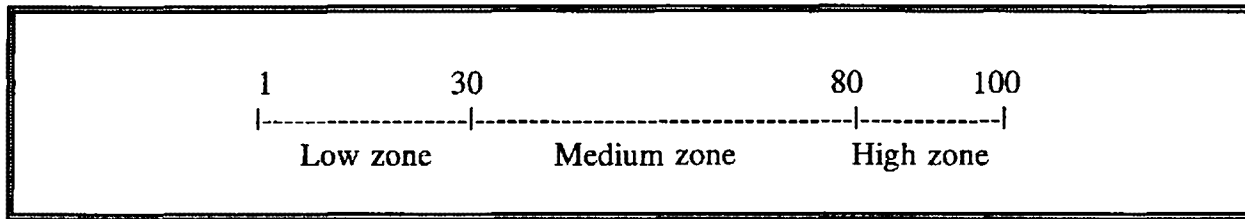
As mentioned in Chapter 1, one of the strengths of the STARRSS program is its multiple-scenario, Monte Carlo approach to compliance planning. "Monte Carlo" merely refers to a methodology whereby multiple simulations of a process are performed; for each simulation, a different set of assumptions is used. STARRSS allows the user to evaluate the cost of compliance strategies under hundreds of different assumptions about future economic and operational situations. STARRSS does this by running hundreds of simulations, where the input assumptions for each data item in each simulation are temporarily fixed at one of the three data item's forecast values (the Low, Medium, or High forecast). STARRSS then "prices out" the compliance strategy based on all of those fixed input assumptions and stores the information. It then runs through the forecast selection process for another simulation/iteration, choosing a whole new set of input assumptions and determining the cost of the compliance plan under those new assumptions. It stores this cost information and repeats the process. The number of simulations is controlled by the user and is defined on the execution screens (see Chapter 7, page 119). By the end of the process, STARRSS has stored hundreds of different values, each of which reflects the cost of the particular compliance strategy under many different combinations of input assumptions. How STARRSS chooses these combinations of input assumptions is known as the forecast selection process and is described below.

The heart of forecast selection is a random number generator. However, STARRSS does not randomly select each iteration's set of input assumptions; the probability distributions that the user defines are the primary determinants of what input assumptions are used in the iterations (and how often they are used). Yet, the selection process for each scenario iteration begins with a random number generator.

During each scenario iteration, STARRSS will generate a random number (between 1 and 100) for each Link Number on the *Probabilities Associated with Forecasts* screen, starting with Link #0. That random number will be used to select the forecasted value (Low, Medium, or High) for each data item that "points" to a probability distribution which has a Link Number of 0. STARRSS first identifies which *Probability Pointers* have a *Link Number* of 0. This subset of pointers have been "linked" by the user. Therefore, within the context of a single iteration, STARRSS will use the same random number to dictate which of the three forecasted "modes" each pointer is in. As will be seen below, this does not necessarily mean that two linked pointers will always be in the same mode (e.g., the High forecast).

STARRSS's use of the randomly generated number to select a pointer's mode is fairly straightforward. For each *Probability Pointer*, STARRSS "stacks" the Low, Medium, and High forecasts' probabilities on a continuous scale from 1 to 100 and thereby defines "zones" of numbers that corresponded to the Low, Medium, or High situations. The size or width of each zone is determined by its probability percentage - the larger the percentage, the larger the zone. Therefore, for *Probability Pointer* #3 in Table 3-5 above (which has a 30%-50%-20% distribution), the Low zone would be from 1 to 30, the Medium zone from 31 to 80, and the High zone would be from 81 to 100, as depicted in Figure 3-2 below:

**Figure 3-2. Zones for Forecast Selection**



Defining such zones ensures that a random number between 1 and 100 would have a 30% chance of falling in the Low zone, a 50% chance of being in the Medium zone, and a 20% chance of being in the High zone -- the exact probability distribution defined by the user for *Probability Pointer #3*.

Assume now that, during a given scenario iteration, STARRSS' random number generator outputs the number "35" for use in selecting the forecast mode for *Probability Pointer #3*. This value would fall in the Medium zone, so STARRSS would select the Medium forecast. Any data item that pointed to *Probability Pointer #3* would be set to its Medium forecast value **for this particular scenario iteration**. STARRSS would perform the same process with all other *Probability Pointers* (and their associated data items) to determine which forecast should be used for all of the data items in the database. STARRSS would then calculate the cost of the compliance strategy **for this particular scenario iteration**.

For the next scenario iteration, the random number generator might output the number "93" for pointer #3. This would put it in the High range. The next iteration might see a random number of "17," leading to the selection of the Low forecast value for all data items that pointed to pointer #3. In actuality, STARRSS does not generate a random number for each *Probability Pointer*, rather, as mentioned earlier, it generates one for each *Link Number*. Therefore, for two or more pointers that have the same *Link Number*, STARRSS will use the same random number (within a particular iteration) to determine the pointers' modes.

## Simulation Example

Although the complete forecast process may sound complicated, it is actually fairly simple. For example, assume that the user had specified the following information (displayed in Tables 3-6 and 3-7 below) in the STARRSS database:

**Table 3-6. Forecasts for Data Items**

Data Item	Low	Medium	High	<i>Probability Pointer</i>
High-Sulfur Coal Price (\$/MMBTU)	0.00	1.10	0.00	0
Low-Sulfur Coal Price (\$/MMBTU)	1.20	1.40	1.60	1
Allowance Price (\$)	300	400	500	2
Scrubber Capital Cost (\$M)	500	525	530	3

**Table 3-7. Probabilities for Forecasts**

<i>Probability Pointer</i>	<i>Link Number</i>	Low	Medium	High
0	0	0.0%	100.0%	0.0%
1	0	25.0%	50.0%	25.0%
2	0	10.0%	50.0%	40.0%
3	1	30.0%	50.0%	20.0%

Note that the High-Sulfur Coal Price has a *Probability Pointer* of 0 (which has a 0%-100%-0% distribution); therefore, there is no need to specify Low and High prices since the user has indicated that the Medium price should be used in all of the STARRSS iterations. Note also that *Probability Pointers* #0, #1, and #2 are linked, in that they all have a *Link Number* of 0. Since there are only two Link Numbers, STARRSS will only generate two random numbers for each iteration.



### Iteration #1

Assume that STARRSS generates two random numbers (say, 17 and 54). The first one is used to dictate the modes for all *Probability Pointers* with a *Link Number* of 0 (namely, pointers #0, #1, and #2). The second one applies to *Probability Pointers* with a *Link Number* of 1 (namely, pointer #3). Through the procedure described above, STARRSS determines which values will be used in Iteration #1 for each of the four data items (as displayed in Table 3-8 below).

**Table 3-8. Selection of Values for Iteration #1**

Random Number	Pointer	Mode	Data Item	Value
17	#0	Medium	HS Coal Price	\$1.10
17	#1	Low	LS Coal Price	\$1.20
17	#2	Medium	Allowance Price	\$400
54	#3	Medium	Scrubber Capital Cost	\$525M

STARRSS will use the values in the right-hand column to calculate the cost of a particular compliance strategy. Note that even though the top three data items are *linked*, they did not end up in the same forecast mode. Because of its specific probability distribution (#1), the Low-Sulfur Coal Price ended up being set to its Low value.

If the strategy involved fuel-switching at a particular generating unit that currently burned the High-Sulfur Coal but could burn the Low-Sulfur Coal, STARRSS would price out that part of the strategy based on a \$0.10/MMBTU price differential (\$1.20/MMBTU - \$1.10/MMBTU) between the two fuels. If the strategy involved buying allowances, those allowances would be priced at \$400 apiece. Finally, if the strategy involved the construction of the scrubber that is included in this example, then that scrubber's capital costs would be \$525 million. STARRSS will process all of this information through standard present value techniques and determine the compliance strategy's total present value cost. Chapter 9 provides the details of these calculations. This iteration's results are stored, and STARRSS proceeds to the next iteration.

### Iteration #2

Assume the random number generator now produces the following two numbers: 72 and 29. The results of the forecast selection process are listed in Table 3-9 below:

**Table 3-9. Selection of Values for Iteration #2**

Random Number	Pointer	Mode	Data Item	Value
72	#0	Medium	HS Coal Price	\$1.10
72	#1	Medium	LS Coal Price	\$1.40
72	#2	High	Allowance Price	\$500
29	#3	Low	Scrubber Capital Cost	\$500M

Again, STARRSS will price out the cost of compliance (in present value terms) for a particular compliance strategy using the selected values for the data items. The process will continue for as many iterations as the user specifies (up to 999; see Chapter 7, page 119 for details).

Through repeated iterations, the total cost of a particular compliance strategy will assume many different values (one for each iteration) that will reflect the strategy's cost under various combinations of economic and operational events. This process is called a Monte Carlo simulation. The cost from any single iteration may not represent the strategy's expected cost. However, if the user runs this type of simulation through enough iterations, the distribution of the costs can yield two important results. First, the "expected value" (or average) of the cost distribution provides a better indication of the likely cost of a compliance strategy than a "static" estimate that is predicated on a fixed set of economic and operational assumptions. Second, the range or variance of the distribution of costs provides the user with an idea of the level of economic risk that is inherent in the compliance strategy.

### **Probability Dependence**

Returning to the discussion of probability distributions, the user must consider the dependence that different data items may have on each other. Generally speaking, there are three different levels of dependence that can be represented in STARRSS: strict dependence, loose dependence, and independence.

Strict Dependence: two or more data items are judged to always move together. When one is high, they are all high; when one is low, they are all low. The user should give these data items the same *Probability Pointer*.

Loose Dependence: two or more data items are judged to generally move together. This is a minor distinction, but it allows the user to define different probability distributions for each data item. Loose dependence can then be reflected by linking those *Probability Pointers*; this is done by giving them all the same *Link Number*. Of course, if two linked *Probability Pointers* have the same probability distributions (e.g., 30%-50%-20%), they are redundant; the user may as well just use the first pointer.

Independence: two or more data items show no "connection" in the values that they may assume. Many variables in STARRSS can be classified as independent. For example, while the SO<sub>2</sub> removal efficiency of a scrubber is based on the capabilities of the technology and the quality of the design and construction, it is unlikely to be affected by the price of allowances, the price of natural gas, or a host

of other data items in STARRSS. Therefore, the user should be careful to specify different, unlinked *Probability Pointers* for all variables that are deemed to be independent.

The user should consider the dependent/independent nature of all of the STARRSS data inputs and sketch out those relationships before defining the *Probability Pointers* in the pointer screen and specifying them throughout the STARRSS database.

## 4.0 FILES

Table 4-1 below shows the *Main Menu* and the *Files* submenu; this is where STARRSS puts the user when the program is started up.

**Table 4-1. Main Menu**

Files	System level Info	Unit level Info	Execute	Reports
<div><div>L Load</div><div>S Save</div><div>M Memory available</div><div>D Temporarily Exit to DOS</div></div>				
<div>Q Quit</div>				
F1 Help   ENTER make selection				

The submenu shows that the *Files* category can be used to:

- ▶ *Load* a database,
- ▶ *Save* a database,
- ▶ Request information on the *Memory Available* in the PC's core memory,
- ▶ *Temporarily Exit to DOS* without quitting from the program, or
- ▶ *Quit* from the program.

Before going to any of the other submenu selections in STARRSS, the user **must** load a database. The user cannot do anything in STARRSS before loading a database.

## 4.1 LOADING A DATABASE

To load a database, the user must select the *Load* command in the Files submenu. STARRSS will search the current directory for all STARRSS databases and display these files in a "pop-up" window (shown in Table 4-2 below).

Table 4-2. *Load* screen

Files	system-Level Info	Unit-Level Info	Execute	Reports
<b>L</b> Load <b>S</b> Save <b>M</b> Memory Avail <b>D</b> Temporarily  <b>Q</b> Quit	<b>Search Pattern</b> C:\STARRSS\*.SDB	<b>database to load</b>		
	<b>Files</b> GENERIC.SDB UTILITY1.SDB UTILITY2.SDB UTILITY3.SDB ZBACKUP.SDB	<b>Directories</b> .. BGI	<input type="button" value="OK"/> <input type="button" value="Cancel"/>	
	GENERIC.SDB	08/27/92	2:00pm	26866
F1 Help   ENTER select database   D change directory				

STARRSS databases are identified by the filename extension "SDB." In other words, every STARRSS database must be named <filename>.SDB, where <filename> can be any eight-character name that the user desires.

To select a particular database, the user simply positions the cursor on the database name and presses <Enter>.

The pop-up window will disappear and, for a second or two, STARRSS will flash a message on the screen that it is loading a database. Once a database is loaded, the user can proceed to examine and modify existing data, run the program, and/or view results. If the user has loaded the wrong database (or simply wishes to view a different database), a new database can be loaded by repeating the above process. The previously-loaded database will be cleared from the PC's core memory and the new one will be pulled in. There is no need to exit from STARRSS.

If the user does decide to load another database (after having updated the current one with new data), the user must realize that --

**Loading a new database into STARRSS will clear out the current database without saving it.**

### **Selecting Databases from Other Directories**

If the user wants to use a STARRSS database that is not in the current directory, the user may instruct STARRSS to search for databases in a new directory location. By typing a "D," the user will cause the cursor to jump over to the directory box in the pop-up window. This box lists the subdirectories that are under the current directory where STARRSS resides. By selecting one of these subdirectories, the user can search for STARRSS databases in that new location. For example, the user may execute STARRSS from the C:\STARRSS directory but have databases in the C:\STARRSS\DATA subdirectory. In this case, the user would type "D" and select the DATA subdirectory. STARRSS would then search for databases in the new location, display all that it found, and return the cursor to the database list. The ".." selection will take the user up one level in the PC's directory hierarchy (similar to the "cd .." command in DOS).

As an alternative to the above procedure, the user can type an "S" and cause the cursor to jump up to the top field in the pop-up window. This field is used to specify the complete directory pathname in which STARRSS will search for databases. The user can modify this pathname to instruct STARRSS to search for databases in a new location.

### **A Shortcut**

While invoking STARRSS from DOS, the user can take a shortcut to the above process and type the name of the desired database (e.g., utility.sdb) on the same line as "starrss":

**C:\STARRSS>starrss utility.sdb**

This shortcut will bring up the banner screen. As always, the user will have to strike a key to get to the *Main Menu*; however, at this point, STARRSS will automatically load the desired database.

## 4.2 SAVING A DATABASE

When the user instructs STARRSS to save a database (by selecting *Save*), the system will save a copy of the currently loaded database to disk. STARRSS will pop-up a window, prompting the user for the database's pathname and filename (e.g., C:\STARRSS\DATA\UTILITY.SDB). As a default, STARRSS will display the current database name and location. If the user wants to save any modifications back into the original database, he or she can merely press <Enter>. STARRSS will interrupt to alert the user that this database already exists and will ask whether or not the user wants to overwrite it. If the user does, he or she should type "Y." **This will permanently change the original database.** If the user wants to preserve the original database, then a different database name must be specified.

Whenever STARRSS is executed, the program will automatically create a database named ZBACKUP.SDB in the current directory. Should STARRSS abort during execution, this safety feature will provide the user with a database that includes all of the data changes that have been made up to that point. However, the user should note that this database will be overwritten every time STARRSS is executed.

A STARRSS database contains all of the input information for a particular utility or system of utilities (i.e., holding companies, power pools) as well as parameters that control the execution of a study. Output results, on the other hand, are not part of the database. Instead, output files are automatically saved onto the same directory from which STARRSS is executed. The user can direct these files to another location, such as C:\STARRSS\REPORTS (see the Reporting Parameters screen, page 112). Regardless, these files will have the same "root name" as the database. In other words, running STARRSS with a database called UTILITY.SDB will generate a series of output files that are called UTILITY.XXX (where XXX represents a variety of filename extensions).

## 4.3 TEMPORARILY EXIT TO DOS

If the user wishes to exit STARRSS temporarily in order to perform tasks in DOS (e.g., copying files, listing files in directories), he or she does not need to quit from STARRSS. Instead, by typing "D" (the *Temporarily Exit to DOS* selection) under the *Files* category, the user can work in the DOS environment without quitting STARRSS. However, the user cannot run other programs (e.g., Lotus 1-2-3, etc.) at the same time that STARRSS is residing in the PC's core memory. To return to STARRSS, the user must type "exit."

## 4.4 MEMORY AVAILABLE

Particularly when working with large databases, the user may want to investigate how much room is available in the PC's core memory. The core memory is different from the hard

disk or floppy disk memory. A PC's core memory is where the machine does all of its processing. Therefore, the user must have enough core memory to accommodate:

- (1) the STARRSS program (Version 1 is about 346,000 bytes),
- (2) any particular STARRSS database, and
- (3) extra "room" for temporary files that are created during the execution of the program.

Every effort has been made to reduce STARRSS' memory requirements and ensure that the program can be executed within a memory limit of 500,000 bytes. The potential size of the database is not limited, however, and the user's PC may not have enough core memory to handle large systems. Also, the user's PC may have other programs that stay resident within the PC's memory during STARRSS execution. Particularly if the user anticipates analyzing large systems, he or she should make every effort to provide STARRSS with as much core memory as possible.

#### **PC Memory Considerations**

**The user should not invoke STARRSS from within other programs (e.g., Windows, Lotus 1-2-3, etc.). STARRSS should be invoked from DOS only.**

Also, the user may have to remove some of the PC's core resident software applications (sometimes called TSRs) such as electronic mail systems, menu software, and modem/communication packages. If TSRs are a problem, they can be removed fairly easily by editing the PC's system set-up files. To do this, the user's system manager should be consulted. He or she may be able to establish a dual configuration process that would allow the user to have the best of both worlds. Prior to invoking STARRSS, the user could run a procedure that used a new set of system configuration files. After each STARRSS session, the user could run another procedure that would put the TSRs back into the PC's core memory.

By placing the cursor on the *Memory Available* selection and pressing <Enter>, the user can assess how much core memory is left at that time. A pop-up window will be displayed that shows how much memory is currently available on the user's PC as well as how much will be required to execute different types of runs in STARRSS. There are four different types of runs that a user can instruct STARRSS to perform: an evaluation of user-specified compliance strategies, and three different optimization processes (Full Enumeration, Hueristic #1, and Heuristic #2). All four execution processes are described in Chapters 7 and 9. The Memory



Available display window shows the amount of core memory that will be required for each of these execution processes.

By selecting *Memory Available* before loading a database, the user can determine how much memory the program itself has taken up and how much is left for the database and execution processes. If the program aborts during the loading of a database with an "insufficient memory" warning, the database is probably too large. To check this, follow these instructions:

- (1) Reboot the PC;
- (2) Check the size of the database in question (by typing "dir" while in DOS) and note the number of bytes that it takes up on the PC's disk memory; this will be very close to the amount of core memory that it will take up;
- (3) Invoke STARRSS;
- (4) Select *Memory Available* and compare the number of bytes available to the size of the database (determined from Step 2).

If a database loads smoothly but insufficient memory occurs while executing STARRSS, the above process should be followed in addition to the following step:

- (5) Select *Memory Available* again after loading the database to see how much memory is left for STARRSS' temporary execution files.

As mentioned above, the program presents estimates of the amount of memory that will be required to execute each of the four STARRSS execution processes (the main evaluator and the three optimizers). If the user's PC does not have enough memory for the desired execution, the user must either reduce the size of the database or get more memory installed in the PC. Again, the user should check to make sure that TSRs (e.g., electronic mail systems, menu software, modem/communication packages) are not permanently residing in the PC's core memory and consuming an inordinate amount of memory.

#### 4.5 QUITTING FROM STARRSS

The user can exit STARRSS by selecting *Quit* under the *Files* submenu. Alternatively, the user may type ALT-X (i.e., hold down the ALT key and type "X") from anywhere in the STARRSS system. In either case, the program will prompt the user with a question to verify that the user intends to exit STARRSS. Typing "N" will keep the user in STARRSS; typing "Y" will cause the program to quit and will return the user to DOS. Any reports that have been generated through executing STARRSS will already be on disk and therefore are automatically "saved." However --

**Any changes to the database itself (i.e., input information and execution parameters) must be saved prior to leaving STARRSS if the user wishes to preserve them. Otherwise, those changes will be lost.<sup>1</sup>**

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<sup>1</sup> If the user is familiar with other PC programs (such as Lotus 1-2-3), he or she will note that STARRSS follows the same standard file handling conventions. If one retrieves a spreadsheet, makes some temporary changes, and exits Lotus 1-2-3 without saving the spreadsheet, the changes are lost. Also, when one retrieves a new spreadsheet, it wipes out whatever was already in core. STARRSS works the same way.

## 5.0 INPUT DATA: SYSTEM-LEVEL INFO

STARRSS is organized in a "top down" hierarchy, that is, the five top-level categories have submenus that display the list of possible selections under each category. Most of these selections represent (and provide access to) another menu, a screen, or a set of screens.

After placing the cursor on the *System-Level Info* selection, the user will see a list of submenus for entering system-level input data (i.e., information that pertains to the entire utility system or to the utility's compliance planning situation in general: data on conservation programs, allowance prices, tax rates, cost of capital rates, etc.). Table 5-1 below shows the *System-Level Info* submenu.

Table 5-1. System-Level Info submenu

Files	System-Level Info	Unit-Level Info	Execute	Reports
	<div><div>B Base Case Conservation/Renewables</div><div>I Incremental Conservation/Renewables</div><div>E Marginal Energy Costs</div><div>C Marginal Capacity Costs</div><div>P Allowance Purchase Prices</div><div>S Allowance Sale Prices</div><div>A Allowance Parameters</div><div>T Tax Rate, Escalation Rates and Cost of Capital</div><div>F Probabilities Associated with Forecasts</div></div>			
F1 Help   ENTER make selection				

As is the case on all of the STARRSS submenus, the user can access any of the screens by typing the letter that is to the left of the selection or by using the up and down **Cursor Arrow** keys to place the cursor on the desired selection and pressing <Enter>. The user can exit screen by pressing the <Escape> key, which will return the user to the *Main Menu*.

### A Note About Nominal versus Constant Dollars

Many of the screens in the System-Level Info category contain annual cost and price information. The user can enter these data in either nominal or constant dollars. Nominal dollars reflect the total cost of an item in any particular year in question and therefore include the effect of inflation. Constant/real dollars do not include inflationary assumptions.

However, the user must be careful to remain consistent throughout the STARRSS data system. For example, if the user chooses to input data items in constant/real terms, all escalation rates and cost of capital rates must be in real terms (i.e., with inflation taken out) and all price/cost forecasts must be in terms of a single year's dollar (usually the study base year).

### Base Case versus Incremental

Before exploring the various screens in the *System-Level Info* submenu, a clear distinction must be made between "base case" data items (existing/current) and "incremental" data items (options/alternatives). Base case values should reflect current or projected standard operations. These values should represent a projection of how things would have been had the CAAA not been enacted. This establishes a base case that is a reference point from which the utility will make decisions that will bring it into compliance with the CAAA. The STARRSS incremental data items refer to the different alternatives that a utility has open to it in order to comply. With these data items, the user will define possible compliance options (e.g., increased conservation, unit-specific compliance activities). However, in order to have a reference point from which to judge the cost-effectiveness of these alternative operations, STARRSS must have information on how the utility's system is currently expected to operate without the implementation of any compliance options (i.e., the "base case").

### Saving Databases

If the user wishes to save the data that has been entered during a STARRSS session, he or she must formally save the database (by selecting *Save* in the *Files* submenu) prior to ending the session. STARRSS will not automatically store the new information.

## 5.1 BASE CASE CONSERVATION/RENEWABLES

**Table 5-2. Base Case Conservation/Renewables screen**

```

===== Base Case Conservation/Renewables -- Screen 1 of 3 =====
Aggregation of planned conservation programs

                LOW                MEDIUM                HIGH    Prob. Ptr
System Marginal SO2 Emissions (lbs/MWH)
                3.2                3.3                3.4        6
Expected MWH Savings
Probability Pointer: 3

Year      MWH      Growth      MWH      Growth      MWH      Growth
1992     100000    2.00      110000    2.10      120000    2.40
1993
1994
1995
1996
1997
1998
1999
2000
2001

                                Enter number

F1 Help      |    F2 Select    |    Ctrl-F fill    |    ESC menu
  
```

The *Base Case Conservation/Renewables* screen (Table 5-2 above) is used to model conservation and renewable energy programs that the utility plans to undertake **regardless of acid rain compliance activity**.

The screen uses a layout that is similar to the Allowance Purchase Prices screen that was discussed in Chapter 3 (see page 23); this format is duplicated on many different input screens throughout STARRSS. Starting about halfway down the screen, the annual energy savings forecasts are arranged vertically and are grouped into Low, Medium and High forecasts across the screen. The screen displays the first ten years of the forecast, as depicted by the column of years on the left-hand side of the screen. The user can view/access later years of the forecasts by pressing the <Page Down> key. At the top of the screen, the user can see a reference to (1) how many screens this particular selection has, and (2) which of those screens the user is in. In this case, the user is in Screen 1 of 3. Screen 2 of 3 has the years 2002 to 2011; Screen 3 of 3 has the years 2012 to 2019. The time frame of the forecast (and hence, the number of screens required to represent the energy savings forecasts and other STARRSS annual data items) is determined by the number of years modelled in the STARRSS database. This is controlled by the database's *Base Year* and *End Year* (two user-specified data items that are discussed later -- see page 59).

The data inputs on this screen represent an aggregate of planned energy savings from DSM programs and planned generation from renewable energy.<sup>1</sup> "Planned" refers to the program information represented on this screen that includes those programs that the utility expects to pursue for non-compliance reasons (i.e., because of cost effectiveness, regulatory mandate, etc.). In other words, these conservation programs are part of the utility's "base case." It is presumed that they would have been implemented even if the 1990 Clean Air Act Amendments had never been passed. In order to reduce the memory requirements for STARRSS, the information for all "base case" conservation programs is entered on a single screen (i.e., all such programs must be added together). A different screen (the *Incremental Conservation/Renewables* screen, displayed later on page 47) provides for the modelling of additional individual programs that could be implemented in the future to reduce SO<sub>2</sub> emissions. Presumably, such programs are not cost-effective on a purely economic basis (or they would have been implemented already); however, now the CAAA may have tipped the balance for these programs.

The inputs for the *Base Case Conservation/Renewables* screen fall into essentially two categories: an estimate of marginal SO<sub>2</sub> emissions, and a forecast of expected MWH savings.

### ***System Marginal SO<sub>2</sub> Emissions***

The *System Marginal SO<sub>2</sub> Emissions* refers to the expected long-range SO<sub>2</sub> emissions reduction that is likely to be achieved for each MWH saved by the conservation programs. Since STARRSS Version 1 does not have a system dispatch capability, the user must provide some insight into how much SO<sub>2</sub> the conservation programs are likely to reduce. This is a function of:

- ▶ What hours of the day or year the conservation programs are expected to achieve their energy savings?
- ▶ What units are expected to be the marginal generating resources during those hours?
- ▶ What emissions rates are expected from those units?

If the program only reduced generation from gas-fired peaking units, the marginal SO<sub>2</sub> emissions rate would be nearly zero. If intermediate coal-fired generation were curtailed, the marginal SO<sub>2</sub> emissions rate would be well above zero.

---

<sup>1</sup> For the sake of clarity, the explanations in this section will only focus on conservation programs; however, since the same screens are used for modelling renewable energy projects, everything that is discussed in this section is equally applicable to renewable resources.

The uncertain nature of the SO<sub>2</sub> emissions reduction that could be attributed to conservation makes it particularly suitable for a scenario representation. As depicted on the screen displayed above (see Table 5-2), the user may specify a low, medium, and high estimate for the marginal SO<sub>2</sub> emissions rate (along with a probability pointer for the forecasts).

**Suggested Procedure: System Marginal SO<sub>2</sub> Emissions**

Use an existing dispatch simulation model under three different operating scenarios (e.g., low, medium, and high load growth cases and/or varying levels of conservation) to run simulations with and without the conservation programs. Calculate the average annual system SO<sub>2</sub> emissions (in lbs.) for all six cases. Calculate the difference in average emissions between the "with" and "without" cases for each of the three scenarios and divide these emissions by the average annual MWH conservation savings.

***Expected MWH Savings***

The *Expected MWH Savings* data item is an annual forecast of the aggregated energy savings from all of the "base case" conservation programs. Neither the peak reduction benefits nor the time of day/seasonal impacts of the energy savings are modelled in STARRSS Version 1; instead, the compliance effects of these conservation programs are assessed by using the MWH savings only. These savings values should represent reduced generator loads and should therefore include the effects of transmission and distribution losses. In other words, 100,000 MWHs of savings at the meter could translate into a 107,000 MWH reduction in generation requirements (assuming line losses of about 6.5%), and the user should input the 107,000 MWH number.

As can be seen on the instructional line at the bottom of the screen, this screen has the standard "Fill" function that was discussed in Chapter 3 (see page 26).

The conservation programs represented on this screen may mean the utility can receive bonus allowances from EPA's conservation and renewable allowance reserve. The EPA will distribute bonus allowances only for programs that achieve savings from 1992 through 1994 for Phase-I-affected utilities and 1992 through 1999 for Phase-II-affected utilities. These savings must come from measures that were implemented or installed after 1991. For example, a high efficiency air conditioner installed in 1991 will result in energy savings for many years; however, these savings will not be eligible for EPA's bonus allowances and should not be included in the STARRSS input data. The energy savings entered on the conservation screen should only represent the savings from conservation measures that were put in place after 1991.

The EPA bonus allowances will be discussed in more detail later (see the *Allowance Parameters* screen, page 56).



## 5.2 INCREMENTAL CONSERVATION/RENEWABLES

**Table 5-3. Incremental Conservation/Renewables screen**

Incremental Conservation Programs/Renewables -- Page 1 of 1				
Name: RESIDENT 1	Description: Residential: Hi-Effic. Appliance Rebates			
Start Year: 1992				
	FORECASTS			Probability
	LOW	MEDIUM	HIGH	Pointer
Expected Energy Savings				
in 1992 (MWH):	5000	6000	7000	4
Escalation Rate (%):	2.00	2.00	2.40	2
System Marginal SO <sub>2</sub>				
Emissions (LBS/MWH):	5.00	6.00	7.00	7
Annual Costs (1992 \$/MWH):	40.000	41.000	42.000	8
Escalation Rate (%):	5.00	5.10	5.30	4
Annual Avoided				
Utility Costs (1992 \$/MWH):	39.700	40.500	41.800	8
Escalation Rate (%):	5.00	5.10	5.30	4
Enter text				
F1 Help   F2 Select   F4 delete program   F9/F10 prev/next program				

The *Incremental Conservation/Renewables* screen (shown in Table 5-3 above) is used to model conservation programs for evaluation as specific compliance options. They are not part of the utility's "base case." These are individual programs or clusters of programs that are not currently implemented (or scheduled to be implemented) but which now may be worthy of further consideration in light of the Clean Air Act requirements. Before the Clean Air Act, these programs may have not been cost-effective (i.e., the costs of the programs were not believed to exceed the avoided costs). Now that the utility's SO<sub>2</sub> emissions probably need to be curtailed (and EPA is providing bonus allowances as an incentive for implementing conservation/ renewable resources), these conservation programs may have some additional benefits that should be factored into the cost-effectiveness tests. STARRSS allows the user to explore and quantify these additional benefits.

### Program Name

The first data item in this screen is the program *Name*; this is merely a label to identify the conservation program on other screens and on STARRSS output reports. It can be anything that the user wants, but it cannot exceed ten characters.

### ***Program Description***

The program *Description* is a longer label (of 40 characters) that can be used to more fully describe a program. Like the program *Name*, it appears on some of the STARRSS output reports.

### ***Start Year***

Underneath the *Name* and *Description* is the *Start Year* of the incremental conservation program. Every compliance option in STARRSS has a *Start Year* to indicate when the activity will begin affecting the utility's operations. This permits the user to investigate the costs and benefits of delaying or advancing the schedule for any particular compliance option. In STARRSS Version 1, there is no designated "End Year" for conservation compliance options; they are assumed to last for the entire length of the study.

### ***Expected Energy Savings and System Marginal SO2 Emissions***

The *Expected Energy Savings* and the *System Marginal SO2 Emissions* are identical to the data items described earlier in the Base Case Conservation discussion -- with one exception. The energy savings for a conservation compliance option are only input for the first year of the program and are escalated throughout the study period based on a user-specified escalation rate. The escalation rate allows the user to represent a rise or decline in the program's savings over time (i.e., because of increased or decreased customer participation, persistence or deterioration of a conservation measure's effectiveness, etc.).

As noted above, conservation programs are assumed to last for the length of the study. Also noted above, STARRSS Version 1 uses a single, average-year approach to compliance modelling (which is discussed in detail in Chapter 9), in that it calculates the year-to-year energy savings of a program and takes the average over the length of the study. Therefore, if a conservation program is only expected to last for a few years, the user should modify the first-year savings estimate to cause STARRSS to come up with the appropriate average-year calculation. For example, assume that a user defines a program in STARRSS as saving 10,000 MWH/year (with 0% escalation). If the program is only going to achieve this level of savings for 10 years (and then drop to zero), then the average value over **20-year study period** will be 5,000 MWH/year -- and that is what the user should enter for first-year savings in the screen displayed above.

## ***Annual Costs***

The *Annual Costs* entry is where the user estimates the long-term stream of costs that the utility will bear in order to produce the expected annual savings. These costs include promotional expenses, rebates, installation costs, incentive payments, and administrative costs. This stream is input in the form of a first-year estimate (in \$/MWH saved) and an escalation rate. There is no provision in STARRSS Version 1 to distinguish between capital expenditures (that may be put in rate base) and yearly expenses. The user should approximate the annual revenue requirements that would occur in the event that a conservation program would involve substantial capital expenditures.<sup>2</sup> The cost entry will be escalated for each year of the study and multiplied by the expected MWH savings in each year, thereby generating a stream of costs.

## ***Annual Avoided Utility Costs***

The *Annual Avoided Utility Costs* should reflect the energy- and capacity-related marginal costs (in \$/avoided MWH) of the resources that will not have to be used because of the implementation of the program.

**Entries for The *Annual Avoided Utility Costs* must be less than the *Annual Costs*.**

This will ensure that each conservation program always has a positive net cost; otherwise, the program represents an investment the utility should have already undertaken -- even if the program did not reduce any SO<sub>2</sub> emissions at all. Considering that STARRSS can use any of the three different forecasted values for both of these data items during its scenario simulations, the user should ensure that the avoided cost value is always less than the annual cost value by **using the same probability pointer for both entries** (and the same probability pointer for both escalation rates) -- as can be seen in the screen displayed in Table 5-3 above.

---

<sup>2</sup> Since STARRSS uses this information for present value calculations and since the present value of revenue requirements for capital expenditures is essentially equal to the capital costs themselves (as of the in-service year), then simply considering the capital expenditures as yearly expenses should be a reasonable approximation. The only discrepancy would be in the tax effects -- and this would be minor.

### **Moving Through the List of Programs**

The user should note that the bottom "instruction" line on the incremental conservation screen displays information about several function keys that have capabilities that are specific to this screen. The F9 and F10 function keys allow the user to "page" through multiple screens of information where each single screen contains all of the information that the user can specify for each individual program. At the top of the screen, the user will see the statement "Page X of Y." This reference provides a quick means for the user to identify:

- (1) the number of programs that have been modelled in the database ("Y"), and
- (2) where the user currently is in the list ("X").

By pressing F9, the user will cause STARRSS to move to the previous program; F10 advances to the next program.

### **Adding a New Program**

To create a new conservation program, the user must press F10 until the end of the list is reached. A "fresh" conservation screen (i.e., one with all blank fields) will then displayed. The same thing will occur if the user selects the incremental conservation screen when there are no programs modelled in the database; in this case, the screen will be referenced as "Page 1 of 1."

### **Deleting a Program**

F4 deletes the current program from the list (after prompting the user with a precautionary question).

### 5.3 MARGINAL ENERGY AND CAPACITY COSTS

Table 5-4. Marginal Energy Costs screen

```

===== Marginal Energy Costs ($/MWH) -- Screen 1 of 3 =====
Costs for Replacement Energy                                     Probability Pointer:  7

Forecasts               Low           Medium           High
                        Cost  Growth   Cost  Growth   Cost  Growth
                        Rate (%)   Rate (%)   Rate (%)   Rate (%)
Year
1992                   40.0    5.00    50.0    5.00    60.0    5.00
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

Enter number

F1 Help      |      Ctrl-F fill      |      ESC menu
  
```

The next input screens in the System-Level Info submenu are the *Marginal Energy Cost* screen (shown in Table 5-4 above) and the *Marginal Capacity Cost* screen. STARRSS uses the information on these screens to calculate the additional costs (or benefits) of replacement power for compliance options that are expected to change the output or capacity of generating units. In other words, if switching a unit to a low-sulfur coal is expected to change its priority in a utility's economic dispatch and cause the unit to run less, then STARRSS will calculate how many fewer MWHs/year the unit is expected to generate. That lost energy will have to be made up from other resources (e.g., other units on the utility's system, the bulk power market, additional conservation). The *Marginal Energy Cost* screen is where the user enters estimates of the annual costs of this replacement energy.

Although the costs of replacement power are likely to vary from unit to unit, the screening nature of STARRSS necessitates the use of simplifying approaches. STARRSS uses the same marginal energy costs and marginal capacity costs for determining replacement power cost for every generating unit. In order to determine appropriate values for the marginal energy and capacity cost screens, the user might want to look to the prices faced by a utility in the bulk power market. This input would reflect the assumption that reductions or increases in any generating unit's energy and/or capacity would be compensated through purchases or sales in the bulk power markets. Such an assumption allows the user to specify a forecast for marginal energy and capacity costs that can be applied to the entire system. The modelling of the

generating unit operational changes (such as capacity derates and changes in utilization) is discussed in detail in the description of the *Edit/Define Compliance Options* screen in Chapter 6 (see page 82).

### **Data Entry**

The screen's layout is similar to the *Allowance Purchase Prices* screen, with three forecasts of year-to-year values (arranged vertically) and definable growth rates to facilitate data entry. Likewise, this screen has the same "Fill" function capability as was discussed in Chapter 3 (see page 26).

### ***Marginal Capacity Cost Screen***

The information on the *Marginal Capacity Cost* screen is virtually identical, with the obvious difference that the values on the **energy** cost screen are entered in \$/MWH while those on the **capacity** cost screen are entered in \$/kW.

## 5.4 ALLOWANCE PURCHASE AND SALE PRICES

**Table 5-5. Allowance Purchase Prices screen**

```
===== Allowance Purchase Prices -- Screen 1 of 3 =====
Market for BUYING Allowances                               Units: $/allowance
Probability Pointer: 3
Forecasts          LOW                MEDIUM                HIGH
Purchase Price
Premium (%):       1.10                1.00                1.00

Year      Price      Growth      Price      Growth      Price      Growth
1992      300.0      3.50      400.0      4.00      500.0      4.00
1993
1994
1995
1996
1997
1998
1999
2000
2001

Enter number

F1 Help      |      Ctrl-F fill      |      ESC menu
```

The *Allowance Purchase Prices* screen (shown in Table 5-5 above) allows the user to define year-by-year forecasts for the expected price of allowances. This screen was examined in Chapter 3 in the discussion of data entry conventions (see page 23); therefore, the discussion here will focus on those issues that were not addressed in Chapter 3.

### Buying versus Selling Allowances

Toward the top of the screen, the user will see the statement that this screen describes the **Market for BUYING Allowances**. In STARRSS, the allowance market is modelled in two distinct segments: the market for purchases and the market for sales. This allows the user to model the "bid-ask spread" -- the differential that often exists between the buying and selling prices for a commodity. Particularly in illiquid markets, bid-ask spreads can be significant. For instance, a utility may be able to purchase allowances at \$400 apiece but may be unable to sell them at any price over \$350. In STARRSS, then, there are two separate input screens for allowance prices: the *Allowance Purchase Prices* screen and the *Allowance Sale Prices* screen - both accessible through the *System-Level Info* submenu. Therefore, the user can model different price forecasts for buying and selling allowances, thereby capturing assumptions about changing market liquidity over time or different tax treatments of allowance sales. Since both

screens' formats are identical, everything presented in this discussion about the purchase price screen can be applied to the sale price screen, with a few exceptions discussed below.

### ***Probability Pointer***

As was discussed in Chapter 3 (see page 20), the *Probability Pointer* designates the specific probability distribution that will be applied to the three allowance price forecasts (Low, Medium, and High). The *Probability Pointer* is set to a value of three in the Table 5-5 example screen above; this designates a particular distribution with Low-Medium-High probabilities of 30%-50%-20%. These probabilities are associated with each of the complete multiyear forecasts. As STARRSS develops a particular scenario, it will select a complete multiyear forecast from the three possibilities (Low, Medium, and High). In other words, 30% of the time, STARRSS will select the Low price forecast for all years of the study. STARRSS will not use the probability distribution to select prices from different forecasts for each and every year.

### ***Price Premium***

Specifying a single price for the purchase of allowances in a particular year may not accurately reflect market circumstances. Depending on the size of the allowance market, a utility may face different prices for purchasing a few allowances versus purchasing a large number. If a utility wanted to purchase 100,000 allowances, it might have to pay more than if it only wanted 5,000 allowances. For example, purchasing more and more allowances might require locating more and more sellers, with each additional seller having progressively higher marginal costs of compliance. If the allowance market is large enough, a single participant's actions probably will not affect the price. However, if the market is "thin," the price of purchased allowances could depend on the quantity. STARRSS permits the user to model this phenomenon through the *Purchase Price Premium*, a data item that reflects the percent change in the price of allowances attributable to the volume of a transaction. For the purpose of determining prices, STARRSS evaluates allowances in blocks of 10,000. The *Purchase Price Premium* represents the percent price increase (i.e., an escalation factor) that would occur for successive blocks of 10,000 allowances. For example, in Table 5-5 above, the Medium forecast has allowances available for \$400 each and a *Purchase Price Premium* of 1%. Therefore, the first 10,000 allowances would cost \$400/allowance. For the next 10,000 allowances, the price would be \$404<sup>3</sup>; for the third block, the price would be \$408.04.<sup>4</sup> The price for each subsequent block of 10,000 allowances would escalate accordingly.

---

<sup>3</sup>  $\$404 = \$400 \times 101\%$

<sup>4</sup>  $\$408.04 = \$404 \times 101\%$



### ***Allowance Sale Prices Screen -- Some Differences***

In the Allowance Sale Prices screen, the user inputs forecasts for the prices allowances might sell for, along with growth rates (if desired). Note that the user cannot change the *Probability Pointer* in this screen; it is automatically set to the *Probability Pointer* defined in the *Allowance Purchase Price* screen. This prevents STARRSS from selecting inappropriate combinations of buying and selling prices during its scenario development. If these price forecasts were not "linked," STARRSS could potentially develop a nonsensical scenario with purchase prices that were lower than selling prices. If such a situation existed, organizations could make money by purchasing allowances at a lower price and selling them for a higher one. Such an unlikely market situation would never last for long. By the same rationale, the user should be careful to specify price forecasts in which the purchase price equals or exceeds the sales price in each of the three states (Low, Medium, and High). STARRSS will generate warnings if this is not the case. For example, Low-Medium-High buying prices of \$300-\$400-\$500 and selling prices of \$250-\$420-\$450 would be invalid, since the Medium situation has a selling price that is greater than the buying price.

Another difference involves the *Sale Price Discount*. Just as the *Purchase Price Premium* (discussed above) allows the user to model the effect on prices of large allowance purchases, the *Sale Price Discount* provides the same capability with allowance selling prices. In this case, however, selling a large quantity of allowances would have the opposite effect on the market, presumably depressing prices. Therefore, STARRSS will subtract the *Sale Price Discount* percentage from 100% and multiply the sale price by this value for successive blocks of 10,000 allowances. For example, if the stated sale price was \$300 and the *Sale Price Discount* was 2%, then the first 10,000 allowances sold would go for \$300 each, the next 10,000 would be \$294<sup>5</sup>, the next 10,000 would be \$288.12<sup>6</sup>, and so forth.

---

<sup>5</sup> \$294 = \$300 x 98%

<sup>6</sup> \$288.12 = \$294 x 98%

## 5.5 ALLOWANCE PARAMETERS

**Table 5-6. Allowance Parameters screen**

Allowance Parameters -- Screen 1 of 3				
Bonus Allowance Supply Percentage				
	LOW	MEDIUM	HIGH	Pointer
Phase I Extension:	50.0	80.0	90.0	7
Conservation/Renewable:	70.0	80.0	100.0	5
Phase II Repowering:	80.0	90.0	100.0	3
Year	Allocated Allowances	Additional Allowances	Maximum Allowed Purchases	Allowed Sales
1995	207000	0	207000	207000
1996	207000			
1997	207000			
1998	207000			
1999	207000			
2000	100630	0	100630	100630
2001	100630			
2002	100630			
2003	100630			
2004	100630			
2005	100630			
2006	100630			
Enter number				
F1 Help   Ctrl-F fill   ESC menu				

The *Allowance Parameters* screen (shown in Table 5-6 above) allows the user to specify miscellaneous information about allowance allocations that may affect the outcome of a STARRSS analysis. The information pertains to three general areas:

- 1) assumptions about the availability of bonus allowances,
- 2) allowance allocation adjustments, and
- 3) constraints over allowance trading activity.

### ***Bonus Allowance Supply Percentage***

There are three major reserves of bonus allowances that the Clean Air Act Amendments set aside to reward specific utility compliance activities. Those activities are:

- (1) Implementing a pollution control technology at a Phase I unit that achieves a 90% SO<sub>2</sub> removal efficiency or better,
- (2) Achieving energy savings from qualifying conservation programs or renewable resources, provided that the conservation/renewable measures are implemented after 1991, and
- (3) Repowering a Phase II unit.

It is expected that one or more of these allowance reserves will be oversubscribed. In other words, just because a utility pursues one of the rewardable activities that does not mean that it is guaranteed to receive all of the bonus allowances to which it is entitled. The user can model the uncertainty surrounding the availability of these bonus allowances with *Bonus Allowance Supply Percentage* fields. For each compliance option that falls under one of the three bonus categories, STARRSS approximates the total number of bonus allowances that a utility would get if there were no oversubscription problem. The *Bonus Allowance Supply Percentage* is used to adjust this number. Zero percent means that the user does not expect the utility to get any bonus allowances at all for implementing that specific compliance option; one hundred percent means the user expects the utility to get all of the bonus allowances it deserves. For each category, the user can specify three forecasts for these adjustment percentages (along with a *Probability Pointer*).

### ***Allocated Allowances***

The *Allocated Allowances* field on the screen is a calculated field (and therefore cannot be changed). STARRSS calculates the total number of Phase I or Phase II allowances that a utility has by adding up the unit allowance allocations depicted on the *Display/Edit Affected Units* screen (referenced under the *Unit-Level Info* screen described in Chapter 6; see page 66).

### ***Additional Allowances***

If the user knows of an adjustment that should be made to the utility's total annual allocation in either Phase I or Phase II (e.g., because of a sale or purchase of allowances), that system-level adjustment can be made through the *Additional Allowances* data item on this screen. This adjustment can be either positive or negative (to reflect additions or deductions from the utility's total number of allowances). This data item does not have a probability pointer associated with

it, as such adjustments are expected to be fixed. Changes from bonus allowance allocations may be highly uncertain, but this issue is specifically addressed by the data items described above. If the adjustment is due to a correction in a generating unit's allocation, that adjustment should be made directly on the *Display/Edit Affected Units* screen (see page 68).

The user should note that the *Additional Allowances* field uses the carry forward convention; in other words, **an adjustment that is intended for just one particular year must be followed by a zero in the following year.** Otherwise, the adjustment value will carry forward into all subsequent years.

### **Allow nce Trading Constraints**

The user may also constrain the amount of allowance market activity the utility engages in. The final two fields of the *Allowance Parameters* screen determine the absolute maximum level of annual allowance buying or selling in which the utility may engage. During STARRSS optimization, the program will discard strategies that violate the constraints. During strategy evaluation, STARRSS will "flag" any strategies that violate the constraints (see Chapter 8, page 133); however, it will still purchase as many allowances as are required to bring the utility into compliance, regardless of whether such an action will exceed the user-specified limit on purchases. In the event that a strategy involves allowance sales that exceed the sales limit, STARRSS will consider any allowances beyond the limit to have been sold without generating any revenues (i.e., at an allowance price of zero).

### **Allowance Banking**

An analysis of the banking of allowances requires a year-by-year perspective. This will be performed in STARRSS Version 2.

## 5.6 TAX RATE, ESCALATION RATES, AND COST OF CAPITAL

**Table 5-7. Tax Rate, Escalation Rates, and Cost of Capital screen**

```
----- Tax Rate, Escalation Rates, and Cost of Capital -- Screen 1 of 3 -----
Base Year:  1992                                Long-Run Effective Tax Rate (%)  34.00
End Year:   2019                                Return on Equity (%)          12.00
                                                Equity Percent of Capital      50.00

Year      Cost of Capital      -----Escalation Rates For-----
1992      10.00                Capital Cost      Variable O&M      Fixed O&M
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

Enter number

F1 Help      |      Ctrl-F fill      |      ESC menu
```

The *Tax Rate, Escalation Rates, and Cost of Capital* screen (shown in Table 5-7 above) defines system-wide financial parameters that will affect the tax accounting and present value calculations in STARRSS.

### ***Base Year and End Year***

The first user inputs to this screen are the *Base Year* and *End Year* of the study. These fields designate the "boundary" years for the STARRSS database, in that no data may be specified for years earlier than the *Base Year* or later than the *End Year*. If the *Base Year* or *End Year* are changed, the user will notice that the years that run down the left-hand side of all annual data screens will change accordingly.

The *Base Year* dictates:

- (1) the year's dollars in which all "non-annual" cost data are input, and
- (2) the reference year for all present value calculations.

Examples of non-annual data are the compliance option capital costs, increased variable O&M costs, and fixed O&M costs; these are entered in single fields, rather than in an annual stream of values such as allowance prices and marginal energy costs. The non-annual data values should be in *Base Year* dollars and will be escalated by STARRSS to determine the costs in future years.

Since a compliance option is meant to represent an action that is being contemplated, rather than one that has already been performed, no compliance option can have a "Start" year that precedes the database's *Base Year*. By the same rationale, no compliance option can have a Start year that is later than the database's *End Year*.

#### **Length of Study**

**The difference between the *End Year* and the *Base Year* does not determine the length of a study during a STARRSS execution.**

The length of a run is specified in the *Execution Parameters* screen of the *Execute* submenu. However, STARRSS will not run a study for more years than it has data for. In other words, STARRSS will not run past the *End Year*.

#### **Taxes**

Like it sounds, the *Long-Run Effective Tax Rate* should represent an estimate of the utility's long-run effective tax rate for federal and state taxes. As this is the effective tax rate, it should include the effects of deferred taxes. Even though over the "long run" all of these deferred taxes will be paid, the utility is likely to continue to accrue additional deferred taxes in future years. Therefore, this estimate should reflect the average current tax liabilities (as a percent of current taxable income) that the utility is expected to have to pay in each year over the course of the study.

### ***Return on Equity and Equity Percent of Capital***

As described in Chapter 9 (see page 167), STARRSS will use this information in calculating estimates of the tax benefits of accelerated tax depreciation and the additional tax-related revenue requirements from equity returns -- both for projects with ratebased capital expenditures.

In order to calculate these tax-related costs and benefits, STARRSS will need some additional information on the utility's capital structure (as it pertains to the calculation of the utility's allowed return on ratebase).

The *Return on Equity* should reflect the expected long-run average percent return given to common and preferred shareholders (or the latest allowed return on equity, if no forecast is available).

The *Equity Percent of Capital* is the percent of the utility's total capital structure that is represented by common and preferred stock. This information can be obtained from the balance sheet of the utility's financial statements. STARRSS assumes that the current capital structure will remain the same over the time span of the study. If the user suspects otherwise, then he or she should input the average anticipated percent over the length of the study.

The user should not spend too much time and effort on refining these data inputs; STARRSS is not a financial planning tool. **The tax calculations that STARRSS performs are very approximate and are appropriate for screening purposes only.** Therefore, some "ball park" estimates for the effective tax rate, the return on equity, and the equity percent of capital are all that are necessary.

### **Discount Rates**

The forecast for the utility's *Cost of Capital* is used primarily for discounting purposes in the program's present value calculations, although it is also used in the tax calculations (see Chapter 9, page 167). Most commonly, studies use the utility's average cost of capital as the discount rate. If the user wishes to use some other discount rate (e.g., the ratepayers' discount rate), there is nothing sacred about the *Cost of Capital* data item being the utility's cost of capital. However, since the data item is used as the utility's cost of capital in the tax calculations, the user should examine and adjust those calculations if necessary. Through the use of the *Detailed Information Flag* (discussed in the *Execution Parameters* screen, see Chapter 7, page 109), the user can examine the specific tax numbers. If they are greater or lesser than they should be, the user can adjust them using the *Tax Benefit Multiplier* and the *Tax Cost Multiplier* on the same *Execution Parameters* screen.

## **Escalation Rates**

Like they sound, the escalation rates for capital costs, fixed operation and maintenance (O&M) costs and variable O&M costs are used for escalating these various cost components out to the appropriate years for defined compliance options.

As mentioned above, the user has a choice about defining costs in STARRSS in nominal dollar terms or constant dollar terms. If the user chooses to express costs in nominal dollars (i.e., including inflation), then all rates (escalation, cost of capital, etc.) must be in nominal terms. Likewise, a STARRSS analysis that is performed in constant dollar terms must have all rates in constant/real terms (i.e., with inflation taken out).



## 5.7 PROBABILITIES ASSOCIATED WITH FORECASTS

**Table 5-8. Probability Pointers screen**

Probabilities Associated with Forecasts -- Screen 1 of 7				
Probabilities in each row must sum to 100%				
Probability Pointer	Link Number	LOW	MEDIUM	HIGH
0	0	0.0	100.0	0.0
1	0	25.0	50.0	25.0
2	0	10.0	50.0	40.0
3	1	30.0	50.0	20.0
4	4	40.0	40.0	20.0
5	4	5.0	90.0	5.0
6	5	15.0	65.0	20.0
7	6	50.0	30.0	20.0
8	7	20.0	30.0	50.0
9	7	10.0	20.0	70.0
10	8	15.0	70.0	15.0
11	8	25.0	50.0	25.0
12	4	33.0	34.0	33.0
13	4	10.0	80.0	10.0
14	4	40.0	40.0	20.0

Enter number

F1 Help | ESC menu

The *Probability Pointers* screen (shown in Table 5-8 above) is crucial to the STARRSS scenario analysis process. The data items on this screen will determine the likelihood of occurrence of the Low, Medium, or High forecast of any given data item during a STARRSS scenario. Some of the data inputs on this screen will also define dependency relationships between forecasts.

**To ensure the best use of the STARRSS scenario analysis process, the user should consider carefully the probabilities he or she would like to associate with different data items, and which data items should be strictly dependent, which should be loosely dependent, and which should be independent.**

Strict dependence is accomplished by giving two data items the same *Probability Pointer*. This would ensure that whenever STARRSS selects, for example, the Low forecast for one data item, it would also select the Low forecast for the second data item. The details of this process are explained in Chapter 3 (see page 21).

The 100 *Probability Pointers* in STARRSS (numbered 0 through 99) are listed on seven screens (accessed by <Page Up> and <Page Down>); the user, however, is by no means required to use

all one hundred. In most STARRSS applications, the user will not need any more than a dozen or so. Table 5-8 shows that the *Probability Pointer* reference numbers are listed down the left-hand side of the screen. The numbers in this column are fixed (i.e., the cursor will not move into that column) and they are in ascending order. The associated probability distributions are toward the right-hand side of the screen. These are the values that the user must input or modify (the delivered databases will have the same 0%-100%-0% probability distribution described for each *Probability Pointer*). **Each row of probabilities must sum to 100 %.** If this is not the case, STARRSS will not let the user exit this screen. Instead, upon pressing the <Escape> key, the user will see a "pop-up" window that reports which *Probability Pointer* has a set of probabilities that do not add up to 100%.

*Probability Pointer* #0 has a permanently fixed probability distribution of 0%-100%-0%. Therefore, anytime that the user does not wish to define multiple forecasts for a data item, he or she may simply input a Medium forecast and leave the *Probability Pointer* set to zero. STARRSS will then overlook any information placed in the Low and High forecast fields, using the Medium value in all simulations.

### ***Link Number***

Between the *Probability Pointer* and its probability distribution is another data item that the user can change: the *Link Number*. The Link Number "links" two or more probability distributions. This is a more advanced form of the probability dependence issue that was alluded to earlier. Strict dependence between two data items (for example, low-sulfur coal prices and allowance prices) can be modelled by simply designating the same *Probability Pointer* for both data items. For instance, assume that the user designated a particular low-sulfur coal price forecast as being \$1.20, \$1.40, and \$1.60/MMBTU for the Low, Medium, and High forecasts, respectively. Likewise, assume that allowance prices of \$300, \$400, and \$500 were similarly defined and that both data items were given a *Probability Pointer* of 3. From Table 5-8, the user can see that the probability distribution for this pointer is 30%-50%-20%. By giving both of these data items the same *Probability Pointer*, the user has ensured that when STARRSS selects the \$1.20/MMBTU coal price for one of its scenarios, it will also select the \$300 allowance price every time. STARRSS will never select \$1.20/MMBTU and the \$400 or \$500 allowance prices at the same time.

To model "loose" dependence between data items, the user can "link" *Probability Pointers*. Generally speaking, there are three different levels of dependence that can be represented in STARRSS: strict dependence, loose dependence, and independence.

Strict Dependence: two or more data items are judged to always move together. When one is high, they are all high; when one is low, they are all low. The user should give these data items the same *Probability Pointer*.

**Loose Dependence:** two or more data items are judged to generally move together. This is a minor distinction, but it allows the user to define different probability distributions for each data item. Loose dependence can then be reflected by linking those *Probability Pointers*; this is done by giving them all the same *Link Number*. Of course, if two linked *Probability Pointers* have the same probability distributions (e.g., 30%-50%-20%), they are redundant; the user may as well just use the first pointer.

**Independence:** two or more data items show no "connection" in the values that they may assume. Many variables in STARRSS can be classified as independent. For example, the SO<sub>2</sub> removal efficiency of a scrubber is based on the capabilities of the technology employed and the quality of the design and construction. However, a scrubber's removal efficiency is unlikely to be affected by the price of allowances, the price of natural gas, or a host of other data items in STARRSS. Therefore, the user should be careful to specify different, unlinked *Probability Pointers* for all variables that are deemed to be independent.

**The user should consider the dependent/independent nature of all of the STARRSS data inputs and sketch out those relationships before defining the *Probability Pointers* in the pointer screen and throughout the STARRSS database.**

## 6.0 INPUT DATA: UNIT-LEVEL INFO

STARRSS is organized in a "top down" hierarchy, that is the five top-level categories seen on the *Main Menu* have submenus that display the list of possible selections under each category. Most of these selections represent (and provide access to) another menu, a screen, or a set of screens.

After placing the cursor on the *Unit-Level Info* selection, the user will see a list of submenus for entering unit- and fuel-specific information (e.g., generating capacities, heat rates, fuel costs, unit-specific compliance options). The *Unit-Level Info* submenu is displayed in Table 6-1 below:

Table 6-1. Unit-Level Info submenu

Files	System-Level Info	Unit-Level Info	Execute	Reports
		<div><div>A</div> Display/Edit Affected Units</div>		
		<div>O</div> Affected Unit Operating Factors		
		<div>E</div> Edit/Define Compliance Options		
		<div>N</div> Display Compliance Option Names		
		<div>F</div> Fuel Inputs		
		<div>R</div> Generating Unit Redundance		
		<div>L</div> Compliance Option Linking		
		<div>V</div> View Compliance Options		
F1 Help		ENTER make selection		

The submenu lists all of the input screens that are under this category. As is the case on all of the STARRSS submenus, the user can access any of these screens by typing the letter that is to the left of the desired selection or by using the up and down **Cursor Arrow** keys to place the cursor on the desired selection and pressing <Enter>. The user can exit a screen by pressing the <Escape> key which will return the user to the *Main Menu*.

Many of the data items discussed in the following pages can be viewed in a condensed format in the system's *Input Summaries* (see the discussion in Section 8.1.9).

### A Note About Nominal versus Constant Dollars

Many of the screens in the System-Level Info category contain annual cost and price information. The user can enter these data in either nominal or constant dollars. Nominal dollars reflect the total cost of an item in any particular year in question and therefore include the effect of inflation. Constant/real dollars do not include inflationary assumptions.

However, **the user must be careful to remain consistent** throughout the STARRSS data system. For example, if the user chooses to input data items in constant/real terms, all escalation rates and cost of capital rates must be in real terms (i.e., with inflation taken out) and all price/cost forecasts must be in terms of a single year's dollar (usually the study base year).

### Base Case versus Incremental

Before exploring the various screens in the *Unit-Level Info* submenu, a clear distinction must be made between "base case" data items (existing/current) and "incremental" data items (options/alternatives). Base case values should reflect current or projected standard operations. These values should represent a projection of how things would have been had the CAAA not been enacted. This establishes a base case which is a reference point from which the utility will make decisions that will bring it into compliance with the CAAA. The STARRSS incremental data items refer to the different alternatives that a utility has open to it in order to comply. With these data items, the user will define possible compliance options (e.g., fuel-switching, reduced utilization, boiler efficiency/heat rate improvements, scrubbing) However, in order to have a reference point from which to judge the cost-effectiveness of these alternative operations, STARRSS must have information on how the system's generating units are currently expected to operate without the implementation of any compliance options (i.e., the "base case").

### Saving Databases

If the user wishes to save the data that has been entered during a STARRSS session, he or she must formally save the database (by selecting *Save* in the *Files* submenu) prior to ending the session. STARRSS will not automatically store the new information.

## 6.1 DISPLAY/EDIT AFFECTED UNITS

**Table 6-2. Display/Edit Affected Units screen**

Affected Units --- Screen 1 of 1						
Database Name: SULFUR POWER & LIGHT						
Unit Name	Capacity (MW)	Heat Rate	Baseline	Calculated	Allowances	
			Heat (TBTUs)	SO2 Emis. (tons)	PhaseI	PhaseII
BIGCOAL 1	650.0	10000	26.700	75293	36500	14000
BIGCOAL 2	650.0	10000	27.300	84761	37000	14500
MEDCOAL 1	350.0	10500	32.320	44656	44000	17500
MEDCOAL 2	350.0	10600	32.800	46244	44500	18000
MEDCOAL 3	350.0	10400	32.860	44424	45000	18000
MEDCOAL 4	350.0	10400	32.260	7984	0	17500
SMALLOIL 1	50.0	13800	0.370	77	0	200
SMALLOIL 2	50.0	13600	0.640	115	0	330
SMALLOIL 3	80.0	13500	1.040	171	0	600

Enter text

F1 Help | ESC menu

The *Display/Edit Affected Units* screen (shown in Table 6-2 above) is one of two screens that contain the majority of the unit-specific information in STARRSS (the other one is the *Affected Unit Operating Factors* screen, described later). Both screens contain information about the generating units' base case operating characteristics.

### *Database Name*

At the top of the screen is the *Database Name*. This is not the same as the STARRSS database's DOS filename (which has the .SDB filename extension and is discussed in Chapters 2 and 4). Instead, this is an internal 40-character name that will appear on all reports. Typically, the user might specify the name of the utility that is being modelled or reference a unique aspect about the analysis for which the database has been developed (e.g., "Analysis of Substitution Units," "Low Inflation Case").

The rest of the screen contains unit-specific data. The information contained in the delivered databases came from publicly available sources and is discussed in Chapter 10.

### *Unit Name*

The *Unit Name* field is where the user enters a 10-character label that will be used throughout

the system to reference each generating unit. The *Unit Name* can only be changed on this screen.

### ***Capacity***

The *Capacity* data item should reflect the generating unit's net dependable capacity (in MWs). A unit's net capacity is different from its nameplate or gross capacity in that it accounts for the unit's power that is consumed internally at the plant (to power fans, pumps, etc.).

### ***Heat Rate***

This data item should represent the generating unit's average net heat rate (in BTU/kWh). This can be calculated by taking the unit's average annual fuel consumption (in BTU) and dividing by the unit's average annual net generation (in kWhs). Naturally, a unit's average heat rate may vary depending on how the utility dispatches the unit. STARRSS Version 2 will be able to incorporate these circumstances into an analysis because it will have system dispatch capabilities and will dynamically calculate all of these values (while using user-specified incremental heat rates at different unit loading points). However, for Version 1, the user must estimate each unit's expected average annual heat rate.

### ***Baseline Heat***

The *Baseline Heat* data item is the generating unit's average 1985-1987 fuel consumption (in trillion BTU), as reported in the National Allowance Database, Version 2.1. This is used by STARRSS in certain bonus allowance calculations, and in some cases for the basis of allowances allocated because of Reduced Utilization or Phase I Substitution plans (see Chapter 11, Section 11.4).

### ***Calculated SO<sub>2</sub> Emissions***

The Calculated SO<sub>2</sub> Emissions field is "grayed out" on the screen, since it cannot be changed by the user. It is the generating unit's projected annual SO<sub>2</sub> emissions (in tons/year) and is calculated through the following Equation 6-1:

$$\text{Emissions} = \text{Cap} * \text{HeatRate} * \text{CapFact} * 8760 \text{ hrs} * \text{FuelSO}_2 * (1 - \text{ExRem}) \quad (6-1)$$

where:

Cap	=	unit's capacity (in MWs)
Heatrate	=	unit's average heat rate (in MBTU/MWh, achieved by dividing the STARRSS input by 1000)
CapFact	=	unit's average weighted capacity factor (calculated across all years and all three forecasts from the <i>Affected Unit Operating Factors</i> screen)
8760 hours	=	the number of hours in a year
FuelSO <sub>2</sub>	=	the SO <sub>2</sub> emissions rate attributable to the fuel or fuel blend that is consumed at the unit
ExRem	=	the SO <sub>2</sub> removal efficiency of the unit's <u>existing</u> pollution control equipment, if any exists (see the <i>Affected Unit Operating Factors</i> screen)

### ***Phase I and Phase II Allowances***

The *Phase I* and *Phase II Allowances* fields represent the net annual allowance allocations for each generating unit. As described in Chapter 10, the allocations depicted in the delivered database(s) have come from the National Allowance Database, Version 2.1 (Environmental Protection Agency, Allowance Branch, Acid Rain Division, June, 1992).

The net Phase I allocations are calculated from the Table A allowances (found in the CAAA) and are adjusted upward for the section 404(a)(3) allowances (for units in Illinois, Indiana, and Ohio) and downward to reflect the withholding of 2.8% of the allowances for the EPA Sales and Auction Reserves.

Similarly, the Phase II allocations included in the delivered database(s) are calculated from the published basic allocations and are adjusted upward for the section 405(a)(3) allowances (for units in ten particular states) and downward for the Sales and Auction Reserves. STARRSS assumes that the value that is input for a unit's Phase II allocation applies indefinitely from the year 2000 on. However, a unit's allocation is likely to change after 2009, when specific provisions in the CAAA expire. The Phase II allowance allocations depicted in the STARRSS delivered database(s) are applicable to the 2000-2009 time frame. If the user determines that the post-2009 changes will be significant, then he or she can



make a system-level adjustment (on the *Allowance Parameters* screen under the *System-Level Info* category; see page 56) that is equal to the sum of the individual unit adjustments.

Neither of the allowance allocation values entered on the *Display/Edit Affected Units* screen should include bonus allowances from the three categories that are modelled on the *Allowance Parameters* screen (under the *System-Level Info* category). First of all, this could lead to double-counting. Second, the allowance allocations on the unit screen are fixed/flat for every year of Phase I (1995-1999) and Phase II (2000-on), while the bonus allocations will involve different year-to-year allotments. If the user wants to model a known distribution of bonus allowances, this is best modelled at a system-level as *Additional Allowances* on the *Allowance Parameters* screen.

### **Adding, Moving, and Deleting Units**

To add, move, or delete an affected unit from the database, the user must first go to the *Affected Unit Operating Factors* screen (see pages 72-81).

## 6.2 AFFECTED UNIT OPERATING FACTORS

**Table 6-3. Affected Unit Operating Factors screen #1**

Affected Unit Operating Factors -- Screen 1 of 3				
Unit Name: BIGCOAL 1				
Commission Date: 1978		Retirement Date: 2025		
Control Technology	LOW	MEDIUM	HIGH	Probability Pointer
Removal Efficiency	0.0	0.0	0.0	0
Variable O&M (\$/MWH)	4.00	4.50	6.00	10
Existing Fuel Blend		Percent		
Fuel 1:	COAL-ILLN	100.0		
Fuel 2:				
Fuel 3:				
F1 Help   F2 Select   F4 delete   F7/F8 prev/next   F3 Move Unit				

The *Affected Unit Operating Factors* screen is the second of the two principal screens for defining generating unit information. It contains information on each unit's following operating characteristics:

- Commission and Retirement Dates
- Existing Pollution Control Systems
- Current Variable O&M Costs
- Current Fuel or Fuel Blend Consumed
- Projected Utilization (Annual Capacity Factors)

The *Affected Unit Operating Factors* screen has multiple "pages," the first of which is displayed in Table 6-3 above.

From this screen the user can add, move or delete units from the system (see pages 78-81).

## Unit Name

By placing the cursor on the *Unit Name* field and pressing F2, the user can access a full pop-up selection list of all of the affected units modelled in the STARRSS database. An example of this pop-up selection list is shown in Table 6-4 below.

**Table 6-4. Affected Unit Operating Factors screen with pop-up selection list**

Affected Unit Operating Factors -- Screen 1 of 3				
Unit Name:	Select a Unit			
Commission	BIGCOAL 1	Retirement Date: 2025		
	BIGCOAL 2			
	MEDCOAL 1			
	MEDCOAL 2			
	MEDCOAL 3			
	MEDCOAL 4			
	SMALLOIL 1			
Control Tec	SMALLOIL 2	OW	MEDIUM	HIGH
Removal Eff	SMALLOIL 3	.0	0.0	0.0
	Add a Unit			
Variable O&	<Return>	.0	4.5	6.0
				10
Probability Pointer				
0				
10				
Existing Fuel Blend				
Percent				
Fuel 1:	COAL-ILLN	100.0		
Fuel 2:				
Fuel 3:				

F1 Help | F2 Select | F4 delete | F7/F8 prev/next | F3 Move Unit

Although the cursor can be placed on this field, the name of a unit cannot be changed on this screen; that is done on the *Display/Edit Affected Units* screen.

## Commission and Retirement Dates

The *Commission* and *Retirement Dates* define the period of commercial operation for a unit. Commissionings are assumed to occur on January 1 of the specified year, and retirements on December 31 of the specified year. This means that a unit is assumed to operate through the full year of either its commission or retirement year. STARRSS will only calculate a unit's generation, emissions, and operating costs during the years of the unit's operating life. There is no need for the user to make any other adjustments in the STARRSS database (i.e., zeroing out fixed costs or projected capacity factors after retirement, etc.).

The data items on this screen represent the base case situation. In other words, if the user wants to explore the possible life-extension or repowering of a power plant, the *Retirement Date*

on this screen should not be changed. Instead, the user should identify this alternative as a compliance option (discussed later on the *Edit/Define Compliance Option* screen, see page 82). On this other screen the user can depict "new" commission or retirement dates (along with any capital or operating costs that may be required to affect such a change).

The default values included in the delivered database(s) are the years 1900 for commissionings and 2100 for retirements. This ensures that no affected units would be inadvertently removed from service in any initial STARRSS analyses. However, the user should modify these assumptions to account for the actual commissionings or retirements that are expected to occur within the time frame of any studies.

### ***Control Technology Removal Efficiency***

Some affected units already have scrubbers or other pollution control technologies installed on them (because of State Implementation Plan requirements, New Source Performance Standards that have applied to units that have come on-line in the last decade, etc.). These existing systems are modelled with this screen's *Control Technology Removal Efficiency* data item. The user should be careful not to confuse the modelling of these existing systems with that of potential compliance projects. The latter are modelled on the *Edit/Define Compliance Options* screen since they represent options that a utility could implement but has not yet undertaken. The control technologies that are modelled on the *Affected Unit Operating Factors* screen are part of the base case and are assumed to already be in operation.

To model an existing system, the user should merely specify the SO<sub>2</sub> removal efficiency of the existing pollution control equipment (in percent of SO<sub>2</sub> removed). This value will be used to reduce the generating unit's base case expected emissions (as calculated in Equation 6-1 in the previous section). The data item has three forecasts (and an associated probability pointer) to provide the user with the flexibility to define a range of estimates for the existing system's performance.

Even though a unit already has existing pollution control equipment it can still be a candidate for additional compliance activities. Many utilities are examining scrubber upgrades, fuel-blending, and cofiring options at units that are already scrubbed. Likewise, in STARRSS, specifying that a unit's emissions are reduced by an existing system does not preclude the user from defining incremental compliance options on the *Edit/Define Compliance Options* screen. The next section (on compliance options) discusses this further.

### ***Variable O&M (\$/MWH)***

As can be seen on the screen (Table 6-3), an affected unit's existing *Variable O&M* (operating and maintenance) costs can be modelled as a triple forecast. These values are entered in *Base Year* dollars/MWH. Each value will be escalated through all of the years of the study by the system-level variable O&M escalator (see *Tax Rate, Escalation Rates, and Cost of Capital* screen, page 59). These costs will be used to determine additional or avoided costs in the event that a generating unit's utilization changes because of a compliance option.

### ***Existing Fuel Blend***

In the *Existing Fuel Blend* field, the user specifies which fuel or blend of fuels a generating unit currently consumes. STARRSS allows the user to specify a fuel blend of as many as three different fuels. Before a fuel can be selected for consumption at a generating unit, the user must first define it in the *Fuel Inputs* screen (see page 98). The percentages that are specified for one or more fuels on this screen should represent the average annual blend (on an MBTU basis) and must add up to 100%. STARRSS will not let the user leave this screen if any unit's fuel blend percentages do not add up to 100%.

### **Altering an Existing Fuel Type Entry**

<b>Altering an Existing Fuel Type Entry</b>	
<b>Instructions</b>	<b>Results</b>
Place the cursor on top of the existing fuel type entry in the <i>Affected Unit Operating Factor</i> screen and press F2.	STARRSS will display a pop-up selection list of all of fuels currently defined in the database.
Move the cursor to the desired selection and press <Enter>.	The existing entry will be replaced with the new selection.

### **Adding a Fuel to the Fuel Blend**

<b>Adding a Fuel to the Fuel Blend</b>	
<b>Instructions</b>	<b>Results</b>
Place the cursor in the next blank <i>New Fuel Type</i> field in the <i>Affected Unit Operating Factor</i> screen and press F2.	STARRSS will display a pop-up selection list of all of fuels currently defined in the database.
Move the cursor to the desired selection and press <Enter>.	The new selection will be added to the fuel blend. A new set of percentages may now be defined for the new fuel blend.

### **Deleting a Fuel from the Fuel Blend**

<b>Deleting a Fuel from the Fuel Blend</b>	
<b>Instructions</b>	<b>Results</b>
Place the cursor on top of the fuel that is to be deleted in the <i>Affected Unit Operating Factor</i> screen and press F2.	STARRSS will display a pop-up selection list of all of the fuels currently defined in the database. At the bottom of the list will be a "(remove fuel from blend)" selection.
Place the cursor on the "(remove fuel from blend)" selection and press <Enter>.	STARRSS will take the fuel out of the fuel blend. The percentages for the remaining fuel(s) should be readjusted so that they sum to 100%.

### ***Forecast of Annual Capacity Factors***

The *Affected Unit Operating Factors* screen has multiple pages. The first page is followed by a series of screens that contain annual utilization projections for every affected unit. Moving between these screens is done by using the <Page Up> and <Page Down> keys.

The capacity factors entered on these screens should represent base case circumstances, as described earlier (see page 67).

Since STARRSS Version 1 does not have production costing capabilities, the user must supply unit capacity factors so that STARRSS can calculate each unit's average annual emissions and assess each compliance option's cost-effectiveness. In Version 2's dispatch simulation, these capacity factors will be ignored.

As can be seen in Table 6-5 below, the user can define triple forecasts (High, Medium, and Low) of a unit's capacity factors for every year of the study. STARRSS will "carry forward" data entries into blank fields; therefore, if the user expects a unit to operate at a relatively consistent capacity factor over time, he or she can simply enter the capacity factor in the first year and leave the rest blank. To verify that the correct values are being used in all years, the user can utilize the Fill function (Ctrl-F) to view a complete picture.

**Table 6-5. Affected Unit Operating Factors screen #2**

```

----- Unit Information -- Screen 2 of 3 -----
Unit Name:  BIGCOAL 1
              FORECASTS OF ANNUAL CAPACITY FACTORS (%)
Probability Pointer:  7

1992          LOW          MEDIUM          HIGH
1993          55.0         60.9             65.0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

Enter number

F1 Help | F2 Select | F4 delete | F7/F8 prev/next | Ctrl-F fill

```

### Adding a Unit

The procedures for adding a unit to the STARRSS database are described below. When the user follows the procedures, STARRSS will automatically place the unit at the bottom of the unit list. It is through a subsequent procedure that the user can move the unit to a different place in the list (see page 79).

Adding a Unit	
Instructions	Results
Place the cursor on the <i>Unit Name</i> field in the <i>Affected Unit Operating Factor</i> screen and press F2.	STARRSS will display a pop-up selection list of all of the affected units in the database, as is shown in Table 6-4 on page 73.
Place the cursor on the <Add a Unit> selection at the bottom of the unit list and press <Enter>.	STARRSS will ask the user for the name of the new unit.
Type in a unit name and press <Enter>.	This name will be displayed in the screen's <i>Unit Name</i> field.
Select the fuel or fuel blend that the new unit will consume (i.e., place the cursor in the fuel field and press F2).	STARRSS will not let the user leave the screen until the new unit's fuel or fuel blend has been specified.
Specify the new unit's projected capacity factor (first, press <Page Down> to advance to the second <i>Affected Units Operating Factors</i> screen).	STARRSS will not let the user leave the screen until the new unit's projected capacity factor has been specified.
Press <Escape> and go to the <i>Display/ Edit Affected Units</i> screen to input the new unit's capacity, heat rate, baseline heat, and Phase I and Phase II allowance allocations.	The user will find the new unit at the bottom of the list of affected units.

As noted in the above instruction chart, STARRSS will not let the user leave the screen until he or she has specified both the fuel (or fuel blend) that the unit will consume and the unit's projected capacity factor (at least for the *Base Year*). If the user does not know what these inputs should be, he or she should enter an educated guess (to satisfy STARRSS so that the user can exit the screen) and return to this screen with refined estimates at a later date.

### Renaming a Unit

A unit's name can only be changed on the *Display/Edit Affected Units* screen.



## Moving a Unit within the Unit List

If the user wishes to change the order in which STARRSS displays the generating units in the system, he or she can move units within the "unit list." This is accomplished one unit at a time. The procedure is described in the instruction chart on the following page.

**Moving units will not affect any STARRSS calculations.** Rearranging the order of the units on the *Display/Edit Affected Units* screen is strictly a cosmetic issue. It will only affect the order of the units on:

- 1) the *Display/Edit Affected Units* screen,
- 2) the internal unit selection list (accessed with the F2 key),
- 3) the screens on which the user selects options for evaluation or optimization runs), and
- 4) the output reports.

### RECOMMENDATION

The user should modify the order of the units in a delivered database before proceeding with the development and refinement of the database.

To move a unit, the user must first delete all of the following items from the database:

- ▶ All User-Specified Compliance Strategies (see page 117)
- ▶ All Generating Unit Redundancies (see page 101)
- ▶ All Compliance Option Linkages (see page 104)

Moving a Unit	
Instructions	Results
Select the unit to be moved (by placing the cursor on the <i>Unit Name</i> field in the <i>Affected Unit Operating Factor</i> screen, pressing F2, locating the unit on the unit selection list, and pressing <Enter>).	The unit and its operating information will appear on the screen.
Press F3 (Move).	STARRSS will check to make sure that the user has complied with the three requirements listed above. If not, STARRSS will display a warning message telling the user that there are still some strategies, redundancies, or linkages that have not been deleted. Provided that the above requirements have been satisfied, STARRSS will redisplay the pop-up unit selection list (with the name of the "moved" unit grayed-out).
Place the cursor on the name of the unit <u>before</u> which the moved unit should be placed, and press <Enter>.	STARRSS will insert the "moved" unit into its new location in the list.

## Deleting a Unit

### RECOMMENDATION

If there are any units that should not be on the affected unit list, the user should delete these units before proceeding with the development and refinement of the delivered database.

To delete a unit, the user must first delete all of the following items from the database:

- ▶ All User-Specified Compliance Strategies (see page 117)
- ▶ All Generating Unit Redundancies (see page 101)
- ▶ All Compliance Option Linkages (see page 104)

Deleting a Unit	
Instructions	Results
Select the unit to be deleted (by placing the cursor on the <i>Unit Name</i> field in the <i>Affected Unit Operating Factor</i> screen, pressing F2, locating the unit on the unit selection list, and pressing <Enter>).	The unit and its operating information will appear on the screen.
Press F4 (Delete).	STARRSS will check to make sure that the user has complied with the three requirements listed above. If not, STARRSS will display a warning message telling the user that there are still some strategies, redundancies, or linkages that have not been deleted. Provided that the above requirements have been satisfied, STARRSS will question the user to ensure that he or she truly wants to delete the current unit.
Press "Y" (to answer "Yes").	STARRSS will delete the unit.

### 6.3 EDIT/DEFINE COMPLIANCE OPTIONS

**Table 6-6. Edit/Define Compliance Options screen #1**

Compliance Options --- Screen 1 of 3					
Generating Unit: BIGCOAL 1					
Compliance Option Descriptor:			WETFGD1		
Compliance Option Name:			Wet Limestone Forced Oxidation Scrubber		
Option Life (in years): 30			In-Service Year: 1995		
Control Technology	LOW	MEDIUM	HIGH	Probability Pointer	
Removal Efficiency	88.0	90.0	92.0	5	
EXISTING		NEW			
Type	%Blend	Type	%Blend		
COAL-ILLN	100.0	Fuel Type #1	COAL-ILLN	100.0	
		Fuel Type #2			
		Fuel Type #3			

F2 Select | F4 delete | F7/F8 prev/next unit | F9/F10 prev/next opt.

The primary function of the STARRSS compliance planning system is to evaluate alternative courses of action. The majority of these compliance options are modelled in one common set of screens: the *Edit/Define Compliance Options* screen (the first of which is shown in Table 6-6 above) and the *Display Compliance Option Names* screen (discussed in the next section).

The *Edit/Define Compliance Options* screen is actually a set of three screens. Moving between these screens is done by using the <Page Up> and <Page Down> keys.

The *Edit/Define Compliance Options* screens and the *Display Compliance Option Names* screens are used to model cost and operating information for the following types of compliance activities<sup>1</sup>:

<sup>1</sup> Chapter 11 contains descriptions and information on all of these types of compliance options.

Compliance Options
Scrubbing (all types of technologies)
Sorbent Injection (and other combustion technologies)
Fuel-Switching/Blending/Cofiring
Repowering
Reduced Utilization
Efficiency Improvements/Upgrades (boiler, precipitator, existing scrubber, etc.)
Fuel Cleaning
New, Cleaner Resources

STARRSS does not have different screens or special switches for modelling different specific options from this list. Rather, all of the above compliance options are modelled on the same screens with the same general set of inputs. However, it is not necessary to use every data item on the compliance option screen to model each type of compliance option. For example, the compliance option screen allows the user to define a new fuel or fuel blend that could be consumed at a particular unit. For the modelling of a scrubbing option, this may not be applicable; in this case, the user would leave the fuel inputs unchanged.

### ***Generating Unit***

The *Generating Unit* field displays the name of an affected unit for which a compliance option can be modelled<sup>2</sup>. In STARRSS terminology, this is known as the "current" unit, since it is the unit for which the user can currently enter compliance option information.

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<sup>2</sup> Although the cursor can be placed on this field, the name of a unit cannot be changed on this screen; that is done on the *Display/Edit Affected Units* screen (see previous section).

## Selecting a Different Unit

Selecting a Different Unit	
Instructions	Results
Place the cursor in the <i>Generating Unit</i> field in the <i>Edit/Define Compliance Options</i> screen and press F2.	The user will be presented with a selection list of all of the affected units in the STARRSS database.
Place the cursor on the name of the desired unit in the selection list and press <Enter>.	STARRSS will prompt the user to select the desired compliance option. STARRSS will pop-up a <u>second</u> selection list which includes a complete list of all of the compliance options that are currently modelled <u>for the selected unit</u> . If the user selects any of these, STARRSS will fill the screen with cost and performance information for that specific compliance option at that specific generating unit.

Alternatively, the user can press the F7/F8 keys to move to the previous/next unit in the STARRSS database.

### *Compliance Option Descriptor*

Like the *Generating Unit* field, the *Compliance Option Descriptor* field cannot be edited; instead, it is used for selecting different compliance options.

### Selecting a Different Compliance Option for the Current Unit

Selecting a Different Compliance Option for the Current Unit	
Instructions	Results
Place the cursor in the <i>Compliance Option Descriptor</i> field in the <i>Edit/Define Compliance Options</i> screen and press F2.	The user will be presented with a selection list of all of the compliance options that are modelled in the STARRSS database for the current unit.
Place the cursor on the desired option in the selection list and press <Enter>.	STARRSS will fill the screen with cost and performance information for that specific compliance option.

Alternatively, the user can press the F9/F10 keys to move to the previous/next compliance option for the current unit.

## Defining a New Compliance Option for the Current Unit

Defining a New Compliance Option for the Current Unit	
Instructions	Results
Place the cursor in the <i>Compliance Option Descriptor</i> field in the <i>Edit/Define Compliance Options</i> screen and press F2.	The user will be presented with a selection list of all of the compliance options that are modelled in the STARRSS database for the current unit. At the bottom of the list, the user will see an <Add a new option> selection.
Place the cursor on <Add a new option> and press <Enter>.	STARRSS will display another pop-up selection list. This one lists those compliance options that are modelled in the database (in the <i>Display Compliance Option Names</i> screen) but are not currently modelled for the current unit. The user is free to select one of these other compliance options or to define an entirely new option. The latter is done by selecting the last choice on the selection list, which is <Define a new name>. Selecting this will transport the user to the <i>Display Compliance Option Names</i> screen (which is discussed in the next section). In this screen the user defines short and long descriptions for each compliance option in the database. The user will then be automatically brought back to the <i>Edit/Define Compliance Options</i> screen.

### The Screen is Largely Blank!

If the user selects a generating unit for which no compliance options have been defined, then the compliance option screen will be largely blank. Only the two fields discussed above will be displayed: the Generating Unit field and the Compliance Option Descriptor field, the latter of which will be blank. By moving the cursor to the Compliance Option Descriptor field and pressing F2, the user can initiate the "selection list" process that is described in the preceding instruction charts. After the user selects a compliance option, the screen will be formatted for data entry (with most of the displayed data values set to zero).



### ***Compliance Option Name***

The *Compliance Option Name* is not a field that the user can edit from this screen. It is determined by the selected *Compliance Option Descriptor* and comes directly from the *Display Compliance Option Names* screen.

### ***Option Life and In-Service Year***

The next line in the compliance option screen contains two data items, the *Option Life* and *In-Service Year*. The latter determines the specific year that the compliance option becomes active; the former dictates how many years the compliance option will last. During the compliance option's life, STARRSS will calculate the costs and emissions reduction impacts. For any study years that are prior to the *In-Service Year* or after the end of the compliance option's life, STARRSS will assume that there are no costs and no impacts. If a compliance option's life extends beyond the end of the study period, STARRSS cuts off the annual revenue requirements and emissions impacts associated with those years that are beyond the end of the study. Similarly, if the *In-Service Year* is prior to the beginning of the study, STARRSS will exclude from its analysis the revenue requirements and emissions impacts of those "pre-study" years. The details of the cost calculations are discussed in Chapter 9.

### ***Control Technology Removal Efficiency***

If the compliance option involves the implementation of a technology that reduces emissions (e.g., scrubbing, sorbent injection, repowering), the user must specify the *Removal Efficiency* of the option. This is the percentage of the unit's existing SO<sub>2</sub> emissions that will be removed by the technology. If the generating unit already has existing pollution control equipment, then STARRSS will use the cross-product of the new technology's removal efficiency and the existing technology's removal efficiency to calculate the resulting emissions reduction.

For example, assume that a unit currently has pollution control equipment that reduces its emissions by 50%; its uncontrolled emissions (without the existing system) would be 100,000 tons of SO<sub>2</sub>/year. Therefore, the current "base case" emissions are 50,000 tons/year. The utility that owns the unit is contemplating the installation of a scrubber with a 90% removal efficiency. STARRSS would calculate the final emissions to be 5,000 tons/year<sup>3</sup>. The removal efficiencies would not be additive. If they were, then the scrubber would entirely clean up the remaining emissions. Instead, STARRSS considers the efficiencies to be multiplicative.

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<sup>3</sup> 100,000 tons/year \* [1 - 50%] \* [1 - 90%]

## New Fuel Blend

If the compliance option involves fuel-switching, fuel-blending, or cofiring with natural gas, then the user must specify the new fuel blend in the lower right-hand area of the screen. On the left-hand side is a reminder of the unit's existing fuel blend. This cannot be changed on this screen; it can only be modified from the Affected Unit Operating Factors screen (see page 72).

## Altering the New Fuel Blend

Altering the New Fuel Blend	
Instructions	Results
Place the cursor on top of the current fuel type entry in the <i>Edit/Define Compliance Options</i> screen and press F2.	STARRSS will display a pop-up selection list of all of fuels currently defined in the database.
Move the cursor to the desired selection and press <Enter>.	The existing entry will be replaced with the new selection.

### Adding a Fuel to the New Fuel Blend

Adding a Fuel to the New Fuel Blend	
Instructions	Results
Place the cursor in the next blank <i>New Fuel Type</i> field in the <i>Edit/Define Compliance Options</i> screen and press F2.	STARRSS will display a pop-up selection list of all of fuels currently defined in the database.
Move the cursor to the desired selection and press <Enter>.	The new selection will be added to the fuel blend. A new set of percentages may now be defined for the new fuel blend.

### Deleting a Fuel from the Fuel Blend

Deleting a Fuel from the Fuel Blend	
Instructions	Results
Place the cursor on top of the fuel that is to be deleted in the <i>Edit/Define Compliance Options</i> screen and press F2.	STARRSS will display a pop-up selection list of all of the fuels currently defined in the database. At the bottom of the list will be a "(remove fuel from blend)" selection.
Place the cursor on the "(remove fuel from blend)" selection and press <Enter>.	STARRSS will take the fuel out of the fuel blend. The percentages for the remaining fuel(s) should be readjusted so that they sum to 100%.

## Compliance Costs

The second screen of the set of the *Edit/Display Compliance Options* screens contains mostly compliance cost information. As can be seen in Table 6-7 below, the top part of the screen merely repeats some of the basic information that is input on the first screen. It cannot be changed on this screen; to do so, the user must return to screen #1 (by pressing <Page Up>).

The remaining five data items on the screen can be entered as triple forecasts (High, Medium, and Low), each with an associated probability pointer.

**Table 6-7. Edit/Define Compliance Options screen #2**

Compliance Options --- Screen 2 of 3				
Generating Unit: BIGCOAL 1				
Compliance Option Descriptor: WETFGD1				
Compliance Option Name: Wet Limestone Forced Oxidation Scrubber				
Option Life (in years): 30 In-Service Year: 1995				
	FORECASTS			Probability Pointer
	LOW	MEDIUM	HIGH	
Capital Costs for Unit Retrofit (1992 \$M):	150.000	160.000	165.000	4
Increased Non-fuel Variable O&M Costs (1992 \$/MWH):	1.00	1.10	1.30	5
Increased Annual Fixed O&M Costs (1992 \$M/YR):	0.350	0.450	0.580	10
Additional Costs (1992 \$M/YR):	0.000	0.000	0.000	0
Escalation (%):	0.00	0.00	0.00	
New Capacity Factor (%):	58.0	60.0	63.0	5
Enter number				
F2 Select   F4 delete   F7/F8 prev/next unit   F9/F10 prev/next opt.				

### *Capital Costs for Unit Retrofit*

The first of the five principal data items on this screen is the compliance option's projected capital costs. These should be input in millions of mid-year *Base Year* dollars and **must include AFUDC** (Allowance for Funds Used During Construction, the financial carrying costs of the construction expenditures). As described in Chapter 9, these costs will be escalated up to the in-service date (based on the *Capital Cost Escalators* on the *Tax Rate, Escalation Rates, and Cost of Capital* screen). The escalated costs should be equal to the project's book value as of its in-service date.

### ***Increased Non-fuel Variable O&M Costs***

The next data item involves the compliance option's *Increased Non-fuel Variable O&M Costs*. These costs should be entered in mid-year *Base Year* dollars/MWH of generation and should represent the incremental costs of generation that will be incurred as a result of the implementation of the compliance option. These costs should not include any fuel-price-related incremental costs, as STARRSS will calculate those costs from other inputs. Also, these costs should be incremental and therefore should not include any of the unit's standard O&M costs. This data item will be escalated throughout all of the years of the study (using the *Variable O&M Cost Escalators* on the *Tax Rate, Escalation Rates and Cost of Capital* screen). However, if the compliance option has a life that is less than the full length of the study, STARRSS will only consider those costs that will be incurred during the option's active life.

Examples of non-fuel variable O&M compliance costs might be the cost of reagent (for a scrubbing option), waste disposal (e.g., for scrubber waste or fly ash), or increased water requirements. This data item should not include the costs of increased power requirements. If a compliance option is expected to derate a unit's capacity, that should be modelled on the next screen (*Edit/Define Compliance Options* screen #3). STARRSS will automatically calculate the replacement power costs for a compliance option.

### ***Increased Annual Fixed O&M Costs***

Like the variable O&M costs, the *Increased Annual Fixed O&M Costs* should just represent the incremental fixed costs of implementing a specific compliance option. They should be expressed in mid-year *Base Year* millions of dollars/year. They will be escalated throughout all of the years of the study (using the *Fixed O&M Cost Escalators* on the *Tax Rate, Escalation Rates and Cost of Capital* screen). However, if the compliance option has a life that is less than the full length of the study, STARRSS will only consider those costs that will be incurred during the option's active life.

Examples of fixed O&M compliance costs might be the wages of additional personnel who will be required to operate and maintain an option on an on-going basis (e.g., the operating crew for a scrubber).

### *Additional Costs*

The *Additional Costs* data item is similar to the *Increased Annual Fixed O&M Costs* in that it is expressed in the same terms (millions of dollars/year). However, it is meant to capture any non-operating expenses (or benefits, which are input as negative values). Such costs might be external to the utility and could include the societal costs of losing local coal mining jobs or the costs or benefits of a compliance option's resulting increase or decrease in the emissions of other, non-SO<sub>2</sub> pollutants.

### *New Capacity Factor*

The last item on screen #2 is an estimation of the long-term effect that a compliance option's implementation may have on a generating unit's utilization. For example, if a unit is fuel-switched to a more expensive compliance coal, its increased cost of generation may change its placement in the utility's dispatch order and cause it to run less. The user could represent this situation by entering a value for the *New Capacity Factor* that is lower than the base case capacity factor.

The user should leave the *New Capacity Factor* values at zero if he or she does not expect the unit's capacity factor to change with the implementation of the compliance option. STARRSS will use the "base case" capacity factors (entered on the *Affected Unit Operating Factors* screen).

It can be very difficult to estimate changes in generating unit utilization brought about by the implementation of a single compliance option since each unit's capacity factor will be affected by the options that are implemented at other units. STARRSS Version 2 will eliminate the need to make such estimations in that it will simulate a utility's dispatch and will dynamically calculate the new utilization levels of all generating units.

## Miscellaneous Inputs

**Table 6-8. Edit/Define Compliance Options Screen #3**

Compliance Options --- Screen 3 of 3				
Generating Unit: BIGCOAL 1				
Compliance Option Descriptor:		WETFGD1		
Compliance Option Name:		Wet Limestone Forced Oxidation Scrubber		
Option Life (in years): 30		In-Service Year: 1995		
	LOW	FORECASTS MEDIUM	HIGH	Probability Pointer
Capacity Deration (%):	3.0	4.0	5.0	4
Heat Rate Multiplier:	1.0000	1.0000	1.0000	0
System Marginal SO2 Emissions (LBS/MWH):	24.00	29.00	35.00	7
Overrides:				
Compliance Costs (1992 \$/TON):	0.0	0.0	0.0	0
SO2 Removed (Tons):	0	0	0	0
	Enter number			

F2 Select | F4 delete | F7/F8 prev/next unit | F9/F10 prev/next opt.

The final *Edit/Define Compliance Options* screen (shown in Table 6-8 above) contains miscellaneous data items -- namely, user inputs for the effect of the compliance option on the boiler, and the compliance option overrides.

### ***Capacity Deration***

In this field, the user should enter any capacity deration that may be caused by the implementation of the compliance option. STARRSS uses this input to calculate compliance costs associated with replacing lost capacity and generation. This input may be negative to reflect options that increase a generating unit's capacity (e.g., repowering).

The *Capacity Deration* data item does not affect the STARRSS fuel consumption calculations. In other words, capacity derations will not translate into decreased fuel consumption. The rationale for this has come from an investigation of the assumptions that have been used in several utility compliance filings. A unit is derated by the adoption of a compliance option frequently because some the unit's capacity is required to power more equipment (such as with the installation of scrubbers). Such a circumstance translates into a reduction in net generation but not a reduction in fuel consumption. The unit has less power that it can supply to the transmission grid, but its fuel consumption is unchanged (all else being equal). If a compliance

option is expected to reduce a unit's fuel consumption, the user should model this through an improvement in the unit's boiler efficiency (see the *Heat Rate Multiplier* data item, below).

### ***Heat Rate Multiplier***

The *Heat Rate Multiplier* is used to model a change in the unit's boiler efficiency because of the implementation of the compliance option. For example, fuel-switching to lower quality coal can result in a loss of boiler efficiency. As it sounds, the *Heat Rate Multiplier* is used as a direct multiplier of the unit's base case heat rate. Its default value is one. If the compliance option improves boiler efficiency, the user may input a value less than one to reflect this.

### ***System Marginal SO<sub>2</sub> Emissions***

This input represents the marginal change in system-wide SO<sub>2</sub> emissions that will result from an increase or decrease in the unit's generation by implementation of this compliance option. Given that a utility must meet its customer load requirements, a decrease in generation at this unit will have to be offset by an increase in generation at other units. Depending on which units provide the replacement power (e.g., gas-fired units, coal-fired units, off-system purchases), this increase in generation may lead to an increase in SO<sub>2</sub> emissions at some other plant. STARRSS considers the total impact of a compliance option, both at the affected unit and throughout the utility system. Therefore, if a compliance option is expected to affect a unit's capacity or capacity factor, the user must provide STARRSS with information on the average emissions rate of the units that will provide the marginal generation from elsewhere on the system. This is the *System Marginal SO<sub>2</sub> Emissions* data item (expressed in lbs. SO<sub>2</sub>/MWh). It will be used to calculate increases (or decreases) in emissions from other affected units caused by reductions (or increases) in generation from the current unit.

### **Overrides: Compliance Costs and SO<sub>2</sub> Removed**

If the user already has information on an option's projected costs (in *Base Year* \$/ton of SO<sub>2</sub> removed) and impact (in average annual tons of SO<sub>2</sub> emissions reduced), he or she may wish to bypass all of the STARRSS calculations and use the compliance option "overrides." If the user inputs values in either of these fields, STARRSS will use these fields and ignore all of the other cost/impact data items. There is one exception to this. Even if a user has defined overrides, STARRSS will examine an option's *Control Technology Removal Efficiency* (on screen #1) to determine whether the option is eligible for Phase I Extension Bonus allowances (i.e., if it achieves an SO<sub>2</sub> removal efficiency equal to or greater than 90%).

**If the user does not wish to use the overrides, he or she must leave both of the override input fields at their default values of zero.**



## Copying a Compliance Option

A user can duplicate any compliance option by following the instructions outlined below. A compliance option can be duplicated for the same unit (in the event that the user wishes to define another option with slightly different characteristics) or for a different unit.

Copying a Compliance Option	
Instructions	Results
Select and display (on the <i>Edit/Define Compliance Options</i> screen) the compliance option that is to be copied. Press F6.	STARRSS will display a pop-up selection list of all of the units currently defined in the database.
Place the cursor on the unit name of the unit <u>to which</u> the compliance option is to be copied. This can be the same unit. Press <Enter>.	STARRSS will display another pop-up selection list. This one lists those compliance options that are modelled in the database (in the <i>Display Compliance Option Names</i> screen) but are not currently modelled for the selected unit.
Place the cursor on the option name <u>to which</u> the original compliance option's information is to be copied and press <Enter>.	STARRSS will display the new compliance option.

Although the "copy" function can be very helpful, **the user must be careful to make appropriate changes to the new option's information** (e.g., capital costs, in-service dates, etc.). It is rare to find compliance options that are perfect duplicates.

## 6.4 DISPLAY COMPLIANCE OPTION NAMES

**Table 6-9. Compliance Option Names screen**

Compliance Option Names -- Screen 1 of 1	
Repowering Construction Period (in Years): 3	
r - Designates Repowering Technology	
Descriptor (10 chars)	Long Description (40 chars)
WETFGD1	Wet Limestone Forced Oxidation Scrubber
WETFGD2	Wet Limestone Magnesium Oxide Scrubber
PRBCOAL	Switch to Powder River Basin LS Coal
WVCOAL	Switch to West Virginia LS Coal
IGCC	r Integrated Gasification Combined Cycle
LOWOIL	Switch to Low-Sulfur Fuel Oil

F1 Help | F5 delete option | F6 add option | ESC menu

Table 6-9 above shows an example of the *Display Compliance Option Names* screen. The *Display Compliance Option Names* screen provides the user with a list of compliance option names defined in the database. The primary function of this screen is to provide a labeling system for compliance options. The user is free to create as many different labels as he or she wants.

There are two components to each compliance option name: the 10-character *Descriptor* and the 40-character *Long Description*. The *Descriptor* provides a brief identification of the compliance option and is used throughout the system whenever space is at a premium. The *Long Description* provides a fuller explanation of a compliance activity and is used whenever possible.

Compliance option names also provide a common label to designate similar or identical activities at several units, if the user wishes. For example, the user may use the option name "PRBCOAL" to signify the possibility of fuel switching to Powder River Basin coal. This compliance activity may be an option at several units. Presumably, the costs and impacts would differ for each unit implementing the option, but the basic activity may be similar enough to warrant the same label. Alternatively, the user can keep each compliance options unit-specific, using a descriptor such as "FGD-BCOAL1" to signify the installation of a flue gas desulfurization system at "BIGCOAL 1."

## Repowering Flags

The *View Compliance Option Names* screen also indicates whether or not options involve repowering of a unit's existing boiler. In the field at the top of the screen, the *Repowering Construction Period* designates the amount of time that any unit must be taken out of service while its boiler is repowered. This allows STARRSS to calculate the cost and emissions impact associated with taking the unit out of service during the construction period, along with the calculation of associated bonus allowances. Another field, the repowering designator, is a single-character field that is located in front of each compliance option's *Long Description*. By pressing the <Spacebar> while the cursor is located in this field, the user can toggle the repowering designator (the letter "r") on or off. If the designator is toggled on, it indicates to STARRSS that the option is a repowering option according to criteria established in the Clean Air Act Amendments. For repowering options, STARRSS calculates Phase II Repowering Bonus allowances and considers the impact on system emissions of having the repowered unit taken out of service for several years prior to the compliance option's *In-Service Year*. The period of time that the unit is temporarily out of service is defined by the *Repowering Construction Period* noted above.

## 6.5 FUEL INPUTS

**Table 6-10. Fuel Inputs screen**

```

Fuel Inputs -- Screen 1 of 3

Fuel Type: COAL-ILLN                      Units: Cents/MMBTU
Description: Illinois Basin High Sulfur Coal

Sulfur Content (Lbs SO2/MMBTU): 4.500      Probability Pointer: 6

Forecasts          LOW          MEDIUM          HIGH
                   Cost  Growth  Cost  Growth  Cost  Growth
Year              Rate (%)   Rate (%)   Rate (%)   Rate (%)
1992              120.0    4.00    125.0    4.00    130.0    4.10
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

Enter number

F1 Help | Ctrl-F fill | F2 Select | F4 delete fuel | F9/F10 prev/next fuel

```

The *Fuel Inputs* screen (shown in Table 6-10 above) is where the user defines all of the fuels that are currently being consumed by the utility's units, as well as those that potentially could be consumed. Defining a fuel in STARRSS requires three pieces of information: a fuel name/label, the fuel's sulfur content, and the fuel's delivered price. In utility operations, the same fuel can have different delivered prices to different power plants (owing to differences in transportation costs). Therefore, in STARRSS, the user may have to define one specific type of fuel as several separate fuels (e.g., PRB-COAL1, PRB-COAL2) to account for the price differences of consuming this fuel type at different plants.

### *Fuel Type and Description*

The *Fuel Type* field provides the user with a labelling reference very much like the *Unit Names* used to reference generating units. The *Description* field provides the user with a longer, 40-character label.

### Selecting a Different Fuel Type

Selecting a Different Fuel Type	
Instructions	Results
Place the cursor on the <i>Fuel Type</i> field in the <i>Fuel Inputs</i> screen and press F2.	STARRSS will display a pop-up selection list of all of fuels currently defined in the database.
Move the cursor to the desired fuel and press <Enter>.	The fuel label, along with associated emissions rate and price forecasts for that fuel will appear.

### Defining a New Fuel Type

Defining a New Fuel Type	
Instructions	Results
Place the cursor on the <i>Fuel Type</i> field in the <i>Fuel Inputs</i> screen and press F2.	STARRSS will display a pop-up selection list of all of fuels currently defined in the database.
Move to the bottom of the list where "add a new fuel" appears, and press <Enter>.	A blank template screen will appear, in which the user can define a new label, emissions rate, and cost information.

Alternatively, the user can press the F10 key until the end of the STARRSS selection list is reached. Similarly to the above process, a blank template screen will appear, in which the user can define a new label, emissions rate, and cost information.

## Deleting a Fuel Type

STARRSS will not allow a user to delete a fuel if there are any units that consume that fuel in either their existing fuel blends or in any of their fuel-switching compliance options.

Deleting a Fuel Type	
Instructions	Results
Select the fuel that is to be deleted (see above instructions).	STARRSS will display the fuel and its associated information on the screen.
Press F4.	STARRSS will check to make sure that the user has complied with the requirement noted above. If not, STARRSS will display a warning message telling the user the specific unit(s) that still burn that fuel. Provided that the above requirements have been satisfied, STARRSS will prompt the user with a question to ensure that it is the user's intention to delete the fuel.
Press "Y" (to answer "Yes").	STARRSS will delete the fuel.

## Sulfur Content

The term "sulfur content" is something of a misnomer; a better description for this input would be "expected emissions rate from the consumption of this fuel" (but was shortened to sulfur content so as to fit on the STARRSS fuel input screen). Technically, a fuel's sulfur content is the percentage by weight of elemental and organic sulfur that is found in the fuel. However, for the STARRSS data item, the user should input the SO<sub>2</sub> emissions rate (in lbs./MMBtu) which would result from burning the fuel without emissions controls.

## Price Forecast

The last fuel input is a triple forecast (High, Medium, and Low) of the fuel's delivered price (in cents/MMBtu). Similar to the conventions used on other annual price screens, the user may specify annual price values and/or growth rates. The user may view the values STARRSS intends to use by pressing <Ctrl-F>.

## 6.6 GENERATING UNIT REDUNDANCE

Table 6-11. Generating Unit Redundance screen

Generating Unit Redundance 1 of 1			
Primary Generating Unit: MEDCOAL 1			
Redundant Generating Unit(s): MEDCOAL 2			
MEDCOAL 3			
F1 Help	F2 Select	F4 del redun.	F9/10 prev/next redun.

The *Generating Unit Redundance* screen (shown in Table 6-11 above) is used to represent units that are fundamentally identical in size and generating characteristics. Identifying a redundancy will speed (and potentially enhance) STARRSS's optimization processing by allowing it to use the inputs for one unit at other identical units. For example, assume that MEDCOAL 1, MEDCOAL 2, and MEDCOAL 3 are identical units and that the user is executing a STARRSS optimization in which the program has been instructed to find the three top compliance strategies. If fuel-switching any of these three units was indeed the least-cost strategy, STARRSS would generate three top strategies that were redundant (namely, fuel-switching MEDCOAL 1, fuel-switching MEDCOAL 2, and fuel-switching MEDCOAL 3). Since these three units are the same, the duplication in the results of the STARRSS optimization process wastes time and space without providing the user with any additional information. If the user flags these units as redundant units, the STARRSS optimization process will execute more quickly and will not take up space on the list of top compliance plans with strategies that are effectively duplications. However, if the user chooses to utilize the unit redundancy features in STARRSS, the program will ignore all operating and compliance option information for the redundant units. STARRSS will consider the *Redundant Generating Units* to be exact carbon-copies of the *Primary Generating Unit* (i.e., same capacity, heat rate, capacity factor, compliance options, etc.). All unit-specific information for the redundant units will still remain in the database but will be ignored as long as the units are modelled as being redundant.

### *Primary Generating Unit*

This is the generating unit that will be "duplicated."

## Defining a Primary Generating Unit

Defining a Primary Generating Unit	
Instructions	Results
Place the cursor in the <i>Primary Generating Unit</i> field in the <i>Generating Unit Redundance</i> screen and press F2.	This will present the user with a pop-up menu of units in the active database.
Move the cursor to the desired unit and press <Enter>.	The unit's name will be placed in the field.

## Redundant Generating Unit(s)

The redundant units are those that will be temporarily replaced (during STARRSS execution processes) with exact copies of the primary generating unit.

## Selecting a Redundant Generating Unit

To select a redundant unit, the user should follow the same process as was described to select the primary unit (described above) except that the user should first place the cursor in the first blank *Redundant Generating Unit* field.

A maximum of four redundant units may be defined. Again, STARRSS will not consider options defined for redundant generating units as long as the redundancy remains in place.

## Adding/Defining a New Redundancy

Press the F10 key until the end of the STARRSS selection list is reached. A blank template screen will appear, in which the user can define a new redundancy.



## Deleting a Redundancy

Deleting a Redundancy	
Instructions	Results
Select the redundancy that is to be deleted (by pressing F9/F10 to find the redundancy to be deleted).	STARRSS will display the redundancy and its associated information on the screen.
Press F4.	STARRSS will prompt the user with a question to ensure that it is the user's intention to delete the redundancy.
Press "Y" (to answer "Yes").	STARRSS will delete the redundancy.

## 6.7 COMPLIANCE OPTION LINKING

**Table 6-12. Compliance Option Linking screen**

Compliance Option Linking -- Link 1 of 1				
Name of Option Linkage (10 chars): GROUPFGD1				
Generating Unit(s): BIGCOAL 1 BIGCOAL 2		Technology Type: WETFGD1 WETFGD1		
Group Name (10 chars): BCOAL 1&2				
Reductions in:	LOW	FORECASTS MEDIUM	HIGH	Probability Pointer
Capital Costs (1992 \$M):	7.000	8.500	10.000	2
Variable Costs (1992 \$/MWH):	0.00	0.00	0.00	0
Annual Fixed Costs (1992 \$M):	0.000	0.000	0.000	0

F1 Help | F2 Select | F4 delete link | F9/F10 prev/next link

There are often economies of scale associated with implementing a compliance option at two or more units within the same plant. For example, if coal handling facilities need to be modified in order to fuel-switch a unit, those expenditures may not be necessary to fuel-switch at a second unit within the same plant. The *Compliance Option Linking* screen (shown in Table 6-12 above) provides the user an opportunity to model this and other situations in which shared facilities reduces costs per unit.

Each compliance option should be modelled as if it were to be implemented on its own. However, if economies of scale will reduce the aggregated costs of two or more compliance options that are implemented at the same time, then the user can reflect these cost savings by "linking" the options. Defining a compliance option link does not mandate that the options must be implemented together. It simply instructs STARRSS that there is a cost savings if the options are implemented together.

### ***Name of Option Linkage***

The *Name of Option Linkage* field is where the user can specify a descriptive 10-character label that will be used to identify the linkage on reports.

### ***Generating Unit(s)***

The *Generating Unit* field is where the user specifies the units at which linked compliance options can be implemented. A maximum of five units/options may be selected for linking.

### ***Compliance Option***

The *Compliance Option* field is where the user specifies an option (associated with the generating unit on the same line) that is to be linked with other options.

### ***Group Name***

The user may define a brief group name identifying the cluster of generating units that are involved in the linkage. This name will appear on certain STARRSS reports, along with the net present value of cost reductions achieved by the linkage.

### ***Reductions in Capital Costs***

The first of the three principal data items on this screen is the projected reduction in capital costs resulting from the linkage. These should be input in millions of mid-year *Base Year* dollars.

### ***Reductions in Variable Costs***

This data item involves the reduction in each unit's variable O&M costs that will be achieved by implementing the compliance options together. These cost reductions should be entered in mid-year *Base Year* dollars/MWH of generation. Examples of cost reductions might include maintenance on common facilities (coal handling, dust control, etc.).

### ***Reductions in Annual Fixed Costs***

This data item should reflect total reductions in fixed costs, in millions of mid-year *Base Year* dollars per year resulting from the linkage. Examples of reductions in fixed compliance costs might be the sharing of an operating crew for scrubbers at two units.

### **Designating a Compliance Option Linkage**

<b>Designating a Compliance Option Linkage</b>	
<b>Instructions</b>	<b>Results</b>
Place the cursor in the first blank <i>Generating Unit</i> field in the <i>Compliance Option Linking</i> screen and press F2.	STARRSS will display a pop-up selection list of generating units in the active database.
Move the cursor to the desired unit and press <Enter>.	The name of the unit will be placed in the field and STARRSS will display a second pop-up selection list of all of the compliance options that are currently modelled at the selected unit.
Move the cursor to the desired option and press <Enter>.	The name of the option will be placed in the <i>Compliance Option</i> field. The user is now free to specify the linkages descriptive labels (the <i>Name of Option Linkage</i> and the <i>Group Name</i> ) and the reductions in costs that can be achieved by implementing the options together.

If one or more compliance option linkages are defined in the database, the user can move between them by pressing the F9/F10 keys (previous/next).

## 6.8 VIEW COMPLIANCE OPTIONS

**Table 6-13. View Compliance Options screen**

View Compliance Options --- Screen 1 of 1		
SULFUR POWER & LIGHT		
Affected Units	Option	Description
Cons/Renew.	RESIDENT 1	Residential: Hi-Effic. Appliance Rebates
BIGCOAL 1	WETFGD1	Wet Limestone Forced Oxidation Scrubber
	PRBCOAL	Switch to Powder River Basin LS Coal
	WETFGD2	Wet Limestone Magnesium Oxide Scrubber
	IGCC	Integrated Gasification Combined Cycle
BIGCOAL 2	WETFGD1	Wet Limestone Forced Oxidation Scrubber
	PRBCOAL	Switch to Powder River Basin LS Coal
	WVCOAL	Switch to West Virginia LS Coal
MEDCOAL 1	WVCOAL	Switch to West Virginia LS Coal

F1 Help

ESC menu

In the course of defining compliance options, the user may find it convenient to view an overall summary of options defined for each unit. The *View Compliance Options* screen (shown in Table 6-13 above) provides this opportunity.

Note that incremental conservation and renewable energy programs are also shown on this screen. This screen is strictly a display screen; there are no data entry inputs (although the user may make changes in other screens and view this screen to confirm that the desired set of compliance options have been defined). This screen is similar in format to screens in the *Execute* submenu, where the user will combine options into compliance strategies or select options for STARRSS to consider in its optimization processes.

## 7.0 HOW TO EXECUTE STARRSS

In order to perform a STARRSS run, the user must select the *Execute* submenu from the *Main Menu*. As can be seen in Table 7-1 below, the user has two primary choices:

- (1) to examine and evaluate one or more "user-specified" strategies, or
- (2) to have STARRSS develop a set of good strategies through one of three different optimization processes.

**Table 7-1. Execute submenu**

Files	System-Level Info	Unit-Level Info	Execute	Reports
				<div><div>X Execution Parameters</div><div>R Reporting Parameters</div></div>
				<div><div>E Evaluate User Strategies</div><div>D Develop STARRSS Strategies</div></div>
F1 Help   ENTER make selection				

### Evaluation versus Optimization

The user may either define and evaluate specific compliance strategies or direct STARRSS to use one of three different optimization processes to determine and evaluate the best compliance strategies that it can find. On the *Execute* submenu, the first type of analysis is performed by selecting *Evaluate User-Specified Strategies*; the second process is begun by selecting *Develop STARRSS Strategies*. Either selection will be followed by a series of screens that enable the user to specify exactly what will be analyzed during the STARRSS execution.

Before turning to these processes, the *Execution Parameters* and *Report Parameters* screens deserve attention.

## 7.1 EXECUTION PARAMETERS SCREEN

Table 7-2. Execution Parameters screen

Execution Parameters 1 of 1	
Years of Study: 5	Start Year of Study: ✓ 1995 (Phase I) 2000 (Phase II)
	Detailed Information Flag: 0 (1=on, 0=off)
	Discount Costs to Mid-Year? (Y/N): Y (Y = July 1, N = January 1)
	Tax Cost Multiplier: 1.000
	Tax Benefit Multiplier: 1.000

F1 Help | ESC menu

The *Execution Parameters* screen (shown in Table 7-2 above) allows the user to control various aspects of the STARRSS execution, the most important of which are the selection of compliance periods (Phase I or Phase II) and the length of the study.

### *Phase I or Phase II*

The user may select a *Phase I* or *Phase II* analysis by moving the cursor to the appropriate selection in the upper right-hand portion of the screen and pressing the <Spacebar>. STARRSS will display a checkmark to designate the selection. Since this is an "either/or" type of selection, if the alternate phase had been previously selected, its checkmark will disappear.

Selecting *Phase I* or *Phase II* determines the "start year" of the STARRSS analysis -- 1995 or 2000, respectively. This is different than the *Base Year* that is specified on the *Tax Rate, Escalation Rates and Cost of Capital* screen. The *Base Year* designates the year in which all costs are entered in the database and which will be the reference year for all present value calculations. The *Base Year* must not come after the start year of the analysis. In other words, STARRSS will not allow the user to execute a Phase I analysis if the *Base Year* is later than 1995.

### *Years of Study*

As is described in Chapter 9 (see page 160), a Phase I analysis is based on the supposition that Phase II never occurs. In other words, a 20-year Phase I run would analyze compliance

strategies over the 1995 to 2014 time frame and would only involve those generating units with non-zero Phase I allowance allocations. A Phase II analysis starts in the year 2000 and examines all units with Phase II allowance allocations. In either case, the length of the study period is determined by the *Years of Study* data item. Since STARRSS Version 1 compresses its analyses into an average-year framework, an analysis that combined Phase I and Phase II would entail the simulation of a combined average year that would be nonsensical. This is why STARRSS will not allow the user to select both Phase I and Phase II for the scope of an analysis. STARRSS Version 2 will provide a year-by-year analytical capability; this will allow a user to examine the complete and exact chronology of CAAA compliance requirements.

**Phase II-affected units may not be the target of a compliance activity in a Phase I analysis.** STARRSS identifies Phase II-affected as those units that have Phase II allowances but no Phase I allowances. If a Phase II-affected unit is to be targeted for emissions reductions during Phase I, then it will be made a "substitution unit" and will be given Phase I allowances. To model this in STARRSS, the user should input these Phase I allowances on the *Display/Edit Affected Units* screen (under the *Unit-Level Info* submenu) for this particular unit. STARRSS will then view this unit as a Phase I-affected unit and will allow it to be addressed in a Phase I analysis (for a further discussion of Phase I Substitution Plans, see Chapter 11, Page 232).

**If the user selects a Phase I analysis, then STARRSS will not allow Phase II units to be selected for compliance activities.**

If the user has previously selected a Phase II analysis, has targeted a Phase II unit in one or more user-specified strategies (a process that will be described in detail below), and then attempts to switch to a Phase I analysis, STARRSS will "deactivate" any and all user-specified strategies that target Phase II units. In other words, these strategies will stay in the database for subsequent Phase II analyses but will not be "accessible" for Phase I analyses (quite literally, STARRSS will not allow the user to position the cursor next to such strategies in the strategy selection process).

### ***Detailed Information Flag***

The *Detailed Information Flag* enables the user to generate a file (named <utility>.DET, provided that <utility>.SDB is the DOS filename for the STARRSS database). This file provides very detailed information on how STARRSS calculates the costs and SO<sub>2</sub> reduction impacts for each compliance option in each evaluated strategy. It should be used with caution since it can create a massive file of information if the user is not careful. This could potentially use up all of the user's disk space. To prevent this from happening, the user should never turn



this flag on when running many scenario iterations (a process described below). In fact, STARRSS checks to make sure that this flag is set to zero during large runs; if the flag is activated, STARRSS will prompt the user with a warning to make sure that the user is aware that the flag is turned on.

### ***Discount Costs to Mid-Year Flag***

STARRSS will automatically discount all costs to the middle of the *Base Year* (i.e., July 1). However, if the user wants to discount costs back to the beginning of the *Base Year* (i.e., January 1), the *Execution Parameters* screen has a flag to instruct STARRSS to perform an extra six months of discounting: the *Discount Costs to Mid-Year* flag. If this flag is left as a "Y", STARRSS will perform the standard process, whereby all present value calculations will be in mid-year terms. By designating an "N" for this flag, the user will cause STARRSS to represent such calculations in beginning-of-year terms. Since the *Cost of Capital* data item that is used by STARRSS for present value discounting purposes is always assumed to go from mid-year to mid-year, STARRSS will assume that the extra six months of discounting will be at the first year's discount rate. As an example, assume that the user entered the following table of values for the *Cost of Capital* on the *Tax Rate, Escalation Rates, and Cost of Capital* screen:

1992	10%
1993	11%
1994	11%
1995	12%

A \$100 million expenditure in the middle of 1995 would be discounted back to January of 1992 as \$70.3 million -- two years (from mid-1993 through mid-1995) at 11%, and a year and a half (from beginning-1992 through mid-1993) at 10%. The 12% value for 1995 would not be used in the calculation since it refers to the expected cost of capital from mid-1995 to mid-1996.

### ***Tax Cost and Tax Benefit Multipliers***

As is discussed in Chapter 9 (see page 166), STARRSS performs two types of tax calculations for capital expenditures. One entails the calculation of the tax benefits from accelerated tax depreciation granted under the current tax code. The other involves an estimation of the tax costs due to the equity portion of the return that is earned on ratebased expenditures. Both calculations are approximations for screening purposes only and are not meant to reflect detailed accounting. In the event that the user wishes to adjust these calculations or turn them off, the *Execution Parameters* screen has two multipliers that can be used to accomplish such goals. To turn off one or both of these calculations, the user can simply set the multiplier(s) to zero.

## 7.2 REPORTING PARAMETERS SCREENS

The *Reporting Parameters* screens are a pair of screens that allow the user to control various STARRSS reporting functions. These reporting features are under the *Execute* submenu (instead of the *Reports* submenu) because most of these features need to be addressed prior to executing the program. The first of the screens is shown in Table 7-3 below. To move between these screens, use the <Page Up> and <Page Down> keys.

**Table 7-3. Reporting Parameters - Screen #1**

Reporting Parameters -- Screen 1 of 2	
Report Title: STARRSS TEST RUN	
Automatically Generate Printer Reports:	
✓	Compliance Strategies Total Cost Report
	Compliance Strategies Unitized Cost Report
	Compliance Strategies Detail Report
	Compliance Option Report by Strategy
	Compliance Option Report by Unit
	Compliance Option Ranking Report
	Input Summaries
Report and Temporary Files Directory:	
C:\STARRSS	
Graphics BGI File Directory:	
C:\STARRSS\BGI	
F1 Help	ESC menu

### ***Report Title***

The user may enter a 40-character report title that will be displayed at the top of each report. This may be useful in identifying the compliance scenarios and assumptions that go into different STARRSS analyses.

### ***Automatically Generate Printer Reports***

STARRSS can generate two types of output. The first type is represented by the reports that are displayed on the PC's screen. The second type is an ASCII file that can be sent to a printer. The user can instruct STARRSS to automatically create printable reports during execution. To select a report for automatic printing, the user merely places the cursor next to the name of the desired report and presses the <Spacebar> to "toggle" the report feature on; the report feature can be toggled off by hitting the <Spacebar> a second time. A checkmark (✓) will appear next to the report the user has selected. The user may select as many reports for printing as he or

she desires. The resulting reports will be placed in a file called <utility>.PRT, provided that <utility>.SDB is the DOS filename for the STARRSS database (see Section 8.3.1, Print Files, for further discussion).

**The user cannot print these reports from within STARRSS. The user must print the ASCII file from DOS through whatever procedures are appropriate for the PC's printer/network configuration. The user should consult his or her system manager for details.**

### ***Report and Temporary Files Directory***

This is the directory location where STARRSS will output all of its report and auxiliary files from a STARRSS run. By designating different output directory locations for different databases, a user can keep the PC's individual directories less cluttered and better organized. **STARRSS will not automatically create the designated directory.** The user must do this first (through the standard DOS make-directory command).

If no directory location is specified in this field, STARRSS will place all output files in the same directory in which the program itself is located.

### ***Graphics BGI File Directory***

When the user installs STARRSS (see Chapter 2, How to Install STARRSS), the installation routine automatically creates a STARRSS directory and a STARRSS\BGI subdirectory. The latter is the default directory for the graphics interface files, a set of files that permit STARRSS to display graphical results of key outputs (see page 150 for details). If the user places or moves these "BGI" files to another location, then that new location must be noted in the *Graphics BGI File Directory* field in every STARRSS database. Otherwise, the STARRSS graphics capability will not work.

## Reporting Parameters Screen #2

The second *Reporting Parameters* screen (shown in Table 7-4 below) allows the user to control a variety of other reporting issues.

**Table 7-4. Reporting Parameters Screen #2**

Reporting Parameters -- Screen 2 of 2	
Help File Directory: C:\STARRSS	
Use Compressed Detail Report? (Y/N): N	
Name Optimizer Strategies? (Y/N): Y	
Lines per Page: 66 (0 = don't make page breaks)	
Enter text	
F1 Help	ESC menu

### ***Help File Directory***

Included in the STARRSS delivery is a file named STARRSS.HLP. This is the Help file; its location must be referenced correctly in each STARRSS database in order for the user to be able to use the Help facility (activated from within STARRSS by pressing F1).

The *Help File Directory* field is where the user must specify the directory location of the Help file. If the installation program was used, the Help file will be placed in the same directory as the STARRSS program (e.g., C:\STARRSS). If the program was put in or moved to a directory other than C:\STARRSS, then the *Help File Directory* fields in all delivered databases must be modified.

### ***Compressed Detail Report Flag***

The Compliance Strategy Detail Report is one of the system's most important reports, providing a complete breakdown of all of the compliance options in each compliance strategy that STARRSS analyzes. The user has the flexibility to control the format of this report. In its "uncompressed" format, the report provides details about base case conservation, bonus allowances, and compliance option linkage cost savings. In its "compressed" format, the report is made a little tighter by dropping these references.

If the user enters "Y" in the *Compressed Detail Report* field, STARRSS will compress the report, dropping references to base case conservation, option linkages, and bonus allowances. The base case conservation and option linkages will still be included in STARRSS's analysis and the report's bottom-line totals, but they will be dropped from the list as individual line items. Therefore, **the list of total costs and impacts will not add up**. Also, instead of reporting bonus allowances on a separate line, STARRSS will include those allowances in the total impacts for the relevant compliance activities (see Section 8.1.4, Compliance Strategies Detail Report, for further discussion). The result is a somewhat shorter report that is preferable to some users.

The default value for this field is "N." The flag does not need to be set prior to execution. The user is free to change the flag after a STARRSS run to obtain the desired formatting of the report.

### ***Name Optimizer Strategies Flag***

In the course of optimization, STARRSS attaches names to the strategies it develops and ranks them based on least expected cost. STARRSS will simply attach the names "Plan 1," "Plan 2," etc., to each strategy that it saves. However, these names have little significance to the user. Entering "Y" for this flag will tell STARRSS to attach names to the strategies that it develops from its optimization processes. The name for each strategy will be a reference to the two compliance options resulting in the largest SO<sub>2</sub> tonnage reduction for each strategy. While this feature provides more descriptive names for STARRSS strategies, it may also create duplicate names if several strategies use the same top two options. In these cases, the user will have to view the Compliance Strategy Detail Report and the Compliance Option Report by Unit to get a better idea of which options comprise each strategy.

### ***Lines Per Page***

As was discussed above, the output from STARRSS can be viewed on the screen and/or sent to an ASCII file for later printing. The *Lines Per Page* data item informs the report generator where to put page breaks in the printable ASCII files it generates. The default value is 66; the user may wish to change this if the point size on the printer fonts causes awkward breaks in printed reports.

### 7.3 EVALUATE USER STRATEGIES

As mentioned earlier, one of the two execution options provided in STARRSS allows the user to define specific compliance strategies that he or she would like to evaluate. STARRSS will "cost out" these strategies and will report the expected value, standard deviation, and range for a variety of output results. A detailed explanation of these results can be found in Chapter 8.

By choosing the *Evaluate User Strategies* selection on the *Execute* submenu, the user will be presented with the *User Strategy* screen (see Table 7-5 below):

**Table 7-5. User Strategy screen**

User Strategy # 1 of 3		
Strategy Name: SCRUB BIGCOAL 1 & 2		
>>SUMMARIZE AND EXECUTE<<		
√ = ACTIVATED [by hitting Spacebar] (one per unit)		
Affected Units	Option	Description
Cons./Renew.	RESIDENT 1	Residential: Hi-Effic. Appliance Rebates
BIGCOAL 1	√ WETFGD1	Wet Limestone Forced Oxidation Scrubber
	PRBCOAL	Switch to Powder River Basin LS Coal
	WETFGD2	Wet Limestone Magnesium Oxide Scrubber
	IGCC	Integrated Gasification Combined Cycle
BIGCOAL 2	√ WETFGD1	Wet Limestone Forced Oxidation Scrubber
	PRBCOAL	Switch to Powder River Basin LS Coal
	WETFGD2	Wet Limestone Magnesium Oxide Scrubber
	IGCC	Integrated Gasification Combined Cycle
Prespecify User Strategies --- Screen 1 of 1		
F1 Help	F2 Select	F4 delete strategy
F9/F10 prev/next strategy		

The screen provides a list of all of the affected units in the database for which the user has modelled compliance options. These options are listed under each unit's name. If the list spans several screens, the <Page Up> and <Page Down> keys can be used to move to different parts of the list. The user may define a compliance strategy by selecting specific compliance options at any or all units.

## Selecting a Compliance Option

Selecting a Compliance Option	
Instructions	Results
Move the cursor down the <i>User Strategy</i> screen until the cursor is next to the desired selection and press the <Spacebar>.	A checkmark will appear where the cursor is placed.

The <Spacebar> can be used to "toggle" the checkmark on and off; therefore, to erase a checkmark, simply place the cursor on the checkmark and press <Spacebar>.

**The user can only select one compliance option per unit.** If the user tries to select a second option for any unit, STARRSS will erase the checkmark from the previously selected compliance option.

If the user wants to perform two different compliance options at a unit, these options should be combined and modelled as a single option. For example, if the user wanted to represent a situation where a unit was to be scrubbed and fuel-switched, he or she could model this on the *Edit/Define Compliance Options* screen (see Chapter 6, page 82). This combined option would then show up on the *User Strategies* screen and could be selected as a single option.

At the top of the list are any incremental conservation programs or renewable energy resources that are modelled in the database (e.g., "RESIDENT 1" in Table 7-5 above). The user can either select or not select each of these resources, in that they each represent a compliance activity in themselves. Below this list is the generating unit list, which may extend onto several screens (depending on the number of compliance options that are modelled in the database).

## Modelling a Specific Compliance Strategy

To model a specific strategy, merely select the desired compliance options and type in an appropriate *Strategy Name* at the top of the screen. This second step is not mandatory but is strongly recommended; otherwise, it will be difficult to tell the strategies apart on many of the STARRSS reports. There is nothing that the user needs to do to "freeze" or save the strategy;

like all of the other STARRSS inputs, it is automatically recorded as it is typed in and can be changed by the user at any time.

**After making any substantive changes to an already-defined strategy, be sure to change the *Strategy Name*. Failing to do so could make for some rather confusing reports.**

Similar to other multiple-menu input screens, the user-specified strategies are in a list. At the top of the screen, the user will see a designation of where he or she is in the list, as well as the number of strategies currently defined in the database (e.g., "User Strategy #1 of 3," as displayed in Table 7-5 above). As is noted on the instruction line at the bottom of the screen, pressing the F9 and F10 keys will move the user back and forth, respectively, through this list. Alternatively, a user can place the cursor on the *Strategy Name* field and press F2; STARRSS will display a selection list of the names of all currently defined strategies.

### **Defining a New Compliance Strategy**

To define a new compliance strategy, the user can merely press the F10 key (Next Strategy) to advance beyond the end of the current list or press F2 and select <Add a Strategy>. STARRSS will display a fresh *User Strategy* screen.

### **Deleting an Existing Strategy**

To delete an existing strategy, the user simply has to press the F4 key while viewing that specific strategy. Prior to deleting the strategy, STARRSS will prompt the user with a question to make sure that this is what the user wants to do.

Once all the desired user-specified strategies have been defined, the user should place the cursor on >>SUMMARIZE AND EXECUTE<< and press <Enter>. This will transfer the user to the *Strategy Summary* screen, which, like its name suggests, presents a summary of all of the user-specified strategies (see Table 7-6 below):



**Table 7-6. Strategy Summary screen**

```

Strategy Summary --- Screen 1 of 1
Number of Scenario Iterations per Strategy: 250
[0 = do not iterate, use mean forecast]

>>>>>>>>>> EXECUTE <<<<<<<<<<<<

Summary of User Strategies:   ✓ = ACTIVATED

✓  User Strategy #1:          SCRUB BIGCOAL 1 & 2
    BIGCOAL 1                 Wet Limestone Forced Oxidation Scrubber
    BIGCOAL 2                 Wet Limestone Forced Oxidation Scrubber

✓  User Strategy #2:          CONSERVE AND SWITCH
    RESIDENT 1                Residential: Hi-Effic. Appliance Rebates
    BIGCOAL 1                 Switch to Powder River Basin LS Coal
    BIGCOAL 2                 Wet Limestone Magnesium Oxide Scrubber

✓  User Strategy #3:          SCRUB BIGCOAL 1 (ENHANCED)
    BIGCOAL 1                 Wet Limestone Magnesium Oxide Scrubber

```

Each strategy is displayed with its name and a complete list of all compliance options that are selected for that strategy. The notation of "User Strategy #1" merely reflects where the strategy is in the list of user-specified strategies and does not indicate anything about the cost, ranking, or desirability of the strategy.

Just because the user has defined and set-up a strategy does not mean that the strategy must be evaluated in a STARRSS run. The user has the flexibility to select any combination of strategies for a particular evaluation. The strategies can be selected very much the same way that compliance options were selected on the previous screen. The user merely moves the cursor down the screen to the desired strategies and presses the <Spacebar> to place a checkmark next to them. Pressing the <Spacebar> again toggles a checkmark off.

### Number of Scenario Iterations

At the top of the screen, the user specifies the *Number of Scenario Iterations*. This data item determines the number of different scenarios or situations that will be simulated **for each compliance strategy**. By designating a zero, the user can direct STARRSS to only run one scenario for each strategy; that scenario will use the mean (i.e. weighted average) forecast value for each and every data item in the database. Otherwise, by specifying a non-zero value for the *Number of Scenario Iterations*, the user will indicate how many STARRSS iterations should occur for each scenario. The term "scenario iteration" refers to the process of (1) selecting specific data values for each STARRSS data item, and (2) "costing out" a particular compliance strategy. During each iteration, STARRSS will "randomly" select which forecast (Low,

Medium, or High) will be used for each data item during the program's calculation of a compliance strategy's cost. Although STARRSS uses random numbers to influence its selection process, the program takes into account the user-specified probabilities associated with the forecasts for each data item. This process is described in detail in Chapter 3 (see page 28).

As an abbreviated explanation, STARRSS will generate a random number (between 1 and 100) for each data item. That random number will be used to select each data item's forecasted value during a scenario iteration. Assume that the user has specified a 30%/50%/20% set of probabilities to go along with the Low, Medium, and High forecasts for a data item (e.g., the capital cost for a particular scrubber at a specific generating unit). STARRSS will "stack" the Low, Medium, and High forecasts' probabilities on a continuous scale from 1 to 100 and thereby define "zones" of numbers that corresponded to the Low, Medium, or High situations. Therefore, the Low zone will be from 1 to 30, the Medium zone from 31 to 80, and the High zone will be from 81 to 100. Defining such zones ensures that a random number between 1 and 100 will have a 30% chance of falling in the Low zone, a 50% chance of being in the Medium zone, and a 20% chance of being in the High zone -- the exact probability distribution defined by the user for the specific data item.

Assume now that during a given scenario iteration, STARRSS' random number generator outputs the number "35." This would fall in the Medium zone, so STARRSS would select the Medium forecast value for the capital cost of the particular scrubber in question. STARRSS would perform the same process with all other data items and determine the cost of the compliance strategy **for this particular scenario iteration**. For the next scenario iteration, the random number generator might output the number "93." This would put the scrubber capital costs in the high range. The next iteration might see a random number of "17," leading to the selection of the Low forecast value for the scrubber's capital cost. Through repeated iterations, the total cost of a particular compliance strategy will assume many different values (one for each iteration) that will reflect the strategy's cost under various combinations of economic and operational events. This is called a Monte Carlo simulation. The cost from any single iteration may not be representative of the strategy's expected cost. However, if the user runs this type of simulation through enough iterations, the distribution of the costs can yield two important results. First, the "expected value" (or average) of the cost distribution provides a better indication of the likely cost of a compliance strategy than a "static" estimate that is predicated on a fixed set of economic and operational assumptions. Second, the range or variance of the distribution of costs provides the user with an idea of the level of economic risk that is inherent in the compliance strategy.

The *Number of Scenario Iterations* field on the *Strategy Summary* screen is where the user designates how many cost simulations STARRSS will perform for **each** selected compliance strategy.

## RECOMMENDED PROCEDURE

In order to generate a reasonable set of STARRSS simulation results, the user should set the *Number of Scenario Iterations* data item to **200** or more.

Except for "test" runs (where the user is merely experimenting with the system), executing STARRSS for only a few iterations is **strongly discouraged**. Any conclusions drawn from a very sparse distribution of results would be virtually worthless. Besides, the STARRSS costing process is quite fast. Of course, computing speed is machine-dependent; but on a standard PC 286 (without a math coprocessor), processing 200 iterations for an average utility's compliance strategy takes less than 2 minutes.

Selecting more iterations will provide results that are more refined. The maximum *Number of Scenario Iterations* is 999. The user is encouraged to experiment with this data item to assess the sensitivity of results to the number of iterations and to determine a point of diminishing returns. For example, for a particular utility system, the user may find that running STARRSS for any more than 350 iterations does not appreciably change the model's results. However, this cutoff point will depend on what is being modelled and will differ between databases.

### >>>EXECUTE<<<

The user is now ready to execute STARRSS and evaluate the selected compliance strategies. Merely position the cursor on >>>EXECUTE<<< and press <Enter>. A "pop-up" window will be displayed in the middle of the screen that will report on where STARRSS is in its processing. STARRSS will spend a few seconds initializing information and performing "up-front" calculations that will speed up the processing of the different scenario iterations. Messages like "Calculating PV (present value) factors" will appear in the pop-up window. As STARRSS begins costing out the compliance strategies, it will display information about how far along it is in this task, reporting the percent of the task that has been completed. Once this display reaches 100%, STARRSS will begin generating reports -- a task that is performed in two passes (as is reported in the pop-up window). The reports (and several auxiliary files) are stored in the PC's directory from which STARRSS was invoked, unless the user specifies a different directory for these files (as was discussed earlier with the *Report Parameters* screen, Pages 112-113). After these files have been written to disk, STARRSS has completed its execution and returns the user to the *Main Menu*. From there, the user can move over to the *Reports* area and view the results of the run (see Chapter 8 for details about the STARRSS reports).

## 7.4 DEVELOP STARRSS STRATEGIES (OPTIMIZATION)

As mentioned earlier, STARRSS can be run in one of two modes:

- (1) evaluating specific compliance strategies, and
- (2) optimizing and developing its own strategies.

In the latter case, the user is leaving it up to STARRSS to find the best strategies. This process is initiated by selecting *Develop STARRSS Strategies* on the *Execute* submenu. The user will be presented with the *Develop STARRSS Strategies* screen displayed in Table 7-7 below.

**Table 7-7. Develop STARRSS Strategies screen**

Develop STARRSS Strategies -- Screen 1 of 1	
--->DEFINE ACTIVE COMPLIANCE OPTIONS<---	
Number of Strategies to be Evaluated/Saved:	5
Number of Scenario Iterations per Strategy:	400
[0 = do not iterate; use mean forecast]	
Number of Iterations for Heuristic #1:	200
	Estimated Execution Time
--->EXECUTE FULL OPTIMIZATION<---	~4 minutes
--->EXECUTE HEURISTIC SOLUTION #1<---	~7 minutes
--->EXECUTE HEURISTIC SOLUTION #2<---	~5 minutes
Enter number	

F1 Help | ESC menu

This is the screen from which the user will execute the STARRSS optimization process; however, for explanatory purposes, a subsequent screen will be described first.

When STARRSS displays the *Develop STARRSS Strategies* screen, the cursor will automatically be placed on the **--->DEFINE ACTIVE COMPLIANCE OPTIONS<---** field. By pressing <Enter>, the user will be presented with a subsequent screen: the *Select Compliance Options* screen (as shown in Table 7-8 below).

**Table 7-8. Select Compliance Options screen**

Select Compliance Options --- Screen 1 of 2		
✓ = ACTIVATED FOR CONSIDERATION		Optimization time: ~19 minutes
Affected Units	Option	Description
RESIDENT 1	✓ Do Nothing	Do not implement this cons/renew. program
	✓ Implement	Residential: Hi-Effic. Appliance Rebates
BIGCOAL 1	✓ Do Nothing	Leave the unit as is
	✓ WETFGD1	Wet Limestone Forced Oxidation Scrubber
	✓ PRBCOAL	Switch to Powder River Basin LS Coal
	WETFGD2	Wet Limestone Magnesium Oxide Scrubber
	✓ IGCC	Integrated Gasification Combined Cycle
BIGCOAL 2	✓ Do Nothing	Leave the unit as is
	✓ WETFGD1	Wet Limestone Forced Oxidation Scrubber
	✓ PRBCOAL	Switch to Powder River Basin LS Coal
	WETFGD2	Wet Limestone Magnesium Oxide Scrubber

F1 Help

| SPACE check (uncheck)

| ESC menu

As the name suggests, this is the screen where the user can select which compliance options will be available for consideration by the STARRSS optimization process. Similar to the *User Strategy* screen described in the previous section (in the discussion of the evaluation of user-specified strategies), the screen displays a complete listing of all of the compliance options that are modelled in the database; again, viewing the entire list may require pressing the <Page Up> and <Page Down> keys. This time, however, the user is not limited to selecting only one compliance option for a generating unit. Since the user is defining all possible compliance activities that he or she wants STARRSS to consider in developing a least-cost plan, no such constraint is necessary. Of course, when STARRSS develops specific strategies, it will not consider implementing more than one compliance option at any one unit at the same time. For example, if the user has designated that a unit can be scrubbed or fuel-switched, STARRSS will not try to implement both at the same time. If scrubbing and fuel-switching simultaneously are an option, the user must model this as a third, distinct compliance option.

The *Select Compliance Options* screen lists all of the compliance options that are modelled in the database. The screen allows the user to define the subset of compliance options that STARRSS will consider during the optimization process. Therefore, just because a compliance option is modelled in the database does not mean that it must be included in the scope of an optimization run. By the same rationale, the user need not delete compliance options from the database just to keep them from being considered in a STARRSS run. A STARRSS database may have many compliance options modelled in it, while the user may choose to select a few during any particular STARRSS execution.

The user can select (or unselect) any particular compliance option using the same "checkmark" process that has been discussed on previous screens. Simply place the cursor next to the desired compliance option and press the <Spacebar>. The <Spacebar> will "toggle" a checkmark on and off, designating the option as having been selected or unselected, respectively.

At the top of the screen, the user will see an estimation of the time that STARRSS will take to perform a Full Optimization run for all of the selected compliance options. A Full Optimization run considers every possible combination of selected compliance options. Naturally, the more options that a user selects, the more combinations that are possible, and the longer the process will take. In fact, the "size" of the optimization problem increases exponentially as more and more options are selected. If the user wishes to examine many compliance options at many generating units, the Full Optimization may take too long. In this case, the user can pick one of two heuristic methodologies that are much faster. However, they take shortcuts and cannot be guaranteed to produce the optimal compliance strategy. In any case, the results from a heuristic optimization run could be used to determine which compliance options should be considered in a Full Optimization run. All three optimization processes are discussed briefly at the end of this chapter and in detail in Chapter 9 (see discussion beginning page 182).

To determine the Full Optimization time estimate, STARRSS monitors which compliance options have been selected and automatically changes the estimate every time the list is modified. STARRSS determines the time estimate by combining the information on which options the user has selected with its knowledge of the speed of the user's computer -- which it obtains by running some trial calculations at the beginning of the session (when the user first invokes STARRSS).

### **Do Nothing**

One important difference exists between the list of compliance options on the evaluation's *User Strategies* screen and the list on the optimization's *Select Compliance Options* screen; the latter includes the option of "doing nothing." In most compliance decisions, this is always an implicit option. In some, however, it is not. For example, in some states, the legislature has required that some utilities scrub specific units. The utilities are free to select the scrubbing technology they want to employ, but they must scrub. Therefore, "doing nothing" at these units is not an option. In order to make sure that STARRSS develops a set of desirable compliance strategies that each include the mandatory scrubbing of these units, the user must have a means of "forcing the program's hand." This is done by unselecting the Do Nothing option (i.e., toggle the checkmark off, using the <Spacebar>). The user may model and activate several different scrubbing technologies, and since the Do Nothing option is deactivated, STARRSS will be forced to pick one of the technologies. As another example, perhaps a utility has already made a firm decision regarding compliance at a specific unit but is still exploring additional measures

at other units to come into system-wide compliance. To model this situation, the user can activate that specific option at the particular unit and deactivate all other options for that unit (including the Do Nothing option). This will ensure that the fixed decision is "imbedded" in each and every strategy that STARRSS considers in its optimization process. Essentially, that fixed decision becomes a foundation from which STARRSS will build different compliance strategies.

By pressing the <Escape> key, the user will return to the *Develop STARRSS Strategies* screen (displayed previously in Table 7-7 and repeated on the following page), from which the optimization run is executed.

The three different optimization approaches are listed in the lower portion of the screen. An estimate of the execution time for each of the approaches appears on the right. The accuracy of these estimates is not guaranteed. It is impossible to predict the actual time that any of the optimization processes will take. Their execution times are dependent on various "decisions" that are made during the optimization process. The outcomes of these decisions cannot be known prior to the optimization run. Therefore, the time estimates are merely meant to provide the user with a ball park approximation (plus or minus 50%). If the size of the optimization problem is small enough, it is entirely likely that the Full Optimization will be faster than the heuristic algorithms. However, as the number of compliance options increases, the heuristic approaches can offer considerable time savings relative to the Full Optimization process and can provide some insights into which compliance options are cost-effective and which are not.

An optimization run is initiated by moving the cursor to one of the three EXECUTE selections and pressing <Enter>. Prior to doing that, the user should consider the optimization parameters that are displayed in the upper portion of the screen.

**Table 7-7. Develop STARRSS Strategies screen**

```
Develop STARRSS Strategies -- Screen 1 of 1

--->DEFINE ACTIVE COMPLIANCE OPTIONS<--

Number of Strategies to be Evaluated/Saved:      5

Number of Scenario Iterations per Strategy:  400
[0 = do not iterate; use mean forecast]

Number of Iterations for Heuristic #1:          200

Estimated Execution Time

--->EXECUTE FULL OPTIMIZATION<---                ~4 minutes
--->EXECUTE HEURISTIC SOLUTION #1<---            ~7 minutes
--->EXECUTE HEURISTIC SOLUTION #2<---            ~5 minutes

Enter number

F1 Help | ESC menu
```

### Optimization Parameters

In all three processes, STARRSS will develop a set of top strategies. As was discussed in Chapter 1, there is no truly optimal compliance strategy because different strategies have different levels of risk associated with them. Judging compliance strategies purely on the basis of least-cost (with no regard for their potential economic risks) ignores a major part of the planning decision. Different individuals and organizations have different tolerances for risk. Some may want the least-cost solution, even if it comes with considerable risks. Others may be willing to pay a premium (similar to insurance) to have a lower-risk plan. The cost/risk trade-off is a decision-making issue that STARRSS can help the user explore and understand. However, the program will not judge or determine the appropriate trade-off for the user. Only the user can make that decision.

Therefore, in its optimization processes, STARRSS will not search for the optimal plan. Rather, the system will identify a set of top low-cost compliance strategies that warrant further analysis. The number of compliance strategies that will be saved (and subsequently sent through the multiple-scenario evaluation process) are determined by the data item: *Number of Strategies to be Evaluated/Saved*. Although this value can be any positive number up to 99, the user should probably keep the number below 20 for most runs. Saving and evaluating too many strategies can take a great deal of run time, consume inordinate amounts of disk memory, and clutter the STARRSS reports.



## Optimization and Heuristic Processes

In all three optimization processes (i.e., Full Optimization, Heuristic #1, and Heuristic #2), the same general sequence of events occur. The discussion here is supplemented by a more detailed explanation in Chapter 9 (see page 182). First, STARRSS develops a master list of different compliance strategies. Each time the program develops a strategy, STARRSS costs out the strategy (based on the mean value of each input data item), and places the strategy in its appropriate position in the list such that the costs are ranked in ascending order. Depending on the optimization process selected, this procedure may consider billions of different compliance strategies.

Next, STARRSS takes the top, lowest-cost "X" number of plans (where "X" is the user-designated *Number of Strategies to be Evaluated/Saved*) and runs them through the full multiple-scenario evaluation process.

The *Number of Scenario Iterations per Strategy* works the same way that it does on the *Evaluate User Strategies* screen; it designates the number of iterations that will be performed for each compliance strategy during this evaluation phase of the optimization run.

The last optimization parameter, the *Number of Iterations for Heuristic #1*, pertains only to the first heuristic optimization process. It is explained in more detail in Chapter 9 (see page 184). Generally, a number in the range of 50 yields good results in a reasonable execution time.

## 8.0 REPORTS, GRAPHS, AND AUXILIARY FILES

STARRSS has three reporting capabilities.

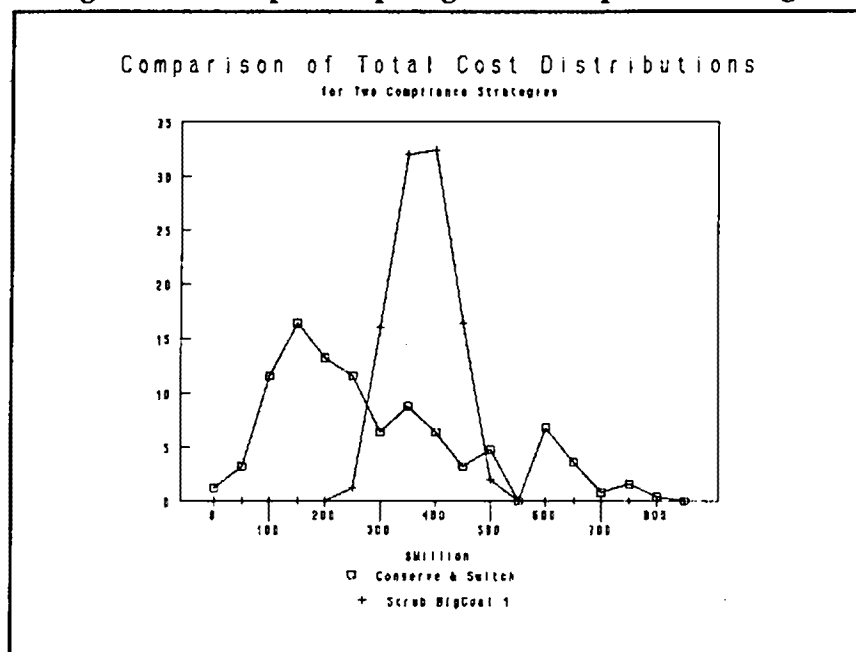
First, the program provides the user with a half dozen different **reports** that display output information from a STARRSS run, as well as several reports summarizing the STARRSS' inputs.

Second, STARRSS can depict several key outputs in a **graphical representation**.

Third, several **auxiliary files** are generated that can provide more detailed information and/or can be imported into other programs (e.g., Lotus 1-2-3).

All three of these capabilities are discussed in this chapter. The chapter's first section reviews the STARRSS reports and discusses exactly how each output is calculated. The second section examines the graphical features in STARRSS, and the third section covers the auxiliary files. An example of one of the types of graphs that STARRSS can produce is shown in Figure 8-1 below:

**Figure 8-1. Graph Comparing Two Compliance Strategies**



The graph exhibits an example of the cost versus risk trade-off that STARRSS is designed to capture. In this example, the "Conserve & Switch" strategy carries the potential for lower costs,

but also carries much greater volatility in costs than the "Scrub BigCoal 1" strategy.

Before exploring the program's graphical and reporting capabilities, however, the user must understand the general report generation process.

As mentioned in Chapter 4 (Section 4.2, Saving a Database), STARRSS will generate output files that have the same root name as the STARRSS database. In other words, if the user loads a database called <utility>.SDB and runs STARRSS, a set of files will be created with the names <utility>.XXX, where XXX stands for a variety of filename extensions. These files will be either on the user's floppy disk (if STARRSS was invoked from the floppy disk) or on the user's hard disk (if, as is recommended, STARRSS is run from the hard disk). By default, the files will be placed in the same directory where STARRSS resides, although the user can designate another location for these files. This report relocation feature is discussed in the *Report Parameters* section (see Section 7.2); it should be used because it will help the user keep the main STARRSS directory better organized.

### **Where Are My Reports?**

To avoid potentially frustrating situations, the user should understand the specific process that STARRSS uses when it displays output reports. If the user wants to view a particular report, he or she can merely select it from the *Report* submenu by typing the letter that is to the left of the report name or by placing the cursor on the report name and pressing <Enter>. STARRSS will search in the relevant directory for the specific file that contains information for that report.

**In determining the name of the report file that it must search for, STARRSS takes the root name of the current database and adds the appropriate extension.**

Therefore, suppose that a user loaded a database called UTILITY.SDB, ran STARRSS, subsequently loaded a new database called UTILITY2.SDB, and then tried to view the reports from the initial STARRSS execution. STARRSS would complain that it could not find any report files. This is because it would be looking for files that matched the current STARRSS database (UTILITY2.SDB). Since the user has not run STARRSS with that database, no report files exist that have the UTILITY2 root name.

If the user wants to view reports that were generated from a previous run, the user must load the STARRSS database that was associated with those reports (i.e., that has the same root name).

The user should be aware, however, that just because a database and a set of reports have the same root name, the results in the reports do not always come from an execution of that database. A user could load a database, make some data changes (e.g., change the forecasts of allowance prices), run STARRSS (and thereby generate report files), and quit from STARRSS without saving the database. The report files and the original database would have the same root name. Therefore, during a subsequent STARRSS session, the user could load the database and view the reports; however, the user would not be able to reproduce the results displayed in the reports by rerunning STARRSS with the original database (since that database would not include the data changes). The user may want to routinely save databases just before executing STARRSS so that this type of discontinuity is prevented. In addition, if the user is examining multiple cases, he/she may want to save the database each time and to make sure that a different root name is designated for each case.

To recap, there are two critical points to remember:

- 1) When reports are generated (by running STARRSS), the system will give the report files the same root name as the **current** database. **If reports with this root name already exist, they will be overwritten.**
- 2) When reports are requested (by selecting them on the Reports submenu), STARRSS will look for report files with the same root name as the **current** database.

With a little planning, the user should have no problem with running STARRSS and viewing the results. In the event that the user would like to see results that were produced during a previous session, he or she has to first load the database with the same root name.

## 8.1 REPORTS

The output results of a STARRSS execution can be viewed by moving the cursor to the final category of the Main Menu, the Reports submenu. This submenu (shown in Table 8-1 below) provides the user with access to all of the system's output reports, input summaries, and graphical capabilities.

**Table 8-1. Reports Submenu**

Files	System-Level Info	Unit-Level Info	Execute	Reports
				<b>W</b> Warnings <b>T</b> Compliance Strategies Total Cost Report <b>D</b> Compliance Strategies Detail Report <b>G</b> Graph of Compliance Statistics <b>S</b> Compliance Option Report by Strategy <b>U</b> Compliance Option Report by Unit <b>R</b> Compliance Option Ranking Report <b>Z</b> Compliance Strategies Unitized Cost Report <b>I</b> Input Summaries
F1 Help		ENTER make selection		

Before exploring each of the reports, the user should be aware of some basic reporting features.

### 8.1.1 Reporting Features

As mentioned earlier in the chapter, STARRSS produces files that contain the output results from the STARRSS execution process. These files are in ASCII format. Although they can be imported into word-processing systems or sent directly to a printer in their current form, they do not include any descriptive notations (titles, column headings, etc.) and would be difficult to interpret. STARRSS provides the user with a specific process for generating fully-formatted reports that can be sent to a printer. These printable reports will still be in ASCII format but will include all of the descriptive notations that the user sees on the computer screen when viewing the reports from within STARRSS.

#### **Printable Reports**

Users may prefer to generate printable reports in order to view STARRSS results, for several reasons. First, printing out a copy gives the user a permanent, hard-copy version. Second, when viewing a report on a computer screen, the user is limited to seeing only a few dozen lines at a time. Printed reports give the user a full page of text. (The user can control the number of lines generated between page breaks on the printer reports -- see Section 7.2, *Report Parameters* screen.)

All desired reports will be clustered into one file, called <utility>.PRT, where <utility>.SDB is the name of the current STARRSS database. The file of printable reports is created through one

of two procedures. One is to view reports in STARRSS through the conventional process (i.e., selecting them one at a time from the *Reports* submenu). When the user sees a report that he or she would like to have printed out, he or she can merely press the F3 key. If the printable report file does not already exist, pressing F3 will create the file and put a fully-formatted version of the report that is on the screen into the file. If the printable report file does already exist, STARRSS will ask the user if the new report should be appended to the information that is already in the file or if the new report should overwrite the existing file.

A second way to create a printable reports file is for the user to designate which reports should be included in the file **prior to execution**. This is done on the *Report Parameters* screen (see Section 7.2).

### **Printing the Printable Reports File**

**Neither of the two methods that the user can select to create the printable report file actually causes the file to be printed.**

To print out the ASCII printable reports file, the user must issue a **print command from the DOS environment**. PC print protocols and printer configurations are machine-specific. Since the printing process is different from one machine to the next, it would have been difficult and problematic to design a STARRSS PRINT capability. If the user does not know how to print ASCII files from his or her PC, the user must consult his or her computer system's manager. However, most PCs have a fairly straightforward procedure for printing ASCII files from within the DOS environment.

### **Automatic Advance**

One last feature deserves note before proceeding to the individual reports. For all of the input data and execution screens, the user had to press <Escape> in order to exit a screen. This is still a valid exit procedure for the report screens; however, another option exists. If the user presses <Enter>, STARRSS will exit the current report and automatically move the cursor selection to the next report. If the user wishes to view that report, he or she merely has to press <Enter> again. This feature allows the user to quickly advance through the listing of reports without the inconvenience of typing different keystrokes. This feature is only available in the *Reports* category.

### **8.1.2 Warnings Screen**

The *Warnings* selection is at the top of the list in the *Reports* submenu. At the beginning of a STARRSS execution, the program will check all of the appropriate data inputs and stop if it finds any information that must be changed or clarified. It will display a pop-up window that will alert the user that one or more warnings have occurred and the execution has been stopped. Provided that the data has passed this initial set of checks, STARRSS may still encounter unusual calculations or occurrences during the execution. These will also generate warning messages. In this case, STARRSS will display a pop-up window at the end of the execution to notify the user that problems were encountered. Regardless of whether or not the problems occurred during the data check phase or during full execution, STARRSS will store the warning message(s) in the *Warnings* report. This was placed at the top of the *Report* submenu because it is the first screen that the user should always check. If warnings have been generated, the results displayed in the subsequent reports may be invalid. The user should identify the nature of the problem, correct it, and rerun the execution.

Many of the warning messages are self-explanatory. However, since they were designed to be brief and to fit on one line, some may require further explanation. Appendix B contains a full listing and description of every possible STARRSS warning message.

### **8.1.3 Compliance Strategies Total Cost Report**

The Compliance Strategies Total Cost Report ranks each compliance strategy according to expected cost, one of the fundamental criteria that compliance planners seek to minimize. The report also lists information about the standard deviation of costs, as well as allowance transactions used by each strategy to achieve the target reduction. An example of the Compliance Strategies Total Cost Report is presented below.

**Table 8-2. Compliance Strategies Total Cost Report**

Compliance Strategies Total Cost Report							
SULFUR POWER & LIGHT				Target Reduction 88363 Tons			
Evaluated 9/10/1992 at 16:22; Phase I (1995-1999) run with 250 iterations							
Plan Rank	Expected Value of Total Cost (\$ million)		Allowance Transactions Purchase Costs (\$ million)		Purchases/(Sales) (tons of SO2)		# of Options
1 SWITCH AT BIGCOAL 1 & 2	203	[ 92]	(28)	[ 14]	(21152)	[ 8833]	2
2 SCRUB BIGCOAL 1 (ENHANCED)	213	[ 17]	(12)	[ 14]	(9109)	[10083]	1
3 SCRUB BIGCOAL 1 & 2	215	[ 59]	(128)	[ 40]	(100293)	[17026]	2
--- End of Data ---							
()							
[ ] = Standard Deviation							
* = Allowance transactions meet or exceed user-specified limits							
ESC Main Menu		PgUp/PgDn View Report			F3 Print Report		

### Database Name and Execution Statistics

At the top of every STARRSS report, the user will find the *Database Name* (as input on the *Display/Edit Affected Units* screen -- e.g., SULFUR POWER & LIGHT) and the execution statistics (namely, the date and time of execution, Phase I or Phase II run, the range of years in the study, and the number of iterations).

### Target Reduction

In the upper right-hand corner of each STARRSS report, the user will find the Target Reduction. This is the expected value of the projected average annual difference between the utility's current SO<sub>2</sub> emissions and its allowance allocation.

### Plan Rank

The leftmost column of this report displays the rank given to each compliance strategy, based on the least expected cost. As the table above demonstrates, strategies are listed in rank order. The *Strategy Name* (that the user specified in the *User Strategies* screen) appears next to the rank.



### **Expected Value of Total Cost**

The next column over lists the Expected Value of the Total Cost, which is calculated as the average of the distribution of costs that were derived from the multiple scenario iterations of the execution simulation. The total cost is the present value of all compliance costs over the course of the study.

The standard deviation of the total cost is shown in brackets to the right of the total cost. This measures quantitatively the risk of each compliance strategy.

### **Allowance Transactions**

The Allowance Transactions associated with each compliance strategy are reported in two respects:

- (1) the expected purchase costs (dollars), and
- (2) the expected annual volume (number of allowances).

The purchase cost value represents the present value of the cost of allowance transactions throughout the study period (expressed in millions of dollars). A value in parentheses indicates revenues from sales (i.e., "negative purchases").

Purchase volume refers to the average annual number of allowances purchased (and is expressed in tons of SO<sub>2</sub> per year); values in parentheses again represent sales volume.

The standard deviation for both of these values is provided in brackets to the right of the value.

If the expected value of the number of annual allowances transacted exceeds the limitations specified by the user in the *Allowance Parameters* screen, an asterisk will appear next to the annual tonnage value in the Purchases column.

### **Number of Options**

The Number of Options flag shows the user how many options (and units) were involved in a particular compliance strategy. For a breakdown of the contribution of each option to the strategy's total cost and allowance impact, the user may consult the Compliance Strategies Detail Report and the Compliance Option Report by Strategy (discussed in sections 8.1.4 and 8.1.5 below).

### 8.1.4 Compliance Strategies Detail Report

The **Compliance Strategies Detail Report** lists information similar to the **Compliance Strategy Total Cost Report** described in Section 8.1.3 above. However, this report breaks down each compliance strategy into its component options, listing cost and impact contributions of each option to the overall expected result. As with the **Total Cost Report**, each strategy is listed in ranking order according to expected cost. An example of the **Compliance Strategies Detail Report** is shown below.

**Table 8-3. Compliance Strategies Detail Report**

Compliance Strategies Detail Report			
SULFUR POWER & LIGHT		Target Reduction 88363 Tons	
Evaluated 9/10/1992 at 16:22; Phase I (1995-1999) run with 250 iterations			
Strategies	Total Cost (\$M)	Impact (tons)	Average \$/ton
1: SWITCH AT BIGCOAL 1 & 2			
BIGCOAL 1 PRBCOAL	115	54469	502
BIGCOAL 2 WVCOAL	116	54589	515
Base Conservation	---	313	---
bonus allowances	---	146	---
Allowance purchases (sales)	(28)	(21152)	313
	-----	-----	-----
Totals for strategy 1 :	203	88364	542
* = Allowance transactions meet or exceed user-specified limits			
ESC Main Menu		PgUp/PgDn View Report	F3 Print Report

### Strategies

The leftmost column of this report displays the rank given to each compliance strategy, based on the expected cost. The *Strategy Name* (that the user specified in the *User Strategies* screen) appears next to the rank. Below this name, each option associated with the strategy is listed. Note also that bonus allowances associated with an option are delineated in a separate line directly below the option. The last option line of each strategy lists the allowance purchases (or sales) necessary to meet the utility's reduction target.

If the user wishes to see an abbreviated version of this report, he or she can activate the *Compressed Detail Report* flag on the *Report Parameters* screen (see Section 7.2).

## **Total Cost**

This column lists the expected value of the total cost (the net present value of all costs over the period of the study) for each compliance option. The totals given at the bottom of each strategy should correspond to the totals given in the Compliance Strategy Total Cost Report described in Section 8.1.3 above. The breakdown of costs includes cost savings associated with linkages defined in the *Compliance Option Linking* screen.

## **Impact**

This column lists the expected annual impact, in tons of SO<sub>2</sub> reduced, for each option in the strategies evaluated. The total Impact for each strategy will always correspond to the utility's Target Reduction unless a strategy exceeds the user-specified allowance trading limitations. If the expected value of the number of annual allowances transacted exceeds the limitations specified by the user in the *Allowance Parameters* screen, an asterisk will appear next to the annual tonnage value in the allowance purchases row.

If allowance purchases exceed user restraints, an asterisk will appear next to the impact value given on the Allowance Purchases line; the total Impact should still equal the Target Reduction, however. Allowance sales, on the other hand, will never exceed user-specified limits. If a strategy involves overcontrol without selling all of the extra allowances, total Impact will exceed the Target Reduction by the amount of extra allowances the utility was unable to sell.

## **Average \$/ton**

This column presents the average unitized cost per ton of SO<sub>2</sub> removed by each option. The unitized cost of an option is equal to its levelized costs (over the entire study period) divided by its average annual impact (again, over the entire study period) -- see page 181 for details about the calculation of unitized costs. **Because the value presented here is unitized, it is not a quotient of the Total Cost and Impact columns.**

### **8.1.5 Compliance Option Report by Strategy**

This report lists each option by strategy, presenting data on the ranges in costs and impacts associated with each option. By presenting ranges, this report supplements the Compliance Strategy Detail Report shown in Section 8.1.4 above. An example of the Compliance Option Report by Strategy is presented below.

**Table 8-4. Compliance Option Report by Strategy**

Compliance Option Report by Strategy				
SULFUR POWER & LIGHT		Target Reduction 88363 Tons		
Evaluated 9/10/1992 at 16:22; Phase I (1995-1999) run with 250 iterations				
Strategies	Mean \$/ton	\$/ton Range	Mean Tons Removed	Range
1: SWITCH AT BIGCOAL 1 & 2				
BIGCOAL 1 PRBCOAL	502	258-943	54469	50398-57737
BIGCOAL 2 WVCOAL	515	201-1172	54589	45552-59474
2: SCRUB BIGCOAL 1 (ENHANCED)				
BIGCOAL 1 WETFGD2	559	409-797	97014	69501-114424
3: SCRUB BIGCOAL 1 & 2				
BIGCOAL 1 WETFGD1	384	287-653	95329	65462-107389
BIGCOAL 2 WETFGD1	504	350-789	92869	70487-107736
--- End of Data ---				

ESC Main Menu

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### Mean \$/ton

This column presents the average unitized cost per ton of SO<sub>2</sub> removed by each option. These values should correspond to the Average \$/ton values presented in the Compliance Strategy Detail Report, discussed in Section 8.1.4 above.

### \$/ton Range

This column presents the range in unitized costs for each option. The range represents the high and low values generated during the scenario iteration process.

### Mean Tons Removed

This column presents the mean tons of SO<sub>2</sub> removed by each option, including the impact of bonus allowances, if applicable.

### Mean Tons Removed Range

This column presents the range in tons of SO<sub>2</sub> removed by each option. The range represents the high and low values generated during the scenario iteration process.

### 8.1.6 Compliance Option Report by Unit

The Compliance Option Report by Unit lists information similar to the Compliance Option Report by Strategy but reports the information on a unit-by-unit rather than a strategy-by-strategy basis. This report will list all options considered by the most recent Evaluation/Optimization run. An example of this table is shown below.

**Table 8-5. Compliance Option Report by Unit**

Compliance Option Report by Unit				
SULFUR POWER & LIGHT		Target Reduction 88363 Tons		
Evaluated 9/10/1992 at 16:22; Phase I (1995-1999) run with 250 iterations				
Unit/Option	Mean \$/ton	\$/ton Range	Mean Tons Removed	Range
Unit: BIGCOAL 1				
WETFGD1	384	287-653	95329	65462-107389
PRBCOAL	502	258-943	54469	50398-57737
WETFGD2	559	409-797	97014	69501-114424
Unit: BIGCOAL 2				
WETFGD1	504	350-789	92869	70487-107736
WVCOAL	515	201-1172	54589	45552-59474
--- End of Data ---				
ESC Main Menu		PgUp/PgDn View Report		F3 Print Report

#### Mean \$/ton

This column presents the average unitized cost for each option. These values correspond to the Average \$/ton values presented in the Compliance Strategy Detail Report, discussed in Section 8.1.4 above.

#### \$/ton Range

This column presents the range in unitized costs for each option. The range represents the high and low values generated during the scenario iteration process.

#### Mean Tons Removed

This column presents the mean tons of SO<sub>2</sub> removed by each option, including the impact of bonus allowances, if applicable.

## Mean Tons Removed Range

This column presents the range in tons of SO<sub>2</sub> removed by each option. The range represents the high and low values generated during the scenario iteration process.

### 8.1.7 Compliance Option Ranking Report

The **Compliance Option Ranking Report** lists compliance option by unit, and gives the rank of each plan in which the compliance option appears. This report can help the user assess the importance of a compliance strategy to the top plans. For example, if a compliance option appears in the top three out of six strategies, it may be integral to the utility's least-cost compliance strategy. An example of this report is shown below.

**Table 8-6. Compliance Option Ranking Report**

Compliance Option Ranking Report		
SULFUR POWER & LIGHT		
Evaluated 9/10/1992 at 16:22; Phase I (1995-1999) run with 250 iterations		
Target Reduction 88363 Tons		
Unit/Option	Description	Plan Rank Where Option Appears
Unit: BIGCOAL 1		
WETFGD1	Wet Limestone Forced Oxidation Scrubber	3
PRBCOAL	Switch to Powder River Basin LS Coal	1
WETFGD2	Wet Limestone Magnesium Oxide Scrubber	2
IGCC	Integrated Gasification Combined Cycle	NOT CHOSEN
Unit: BIGCOAL 2		
WETFGD1	Wet Limestone Forced Oxidation Scrubber	3
PRBCOAL	Switch to Powder River Basin LS Coal	NOT CHOSEN
WVCOAL	Switch to West Virginia LS Coal	1
--- End of Data ---		
+ = More plans than those listed used this compliance option		
ESC Main Menu	PgUp/PgDn View Report	F3 Print Report

## Unit/Option

This column lists each option under the unit for which the option was defined. Units are listed in the order in which they appear in the *Display/Edit Affected Units* screen.

## Description

This description corresponds to the detailed description specified by the user in the *Edit/Define Compliance Options* screen.

## Plan Rank Where Option Appears

This column lists the rank of each compliance strategy in which the option appears. If, during an optimization run, STARRSS does not choose an option the user has selected for consideration, the words "NOT CHOSEN" will appear in this column. If the option appears in more than five plans, a "+" sign will appear at the end of the string of numbers in this column to signify that there were more plans that used the option.

### 8.1.8 Compliance Strategies Unitized Cost Report

The Compliance Strategies Unitized Cost Report reflects the cost of each compliance strategy in terms of tons of SO<sub>2</sub> removed (i.e. cost per unit). Table 8-7 below shows an example of this report.

**Table 8-7. Compliance Strategies Unitized Cost Report**

Compliance Strategies Unitized Cost Report			
SULFUR POWER & LIGHT		Target Reduction 88363 Tons	
Evaluated 9/10/1992 at 16:22; Phase I (1995-1999) run with 250 iterations			
Plan Rank	Plan Name	Average \$/ton Removed	Marginal \$/ton Removed
1	SWITCH AT BIGCOAL 1 & 2	542 [ 218]	574 [ 200]
2	SCRUB BIGCOAL 1 (ENHANCED)	583 [ 55]	559 [ 56]
3	SCRUB BIGCOAL 1 & 2	582 [ 137]	509 [ 88]
--- End of Data ---			
() = Negative Values		[] = Standard Deviation	
ESC Main Menu		PgUp/PgDn View Report	F3 Print Report

## Plan Rank

The leftmost column of this report displays the rank given to each compliance strategy, based on the least expected cost. As the table above demonstrates, strategies are listed in rank order.

### **Plan Name**

The name of the strategy provided by the user in the *Execute* submenu appears next to the rank.

### **Average \$/ton Removed**

This column presents the average unitized cost for each strategy. This value corresponds with the value on the "Strategy Totals" line of the Compliance Strategy Detail Report (discussed in Section 8.1.4). The standard deviation of this value is presented in brackets to the right.

### **Marginal \$/ton Removed**

This column presents the marginal unitized cost for each strategy. This value corresponds with the value of the *most expensive* compliance option in the Compliance Strategy Detail Report (discussed in Section 8.1.4). Because the marginal cost values do not include the costs of allowance transactions, the Average \$/ton Removed may in some cases be higher than the Marginal \$/ton Removed. The standard deviation of this value is presented in brackets to the right.

### **8.1.9 Input Summaries**

The *Input Summaries* report allows the user to view his or her inputs to the *Unit-level Info* screens more concisely. The user can quickly determine if he/she needs to edit the inputs. The table below presents the *Input Summaries* submenu.



**Table 8-8. Input Summaries submenu**

Files	System-Level Info	Unit-Level Info	Execute	Reports
				<b>W</b> Warnings <b>T</b> Compliance Strategies Total Cost Report <b>D</b> Compliance Strategies Detail Report <b>G</b> Graph of Compliance Statistics <b>S</b> Compliance Option Report by Strategy <b>U</b> Compliance Option Report by Unit <b>R</b> Compliance Option Ranking Report <b>Z</b> Compliance Strategies Unitized Cost Report <b>I</b> Input Summaries
	<b>G</b> Generating Unit Operating Factors <b>D</b> Display Generating Units <b>R</b> Retirement and Commission Years <b>L</b> Option Life, Efficiency, and Fuel <b>C</b> Compliance Option Costs <b>D</b> Option Derate and Overrides <b>F</b> Fuels			
F1 Help                           ENTER make selection				

**For triple-forecast data items, the Input Summaries report the weighted average value of these data items (based on the probability distribution that is associated with each data item).**

The following sections will briefly describe each selection from the *Input Summaries* submenu.

## Generating Unit Operating Factors

This report summarizes the inputs to the *Generating Unit Operating Factors* screens. An example of this screen is shown below.

**Table 8-9. Generating Unit Operating Factors Input Summary**

Generating Unit Operating Factors						
SULFUR POWER & LIGHT STARRSS TEST RUN						
Unit Name	SO2 Rem. Effic.	Var O&M (\$/MWH)	SO2 Rate	Fuel	% blend	Capacity Factor
BIGCOAL 1	0.0	4.7	4.500	COAL-ILLN	100.0%	58.8
BIGCOAL 2	0.0	5.7	4.500	COAL-ILLN	100.0%	66.2
MEDCOAL 1	0.0	6.3	4.500	COAL-ILLN	100.0%	61.7
MEDCOAL 2	0.0	6.3	4.500	COAL-ILLN	100.0%	61.7
MEDCOAL 3	0.0	6.3	4.500	COAL-ILLN	100.0%	61.7
MEDCOAL 4	81.8	5.9	0.819	COAL-ILLN	100.0%	61.1
SMALLOIL 1	0.0	4.1	1.000	HIGHOIL	100.0%	2.5
SMALLOIL 2	0.0	2.9	1.000	HIGHOIL	100.0%	3.8
SMALLOIL 3	0.0	4.0	1.000	HIGHOIL	100.0%	3.6
--- End of Data ---						
ESC Main Menu   PgUp/PgDn View Report   F3 Print Report						

For each data item that is input in the form of a triple forecast, the report displays the weighted average value (based on the probability distribution that is associated with that data item).

The SO<sub>2</sub> rate is calculated from the unit's existing fuel blend and pollution control technology.

The fuel type that is displayed on the screen is the first fuel in the unit's existing fuel blend. It is displayed along with its fuel blend percentage to let the user know whether there are any other fuels consumed at the unit.

The capacity factor is a weighed average over all three forecasts for the commission year of the unit, the base year of the database, or 1995, whichever comes latest.

## Display Generating Units

This report shows affected generating units in the same format as they appear in the *Display/Edit Affected Units* screen. From this report screen, though, the user may generate a print file to make hardcopy reports (see Section 8.1.1, Reporting Features). An example of this report is shown below.

**Table 8-10. Display Generating Units Input Summary**

Display Generating Units						
SULFUR POWER & LIGHT STARRSS TEST RUN						
Unit Name	Capacity (MW)	Heat Rate	Baseline Heat (TBTUs)	Calculated SO2 Emis. (tons)	Allowances	
					PhaseI	PhaseII
BIGCOAL 1	650.0	10000	26.700	75293	36500	14000
BIGCOAL 2	650.0	10000	27.300	84761	37000	14500
MEDCOAL 1	350.0	10500	32.320	44656	44000	17500
MEDCOAL 2	350.0	10500	32.320	44656	44500	18000
MEDCOAL 3	350.0	10500	32.320	44656	45000	18000
MEDCOAL 4	350.0	10400	32.260	7984	0	17500
SMALLOIL 1	50.0	13800	0.370	77	0	200
SMALLOIL 2	50.0	13600	0.640	115	0	330
SMALLOIL 3	80.0	13500	1.040	171	0	600
--- End of Data ---						

ESC Main Menu

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| F3 Print Report

### ***Retirement and Commission Years***

This report summarizes the inputs for retirement and commission years from the *Generating Unit Operating Factors* screen. An example of this report is shown below.

**Table 8-11. Retirement and Commission Years Input Summary**

Retirement and Commission Years		
SULFUR POWER & LIGHT STARRSS TEST RUN		
Unit Name	Commission Year	Retirement Year
BIGCOAL 1	1978	2025
BIGCOAL 2	1980	2025
MEDCOAL 1	1966	2020
MEDCOAL 2	1966	2020
MEDCOAL 3	1966	2020
MEDCOAL 4	1976	2025
SMALLOIL 1	1942	2005
SMALLOIL 2	1950	2015
SMALLOIL 3	1958	2020
--- End of Data ---		

ESC Main Menu

| PgUp/PgDn View Report

| F3 Print Report

## Option Life, Efficiency, and Fuel

This report summarizes the inputs for compliance option life, SO<sub>2</sub> removal efficiency, and new fuel (as applicable) from the *Edit/Define Compliance Options* screen #1. An example of this report is shown below.

**Table 8-12. Option Life, Efficiency, and Fuel Input Summary**

Option Life, Efficiency, and Fuel						
SULFUR POWER & LIGHT STARRSS TEST RUN						
Unit	Option	Life (years)	In-Service Year	Removal Efficiency	New Fuel	% blend
BIGCOAL 1	WETFGD1	30	1995	90.0	-----	-----
	PRBCOAL	30	1995	0.0	COAL-PRB	100.0%
	WETFGD2	30	1995	94.1	-----	-----
	IGCC	30	2003	94.9	-----	-----
BIGCOAL 2	WETFGD1	30	1995	89.8	-----	-----
	PRBCOAL	30	1995	0.0	COAL-PRB	100.0%
	WVCOAL	30	1995	0.0	CNT-APP	100.0%
	WVCOAL	30	1995	0.0	CNT-APP	100.0%
MEDCOAL 1	WVCOAL	30	1995	0.0	CNT-APP	100.0%
MEDCOAL 2	WVCOAL	30	1995	0.0	CNT-APP	100.0%
MEDCOAL 3	WVCOAL	30	1995	0.0	CNT-APP	100.0%
SMALLOIL 1	LOWOIL	30	2000	0.0	LOWOIL	100.0%
SMALLOIL 2	LOWOIL	30	2000	0.0	LOWOIL	100.0%
SMALLOIL 3	LOWOIL	30	2000	0.0	LOWOIL	100.0%
--- End of Data ---						
<div> <div>ESC Main Menu</div> <div>PgUp/PgDn View Report</div> <div>F3 Print Report</div> </div>						

For the data item that describes a compliance option's Removal Efficiency, the report displays the weighted average value (based on the probability distribution that is associated with that data item).

For fuel-switching options, the report displays the first fuel in the new fuel blend (and its associated percentage of the new fuel blend). Dashed lines reflect the fact that the compliance option does not involve a change in fuels.

## Compliance Option Costs

This report summarizes the inputs for capital costs, non-fuel variable O&M costs, fixed O&M costs, additional costs, and new capacity factor (as applicable) from the *Edit/Define Compliance Options* screen #2. An example of this report is shown below.

**Table 8-13. Compliance Option Costs Input Summary**

Compliance Option Costs						
SULFUR POWER & LIGHT STARRSS TEST RUN						
Unit	Option	Capital (\$M)	Var. O&M (\$/MWH)	Fixed O&M (\$M)	Additional Costs	New Capacity Factor
BIGCOAL 1	WETFGD1	157.000	1.11	0.454	0.000	60.0
	PRBCOAL	7.260	0.19	0.119	0.000	58.0
	WETFGD2	190.500	1.38	0.605	0.000	60.4
	IGCC	446.000	3.30	1.200	0.000	63.2
BIGCOAL 2	WETFGD1	164.750	1.30	0.493	0.000	66.9
	PRBCOAL	14.700	0.76	0.280	0.000	59.4
	WVCOAL	9.100	0.09	0.105	0.000	62.3
MEDCOAL 1	WVCOAL	3.500	1.60	0.256	0.000	(same)
MEDCOAL 2	WVCOAL	3.500	1.60	0.256	0.000	(same)
MEDCOAL 3	WVCOAL	3.500	1.60	0.256	0.000	(same)
SMALLOIL 1	LOWOIL	2.000	0.00	0.000	0.000	(same)
SMALLOIL 2	LOWOIL	3.000	0.00	0.000	0.000	(same)
SMALLOIL 3	LOWOIL	2.500	0.00	0.000	0.000	(same)
--- End of Data ---						
<div>ESC Main Menu   PgUp/PgDn View Report   F3 Print Report</div>						

Since all of the data items on this report are input as triple forecasts, the report displays the weighted average values (based on the probability distribution that is associated with each data item).

For New Capacity Factors, STARRSS will note that an option's New Capacity Factor is the same as the generating unit's current one if the user did not specify otherwise.

## Option Derate and Overrides

This report summarizes the inputs for compliance option derations, heat rate adjustments, and override inputs (as applicable) from the *Edit/Define Compliance Options* screen #3. An example of this report is shown below.

**Table 8-14. Option Derate and Overrides Input Summary**

Option Derate and Overrides						
SULFUR POWER & LIGHT STARRSS TEST RUN						
Unit	Option	Deration	Heat Rate Adjust	Marginal SO2	OVERRIDES: Cost	Impact
BIGCOAL 1	WETFGD1	3.8	1.0000	27.70	-----	-----
	PRBCOAL	1.7	1.0200	26.50	-----	-----
	WETFGD2	3.9	1.0000	17.00	-----	-----
	IGCC	-16.8	1.1680	19.30	-----	-----
BIGCOAL 2	WETFGD1	3.9	1.0000	23.80	-----	-----
	PRBCOAL	3.5	1.0680	25.80	-----	-----
	WVCOAL	1.7	1.0000	25.80	-----	-----
MEDCOAL 1	WVCOAL	0.0	1.0600	19.00	-----	-----
MEDCOAL 2	WVCOAL	0.0	1.0600	19.00	-----	-----
MEDCOAL 3	WVCOAL	0.0	1.0600	19.00	-----	-----
SMALLOIL 1	LOWOIL	0.0	1.0000	0.00	-----	-----
SMALLOIL 2	LOWOIL	0.0	1.0000	0.00	-----	-----
SMALLOIL 3	LOWOIL	0.0	1.0000	0.00	-----	-----
--- End of Data ---						
<div>ESC Main Menu   PgUp/PgDn View Report   F3 Print Report</div>						

Since all of the data items on this report are input as triple forecasts, the report displays the weighted average values (based on the probability distribution that is associated with each data item).

The dashed lines represent that overrides are not specified. If the user does specify overrides for a compliance option, the other data fields in the Input Summaries for that compliance option will be filled with dashes.

## ***Fuels***

This report summarizes inputs to the *Fuel Inputs* screen, displaying each fuel's sulfur content and price forecast. Price forecasts resulting from user inputs are shown for every fifth year of the study from the start year. An example of this report is shown below.

**Table 8-15. Fuels Input Summary**

Fuels					
SULFUR POWER & LIGHT STARRSS TEST RUN					
Fuel Name	S content (lbs/MMBTU)	1995	Price Forecasts		
			2000	2005	2010
COAL-ILLN	4.500	141.0	171.7	209.1	254.7
COAL-PRB	1.000	173.3	211.1	257.1	313.1
CNT-APP	1.400	159.6	194.9	238.2	291.0
LOWOIL	0.200	440.1	536.0	652.8	795.0
HIGHOIL	1.000	392.8	478.4	582.6	709.6
--- End of Data ---					

ESC Main Menu

| PgUp/PgDn View Report

| F3 Print Report

## 8.2 GRAPHS

Results generated in STARRSS evaluation and optimization runs can be viewed graphically. Furthermore, graphic results from several strategies can be overlaid, allowing the user to easily compare probability distributions of costs and impacts between several strategies. Viewing distributions of results also allows the user to address the relative risk of compliance strategies and the structure of the distributions (for example, is the distribution peaked in the center, or skewed to the right or left, etc.). Finally, although STARRSS cannot print graphs directly, it does allow user to save the basic data used to build the graphs; this data can be converted into printable graphs using standard graphics programs. The first part of this section discusses general graphing features. The last five sections will discuss each individual graph selection.

### 8.2.1 Graphing Features

For each compliance strategy saved by the most recent *Execute* run, STARRSS can graphically show five distribution results: total cost, average unitized cost, marginal cost, total allowances purchased, and total cost of allowances. The graphic selection submenu is shown in Table 8-16 below.

**Table 8-16. Graph of Compliance Statistics submenu**

Files	System-Level Info	Unit-Level Info	Execute	Reports
		<b>W</b> Warnings <b>T</b> Compliance Strategies Total Cost Report <b>D</b> Compliance Strategies Detail Report <b>G</b> Graph of Compliance Statistics		
	Total Cost of Compliance Strategies Average Unitized Cost (\$/ton) Marginal Unitized Cost (\$/ton) Purchased Allowances Total Cost of Purchased Allowances			tion Report by Strategy tion Report by Unit tion Ranking Report rategies Unitized Cost Report es ameters

F1 Help

ENTER make selection

The user can move through this list with the arrow keys, and choose the graph by pressing <Enter>. A second menu will pop-up listing all of the compliance strategies evaluated in this run. An example of this pop-up menu is presented in Table 8-17 below. From the pop-up menu, the user selects the strategies he or she wants to view by pressing the <Spacebar> to toggle each strategy on or off. A check mark (√) will appear, indicating that a particular



strategy will be graphed. If the user checks more than one strategy, all strategies will appear on the graph overlaid. Pressing <Enter> from the pop-up menu will generate the graphs the user wishes to view. If no strategies have been marked, the strategy underneath the cursor will be graphed.

**Table 8-17. Graph of Compliance Statistics - Strategies Pop-up Menu**

Files	System-Level Info	Unit-Level Info	Execute	Reports
				<b>W</b> Warnings <b>T</b> Compliance Strategies Total Cost Report <b>D</b> Compliance Strategies Detail Report <b>G</b> Graph of Compliance Statistics
	Total Cost of Compliance Strategies Average Unitized Cost (\$/ton) Marginal Unitized Cost (\$/ton) Purchased A Total Cost	Choose strategies to display <input checked="" type="checkbox"/> SCRUB BIGCOAL 1 & 2 <input checked="" type="checkbox"/> SCRUB BIGCOAL 1 (ENHANCED) <input checked="" type="checkbox"/> CONSERVE AND SWITCH Return or Esc		tion Report by Strategy tion Report by Unit tion Ranking Report strategies Unitized Cost Report
F1 Help   ENTER make selection				

To summarize, the user must follow these three steps to view a graph:

- 1) **Select** *Graph of Compliance Statistics* from the *Reports* submenu;
- 2) **Choose** which graph to view from the list of five available graphs; and,
- 3) **Mark** (with the <Spacebar> selection process) which compliance strategies should appear on this graph.

While the graphics appear quickly and are sharp, some features are common to all of the graphs. First, the names of the compliance strategies do not carry through into the graphics mode. Each strategy is denoted in the legend simply as "Strategy 1," "Strategy 2," and so on. The number of the strategy corresponds to the position of the strategy in the Compliance Strategies Total Cost Report (or the Plan Rank, see Section 8.1.4). The user may find it helpful to jot the strategy names down before viewing graphs.

As mentioned previously, graphs cannot be printed directly from STARRSS. Instead STARRSS will create an output file that can be easily used to create graphs from a standard

spreadsheet/graphics program. If the user presses the <F3> key, STARRSS will prompt the user to name the file; the user then names the file and presses <enter>. STARRSS creates an ASCII file with one column of numbers representing the values for the x-axis, and one column of numbers for each strategy graphed. Each column is labelled at the top; the x-axis column receives the label "x-axis," and each strategy receives the same label given in the graph legends (i.e., "Strategy 1"). **It is up to the user to import the file into a graphics program and provide the labels and other structures necessary for printable graphs.**

When creating graphs from a standard graphics program, the user should be aware of two features about the data file created by STARRSS:

- 1) The x-axis values are relatively accurate but may not be in an appropriate scale (i.e. \$100 million may be represented as 1, or .1, etc.)
- 2) The values given for each compliance strategy represent relative probabilities that the strategy will take on a certain value. STARRSS represents these probabilities as fractions of 100 (percentages). Each column of values corresponding to the compliance strategies should therefore sum to 100 (or very close).

Figure 8-1 below presents a graph generated from the STARRSS test run shown in this document. The graph was generated using Lotus 1-2-3.

**Figure 8-1. Graph Comparing Two Compliance Strategies**

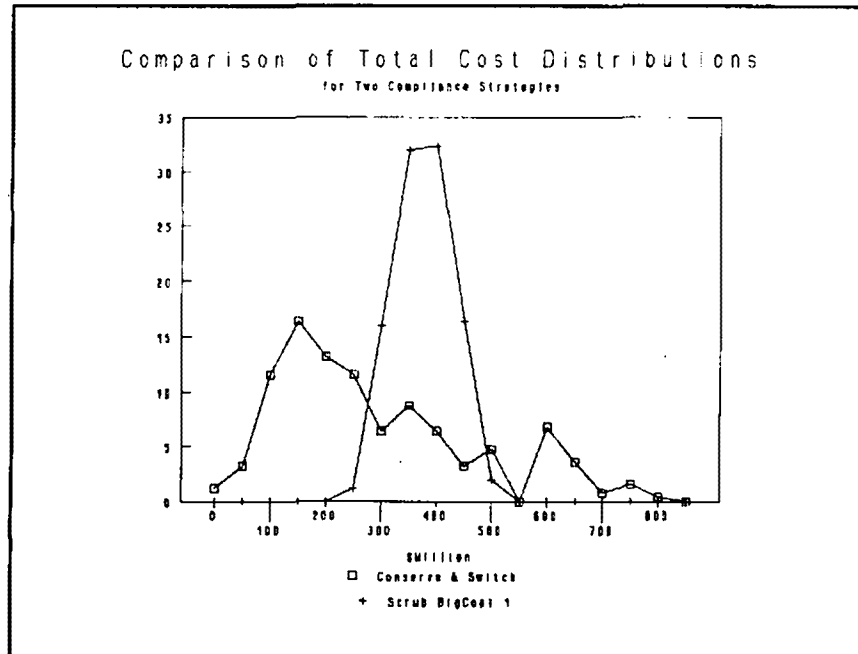


Figure 8-1 exhibits an example of the cost versus risk trade-off STARRSS is designed to capture. In this example, the "Conserve & Switch" strategy carries the potential for lower costs, but also carries much greater volatility in costs than the "Scrub BigCoal 1" strategy.

### **8.2.2 Total Cost of Compliance Strategies**

This graph presents probability distributions for the total cost data presented in the Compliance Strategies Total Cost Report (see discussion in Section 8.1.3). Pressing any key will return the user to the STARRSS *Graph of Compliance Statistics* submenu. Pressing F3 will generate a file for creating graphics (see Section 8.2.1).

### **8.2.3 Average Unitized Cost (\$/ton)**

This graph presents probability distributions for the average unitized cost data presented in the Compliance Strategies Unitized Cost Report (see discussion in Section 8.1.8). Pressing any key will return the user to the STARRSS *Graph of Compliance Statistics* submenu. Pressing F3 will generate a file for use in creating graphics (see Section 8.2.1).

### **8.2.4 Marginal Unitized Cost (\$/ton)**

This graph presents probability distributions for the marginal unitized cost data presented in the Compliance Strategies Unitized Cost Report (see discussion in Section 8.1.8). Pressing any key will return the user to the STARRSS *Graph of Compliance Statistics* submenu. Pressing F3 will generate a file for use in creating graphics (see Section 8.2.1).

### **8.2.5 Purchased Allowances**

This graph presents probability distributions for the total allowances purchased (or sold) presented in the Compliance Strategies Total Cost Report (see discussion in Section 8.1.3). A line marks the point of zero purchases/sales, and indicates which direction represents purchases and which direction represents sales. In addition, if the user has specified constraints on allowance transaction volume, this graph will mark the point of the constraint. This will allow the user to determine how the constraint affects the utility's participation in the allowance market. Pressing any key will return the user to the STARRSS *Graph of Compliance Statistics* submenu. Pressing F3 will generate a file for use in creating graphics (see Section 8.2.1).

### **8.2.6 Total Cost of Purchased Allowances**

This graph presents probability distributions for the total cost of purchased allowances presented in the Compliance Strategies Total Cost Report (see discussion in Section 8.1.3). Pressing any key will return the user to the STARRSS *Graph of Compliance Statistics* submenu. Pressing F3 will generate a file for use in creating graphics (see Section 8.2.1).

### 8.3 AUXILIARY FILES

This section will briefly discuss a number of auxiliary files created by STARRSS in the course of execution runs and report production. There are three types of files created by STARRSS (and denoted by their filename extensions) that the user should know about: printable files (.PRT), detailed information files (.DET), and raw data files for importing into spreadsheet programs (.RAW).

#### 8.3.1 Print Files

Whenever a user views a report, he or she can generate a printable form of that report by pressing F3 (see Reporting Features, Section 8.1.1, for further discussion). STARRSS will prompt the user to indicate whether this report should overwrite a previously existing report file, or append this file to it. The report files created in this way have the filename <utility>.PRT, where <utility> represents the root name of the STARRSS database.

#### 8.3.2 Detail Files

If the user activates the *Detailed Information Flag* from the *Execute* submenu (see page 109), STARRSS will create a file with information breaking down the exact components of costs and impacts associated with compliance options under evaluation (capital costs, O&M costs, purchased power costs, etc.). This is a flat ASCII file with the filename extension ".DET." The user can view this file by exiting to DOS and typing "MORE < <utility>.DET" where <utility>.SDB is STARRSS database that was used in the program execution. As an example, a section of this file is shown in Table 8-18 on the next page.

#### 8.3.3 Raw Data Files

Each time STARRSS evaluates strategies, it creates a file of the output results denoted by the filename "<utility>.RAW" (where <utility> represents the root name of the STARRSS database). This file contains the data generated by each scenario iteration and can be imported into spreadsheet programs for further evaluation or for generating graphs or reports. If the user chooses to import the .RAW file into Lotus 1-2-3, he or she should import the file as a "Numbers" file. The .RAW file has been arranged to preserve the descriptive headers for each column of numbers. Use of the .RAW file is entirely optional, but the user may find it helpful in generating graphs, or in understanding the STARRSS scenario iteration process.

**Table 8-18. Detailed Information Report (a portion)**

*** ** STRATEGY #1: TEST *** **			
Iteration 1 of 1 -----			
----- Unit BIGCOAL 1 option WETFGD1 -----			
Option's effects on:			
	OLD	NEW	CHANGE
Fuel cost (\$)	110655768	110655768	0
Consumption (MBTU)	26280000	26280000	0
Generation (MWH)	2628000	2522880	-105120
Unit Emiss. (tons)	62415.0	6241.5	-56173.5
Other Emiss. (tons)	0.0	1051.2	1051.2
Total Emiss. (tons)	62415.0	7292.7	-55122.3
Breakdown of impact:			
Option Impact	55122.301 tons/year		
Phase I bonuses	27285.400 tons/year	( 136427.002 total)	
Phase II bonuses (repowering extension)	0.000 tons/year	( 0.000 total)	
<u>Total</u>	82407.703		
Breakdown of costs:			
Capital cost	85.616 \$M		
Tax benefits	-4.164 \$M		
Tax costs	22.166 \$M		
Increased fixed O&M	31.767 \$M		
Additional costs	47.651 \$M		
Change in fuel costs	0.000 \$M		
Increased var. O&M	38.403 \$M		
Marginal Capacity	6.860 \$M		
Marginal Energy	18.029 \$M		
<u>Total Cost</u>	246.330 \$M		
Marginal Cost	716.848 \$/ton		

As the user can see from the lower half of Table 8-18, the Detailed Information file provides a breakdown of all of the costs associated with all of a strategy's compliance options within each scenario iteration of a STARRSS run. This file serves as background material for all of the values in the STARRSS reports.

## 9.0 HOW STARRSS WORKS

STARRSS has two "modes" of operation:

- 1) Evaluation of user-specified strategies, and
- 2) Development of its own recommended strategies (optimization).

### **Mode #1: Evaluation**

In the first mode, STARRSS examines strategies that have been defined by the user in the *User Strategy* screen (see page 117). Through a multiple-scenario process, STARRSS evaluates these strategies and reports their total costs. These costs are an approximation of a utility's incremental present worth of revenue requirements.

#### Approximation

These costs are an approximation of revenue requirements in the sense that STARRSS does not perform full tax calculations. The program uses an estimation process described below.

#### Incremental

These costs represent the incremental costs of a utility's compliance activities. They do **not** include the "base case" costs of fuel, O&M, existing plant depreciation, etc. They only represent the additional revenue requirements that will be borne by the ratepayers because of the implementation of the utility's Clean Air Act compliance strategy.

#### Present Worth of Revenue Requirements

The STARRSS costs represent the total **present value** of the costs of compliance over the entire study period. The length of the study period is controlled by the user (with the *Years of Study* data item on the *Execution Parameters* screen). The yearly discount rates that are used to calculate the present value of the yearly costs are defined as the *Cost of Capital* data items on the *Tax Rate, Escalation Rate and Cost of Capital* screen.

STARRSS has two ways for using the database's input information and calculating a strategy's costs:

- 1) single cost calculation, and
- 2) multiple-scenario calculation.

## Single Cost Calculation

The first process produces a single set of results. In this case, STARRSS does not run through its Monte Carlo multiple-iteration procedure; instead, STARRSS will simply use the mean (i.e., weighted average) of each data item's triple forecast and generate one expected value for the cost of a compliance strategy.

In other words, if the user inputs allowance purchase prices of \$300, \$400, and \$500 (for the low, medium, and high forecasts) with a probability pointer that references a 40%/40%/20% probability distribution, the mean forecast for allowance purchase prices would be \$380<sup>1</sup>.

The user stipulates this processing mode by specifying a **zero** for the *Number of Scenario Iterations per Strategy* on the *Strategy Summary* screen and/or the *Develop STARRSS Strategies* screen.

Although this cost calculation process is obviously faster than performing multiple iterations, it will not provide the user with any information on the potential risks and range of costs that the adoption of a strategy may entail. All standard deviation references that appear on the STARRSS reports of course will be zero.

Also, running STARRSS in the "mean forecast" mode may be fast, but the total cost results can be substantially different from the expected value results that come out of the multiple scenario calculation process. In the former case, STARRSS will calculate a strategy's cost once (based on the mean forecasts for all data items). In the latter case, STARRSS will generate hundreds of costs for a strategy. The mean of this cost distribution (known as the expected value) will not be the same as the value that comes out of a STARRSS single calculation run (which uses the mean of the inputs).

The single mode calculation option is useful for obtaining ball-park estimates; however, the multiple scenario calculation mode provides more accurate information about the expected value of a compliance strategy's costs.

## Multiple Scenario Calculation

The second process is the multiple iteration procedure that has been discussed throughout the manual. The user controls this processing mode by specifying a **non-zero** value (preferably 200 or higher) for the *Number of Scenario Iterations per Strategy* on the *Strategy Summary* screen and/or the *Develop STARRSS Strategies* screen. This instructs the STARRSS evaluation process to perform multiple "costing runs" or iterations. During each iteration, STARRSS will select one of the three values from each data item's triple forecast and determine the cost of a

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<sup>1</sup>  $\$380 = [40\% \times \$300] + [40\% \times \$400] + [20\% \times \$500]$



compliance strategy through the process described below. This iterative selection/calculation process is known as a Monte Carlo simulation and is described in Chapter 3 (see page 28).

## **Mode #2: Optimization**

The second STARRSS operating mode is optimization. If the user so specifies, STARRSS will develop its own set of least-cost compliance plans. Each of these plans in turn will be evaluated in the same manner that user-specified plans are.

A STARRSS optimization is a two-step process. First, STARRSS develops a list of top strategies; then it evaluates all of these plans. For this second step, the user has the same single vs. multiple scenario calculation option that is available for standard evaluation runs. The first step (i.e., the actual optimization process) is described in sections 9.2 and 9.3 below.

## **9.1 EVALUATION CALCULATIONS**

The STARRSS evaluation process utilizes the procedures described below for calculating the costs and impacts of compliance strategies. If the user chooses the multiple scenario feature, the entire process will occur for each iteration. Therefore, within the context of the calculations described below, there is no uncertainty or variability in the input numbers. STARRSS is assumed to be using specific values that have already been selected through the number-drawing process described in Chapter 3 (see page 28).

In STARRSS Version 1, the program adopts an average-year approach for the calculation of all emissions and emissions reductions. Year-to-year variations in these items are not explicitly monitored but will be in Version 2. Instead, STARRSS Version 1 analyzes compliance strategies within the context of an average, single-year snapshot. Therefore, if STARRSS reports that a compliance strategy is expected to require allowances purchases, the user must interpret this information as an average for the entire study period. Under such a strategy, the utility is expected to be an allowance buyer on average. Potentially, this information could translate into a situation where the utility could be selling allowances in the first few years of the study period while buying significant quantities of allowances in later years.

One last note before getting into the details of the evaluation calculations: STARRSS Version 1 requires that the user select either a Phase I or a Phase II analysis. A Phase I analysis always begins in 1995 (although the user can specify an earlier *Base Year* as a reference point for discounting purposes - see page 59).

**In a Phase I analysis, STARRSS Version 1 assumes that Phase I lasts for the entire length of the study.**

In other words, a 20-year Phase I run will go from 1995 through the end of 2014 and will assume that Phase II never happens. Such a run will only analyze the projected emissions and potential emissions reductions for those units that are affected under Phase I. In addition, the allowance allocations for the Phase I units will not change; they will stay at their Phase I levels for the entire length of the study.

#### **Calculate Target Reduction**

STARRSS first defines the extent of the compliance challenge by calculating a utility's target reduction. This is the difference between the utility's average annual projected emissions and its allocated allowances.<sup>2</sup>

#### **Calculate Costs of Individual Compliance Options**

STARRSS then calculates the present value over the length of the study of all of the costs for each selected compliance option. For the sake of this discussion, STARRSS compliance options refer to all of the compliance-related activities that the user defines in the database either through the *Edit/Define Compliance Options* screen or the *Incremental Conservation/Renewables* screen; allowance purchases are excluded at this point but are considered later.

#### **Calculate Impacts of Compliance Options**

STARRSS calculates the impact or expected emissions reduction that will be achieved by each compliance option.

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<sup>2</sup> This number potentially could be negative if the utility is already in compliance with the Clean Air Act Amendments. This will not cause any problems with STARRSS. The program can be used to explore the possibilities of additional emissions control to generate more allowances for sale.

### **Calculate Bonus Allowances**

As the adoption of certain compliance options are promoted by distributions from EPA of "bonus" allowances, STARRSS calculates an approximation of these bonus allowances and credits specific compliance options by adding the bonus allowances to each option's calculated impact.

### **Calculate Allowance Purchases/Sales**

STARRSS then adds up the total impacts (both real impacts and bonus allowances) of all active compliance options and compares this total to the utility's reduction target. Any shortfall is made up with allowance purchases, and any excess results in allowance sales, subject to the user-specified allowance trading constraints.

### **Calculate Costs of Allowance Purchases/Sales**

STARRSS multiplies the allowance purchases or sales by the appropriate market prices to determine the costs or revenues from allowance trading. This process incorporates the user-specified price premiums or discounts that are defined on the *Allowance Purchase Prices* and *Allowance Sale Prices* screens.

### **Calculate Total Costs of Compliance Strategy**

Last, STARRSS adds the present value of the costs of all of the individual compliance options in a strategy and the costs or revenues of allowance transactions, deducts the present value of the costs of any compliance option linkages (see page 104), and arrives at a grand total for a compliance strategy.

These procedures are repeated for each iteration of the STARRSS multi-scenario process. For example, if the user runs STARRSS for 300 iterations, then the program will develop 300 values for:

- 1) the target reduction for the utility,
- 2) the total cost of a compliance strategy,
- 3) the total number of allowances purchased/sold per year, and
- 4) the total costs/revenues associated with those allowances.

From these 300 values, STARRSS calculates expected values and statistical standard deviations for each of the above items. In addition, STARRSS stores information on each compliance option's expected value and range of costs and impacts.

The following discussion provides a detailed explanation of each of the general procedures outlined above.

### 9.1.1 Calculation of Target Reduction

The calculation of a utility's target reduction is performed by STARRSS in the following way.

#### Step 1:      Calculate Each Affected Unit's Base Case Emissions

For each affected unit, STARRSS multiplies the unit's original average annual fuel consumption by the sulfur "content" of the existing (i.e., current) fuel (or fuel blend). The sulfur content of the fuel or fuel blend is expressed in Lbs/mmBTU. The average annual fuel consumption is expressed in mmBTU/year and is calculated using Equation 9-1 below. The average consumption is calculated over the entire length of the study period. For example, assume that a unit has an annual fuel consumption of 10 trillion BTU/year for the first 10 years of a 20-year study and that the unit is expected to be retired after that point. STARRSS calculates the unit's average annual fuel consumption to be 5 trillion BTU/year.

$$\text{FuelCons}_j = \text{CapFact}_j * \text{Cap}_j * \frac{8760 \text{ hrs}}{\text{year}} * \text{HtRate}_j \quad (9-1)$$

where:

FuelCons <sub>j</sub>	=	average annual fuel consumption at unit j
CapFact <sub>j</sub>	=	average annual capacity factor for unit j
Cap <sub>j</sub>	=	capacity for unit j
HtRate <sub>j</sub>	=	average heat rate for unit j

The unit's capacity and average heat rate are inputs on the *Display/Edit Affected Units* screen. The unit's average capacity factor is the average (over the course

of the study period) of the annual capacity factors that are input on the *Affected Units Operating Factors* screen, adjusted for any commission dates or retirement dates that occur within the study period. For example, assume that a new, SO<sub>2</sub>-emitting generating unit will be commissioned during Phase I and that the unit's expected annual capacity factor will be 50%. The user is free to specify this capacity factor value for 1995 (i.e., the beginning of Phase I) even if the unit is not expected on-line until later. In fact, this is a preferred approach. That way, as the user changes the commission date, STARRSS automatically makes the necessary adjustments to its internal calculations. If the user executes a 5-year Phase I run (i.e., from 1995 through 1999) and specifies a commission date of 1997, STARRSS calculates the effective average Phase I capacity factor for the unit to be 30%<sup>3</sup>. This results in the appropriate calculation of average generation, fuel consumption, and emissions for the single-year analysis performed by STARRSS Version 1.

**Step 2:      Calculate Base Case Conservation Emissions Reduction**

STARRSS calculates the average annual emissions reduction that will be achieved by the base case conservation/renewable projects by multiplying each study year's projected annual energy savings (as entered on the *Base Case Conservation/Renewables* screen) by the *System Marginal SO<sub>2</sub> Emissions* (a data item that is expressed in Lbs of SO<sub>2</sub>/MWH and is entered on the same screen). STARRSS takes the average of these emissions reductions over the years of the study and deducts this value from the total unit emissions. Therefore, the capacity factors for the system's generating units should be entered on a "before-conservation" basis. If they are entered on an "after-conservation" basis, the user should specify a value of zero for the base case conservation's *System Marginal SO<sub>2</sub> Emissions* data item (so as not to double count the conservation's emissions reductions).

**Step 3:      Calculate Total Base Case Emissions**

STARRSS adds up the base case emissions that were calculated for all affected units in Step 1 and subtracts the conservation emissions reduction calculated in Step 2. For a Phase I run, the unit emissions will only include those from Phase I affected units.

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<sup>3</sup> = 50% x 3 years/5 years

**Step 4:        Calculate Total Basic Allowance Allocation**

STARRSS adds up the basic allowance allocations for all affected units. This total value is calculated and displayed on the *Allowance Parameters* screen. This value does not include any bonus allowances; instead, bonus allowances are included in the emissions reductions for specific compliance options. The total basic allowance allocation is merely the sum of the allocations that are input on the *Display/Edit Affected Units* screen. Again, for a Phase I run, the total only includes the allowances for Phase I affected units.

**Step 5:        Calculate Total Target    eduction**

The last step is merely the subtraction of the total basic allowance allocation from the total base case emissions. This is the total target reduction and represents the average number of tons of SO<sub>2</sub> per year that must be reduced or compensate for (with allowance purchases or bonus allowance allocations).

**9.1.2   Calculation of Costs of Individual Compliance Options**

The total cost for a compliance option is the present value of all expenses relating to that compliance option over the course of the study. All escalated values are escalated from the *Base Year*, and all calculations of present values are in *Base Year* dollars. The discount rate for the present value calculations is the utility's cost of capital. Both the *Base Year* and the *Cost of Capital* are input on the *Tax Rate, Escalation Rates, and Cost of Capital* screen (see page 59). Negative values for individual terms in the cost calculations are permitted (representing a decline in certain costs for a generating unit should that particular compliance option be implemented). However, STARRSS produces a message in the STARRSS Warnings Report if it finds any compliance options that have total costs which are negative. This unrealistic situation would imply that reducing emissions would be a money-making proposition. Presumably, if a utility's costs would be reduced by implementing a compliance option, then the option should have already been implemented.

Within STARRSS, compliance options can be separated into two broad categories: conservation/renewable programs, and generating-unit-specific compliance options. The STARRSS calculation of the present value of the cost for both types of compliance options is described below.

## **Incremental Conservation Programs and Renewable Projects**

A distinction must be made between **Base Case** programs and **Incremental** programs. Base case programs in STARRSS do not have any cost inputs because the system only calculates incremental revenue requirements. By definition, base case programs are those that were expected to be implemented even without the passage of the CAAA, and therefore, their costs should not be included in an assessment of a utility's cost of compliance. Thus, only incremental programs have cost information in STARRSS, and it is used in the following fashion.

### **Step 1: Calculate Incremental Program's Avoided Costs**

For each incremental program, STARRSS merely multiplies each year's forecast of *Expected Energy Savings* (in MWH) by the program's forecasted *Annual Avoided Utility Costs* (in \$/MWH), thereby developing a stream of avoided costs for all of the years of the study.

### **Step 2: Calculate Cost of Incremental Program**

For each incremental program, STARRSS merely multiplies each year's forecast of *Expected Energy Savings* (in MWH) by the program's forecasted *Annual Costs* (in \$/MWH), thereby developing a stream of program costs for all of the years of the study.

### **Step 3: Calculate Present Value of Incremental Program's Net Economic Cost**

For each incremental program, STARRSS calculates the present values of the streams of avoided costs and program costs (that are calculated in Steps 1 and 2, respectively). STARRSS then calculates the difference between these values, subtracting the first from the second. This is the present value of the program's net cost. This should be a positive number. If the avoided costs were already greater than the program costs, then the program should have already been implemented for purely economic reasons.

## **Generating-Unit-Specific Compliance Options**

For all compliance options that are specified through the *Edit/Define Compliance Options* screens, STARRSS calculates the present value of the following costs:

Capital Costs
Tax Benefits
Tax Costs
Incremental Fixed O&M Costs
Additional Costs
Fuel-Related Costs
Incremental Variable-O&M-Related Costs
Replacement Capacity Costs
Replacement Energy Costs

This is provided that the user has not specified either of the two override values on the *Edit/Define Compliance Options* screen. The user has the option to bypass the regular cost calculations by inputting cost overrides for any compliance option (in the form of base year \$/ton and total annual tons removed). If the user chooses to do this, STARRSS multiplies these two numbers to get the annual levelized total cost for the option. This levelized value is converted into a total present value by extending its value from the compliance option's *In-Service Year* (or the study's start year, whichever comes later) through the end of the option's life (or the end of the study, whichever comes first) and discounting this stream of costs by the utility's *Cost of Capital*.

If the user has not specified these overrides, then STARRSS calculates a compliance option's total costs in the following manner:

**Step 1:      Calculate Present Value of Capital Costs**

STARRSS escalates the option's capital costs (which are input in *Base Year* mid-year dollars) out to the beginning of the option's *In-Service Year* using the capital cost escalation rates on the *Tax Rate, Escalation Rates, and Cost of Capital* screen. Since costs are being escalated from mid-year to beginning-of-year, this entails a half-year's escalation. For example, if the *Base Year* were 1992 and an option's *In-Service Year* were 1995, then STARRSS would escalate the capital costs two and a half years (from July 1, 1992 to January 1, 1995). Capital costs are the only costs that receive this half-year treatment, which assumes that compliance options will be placed in-service at the beginning of a year. A project's capital costs should be evaluated then. All of a project's operating costs, on the other hand, will occur throughout the year and should be evaluated on an averaged (i.e., mid-year) basis.



STARRSS then discounts the escalated capital costs back to the *Base Year*. This provides STARRSS with the present worth of a project's direct capital-related revenue requirements (i.e., annual depreciation and total return on ratebase).

**STARRSS does not consider any costs or benefits that fall outside of the study period.** If the compliance option has an *In-Service Year* that is before the study's start year or if the option's life extends beyond the end of the study, STARRSS calculates an appropriate adjustment (through proration and discounting) to reduce the option's capital-related revenue requirements to account for that the full costs that will not be within the study period. STARRSS does not calculate salvage values or other "end effects" issues for options that go beyond the end of the study.

## **Step 2:        Calculate Present Value of Tax Benefits**

STARRSS develops an approximation of the tax benefits associated with a compliance option's capital expenditures. Since the IRS allows capital investments to be depreciated (for tax purposes) on an accelerated basis, the implementation of compliance options with capital expenditures will permit the deferrance of taxes. Although the total amount of the tax dollars that will be paid by the end of the project will be the same as without the deferrance, such deferred taxes result in a present value benefit because of the timing of the tax payments. Effectively, this benefit reduces the total capital costs of a project by offsetting them with the value of the tax advantages. Therefore, STARRSS calculates the tax benefit as a "negative" cost. Generally, this affect is relatively small in present value terms, resulting in a 3-5% reduction of the present value of capital costs. Therefore, for speed considerations, STARRSS Version 1 does not perform a detailed tax benefit calculation. Instead, the program uses information from a regression analysis that Hagler, Bailly performed. By performing detailed tax benefit calculations for over 1,200 different sets of financial assumptions, Hagler, Bailly developed a linear regression equation that closely approximates project tax benefits under of variety of conditions.<sup>4</sup> The equation uses the *Long-Run Effective Tax Rate*, the *Return on Equity*, the *Equity Percent of Capital*, and the average *Cost of Capital* data inputs (all of which are input on the *Tax Rate, Escalation Rates, and Cost of Capital* screen) and assumes that the compliance project is in the 20-year Tax Class, using the 150%-declining-balance/switching-to-straight-line tax depreciation method. If the user finds that the STARRSS calculation underestimates or overestimates the actual tax benefits, the STARRSS calculation can be modified through the *Tax Benefit Multiplier* on the *Execution Parameters* screen. This data item directly adjusts

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<sup>4</sup> The regression analysis had an R-squared of 0.9629

the tax benefits that are calculated by STARRSS. By setting the multiplier to zero, the user can eliminate the consideration of all compliance options' tax benefits.

**Step 3:      Calculate Present Value of Tax Costs**

Similar to the process in Step 2 above (for the calculation of a compliance option's tax benefits) STARRSS develops an approximation of the tax costs associated with a compliance option's capital expenditures. Since the equity portion of the return that a utility earns on rate-based capital expenditures is taxable, then the adoption of compliance options that involve capital expenditures will increase the utility's tax payments over the life of the option. Similar to the tax benefit calculation, STARRSS uses information from a regression analysis that RCG/Hagler, Bailly performed. By performing detailed tax benefit calculations for over 1,200 different sets of financial assumptions, Hagler, Bailly was able to develop a linear regression equation that closely approximates project tax costs under a variety of conditions.<sup>5</sup> The equation uses the *Long-Run Effective Tax Rate*, the *Return on Equity*, the *Equity Percent of Capital*, and the average *Cost of Capital* data inputs (all of which are input on the *Tax Rate, Escalation Rates, and Cost of Capital* screen). If the user finds that the STARRSS calculation underestimates or overestimates the actual tax costs, the STARRSS calculation can be modified through the *Tax Cost Multiplier* on the *Execution Parameters* screen. This data item directly adjusts the tax costs that are calculated by STARRSS. By setting the multiplier to zero, the user can eliminate the consideration of all compliance options' tax costs.

**Step 4:      Calculate Present Value of Fixed O&M Costs**

STARRSS calculates each compliance option's yearly increased fixed O&M (operation and maintenance) costs by escalating the option's *Increased Annual Fixed O&M Costs* (found on the *Edit/Define Compliance Options* screen) from the *Base Year* through the end of the study. It then takes the costs that are incurred during the option's life that is within the study and discounts that stream of costs back to the *Base Year*. In other words, if the option only lasts through the first half of the study period, then the increased fixed O&M costs are assumed to stop at that time. The sum of these discounted values is the present value of the increased fixed O&M expenses.

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<sup>5</sup> The regression analysis had an R-squared of 0.9929

As a numerical example of this process, assume that the *Increased Annual Fixed O&M Costs* for a compliance option are \$1 million in 1992 dollars. Assume that the fixed O&M escalation rate is 5% and the utility's cost of capital (i.e., the discount rate) is 12%. Table 9-1 below shows the calculations that would be performed for a 5-year Phase I run: the escalation of the \$1 million into current year values, the discounting of each year's value (1995-1999) back to 1992, and the aggregation of these discounted values into a total present value. As can be seen from the last value in the last column of the table, the present value for the increased fixed O&M caused by the implementation of this hypothetical compliance option would be \$3.636 million.

**Table 9-1. Calculation of the Present Value of Increased Fixed O&M Expenses**  
(all expenses in millions of dollars)

<u>Year</u>	<u>Fixed O&amp;M</u>	<u>Discounted O&amp;M</u>	<u>Accumulated Discounted O&amp;M (present value)</u>
1992	1.000		
1993	1.050		
1994	1.103		
1995	1.158	0.824	0.824
1996	1.216	0.772	1.596
1997	1.276	0.724	2.321
1998	1.340	0.679	3.000
1999	1.407	0.637	3.636

**Step 5: Calculate Present Value of Additional Costs**

STARRSS performs the identical procedure for an option's *Additional Costs* data item. Note that this data item has its own compliance-option-specific escalation rate (see page 90).

**Step 6: Calculate Present Value of Fuel-Related Costs**

STARRSS calculates a compliance option's fuel-related incremental costs by accounting for two main factors: projected changes in a unit's fuel consumption (e.g., because of changes in system dispatch, changes in boiler efficiency), and,

in the event of fuel-switching, price differentials between currently-consumed fuels and proposed fuel blends. The implementation of a compliance option at an affected generating unit can increase or decrease the unit's fuel costs even if the option does not entail any switching of the unit's fuel supply. Specifically, if a compliance option changes the unit's operations (i.e., capacity factor), a different level of fuel consumption will occur. In determining the true cost of implementing a specific compliance option, STARRSS comprehensively considers all cost increases or decreases that are caused by the option.

A compliance option's fuel-related incremental costs are calculated as the difference between the product of the new projected fuel consumption and the price of the new fuel blend and the product of the current fuel consumption and the price of the existing fuel supply. Equation 9-2 below displays this in mathematical terms.

$$\text{FuelCost}_{i,j} = (\text{NewCons}_{i,j} * \text{NewPrice}_{i,j}) - (\text{OldCons}_j * \text{OldPrice}_j) \quad (9-2)$$

where:

$\text{FuelCost}_{i,j}$	=	incremental fuel cost of implementing compliance option i at unit j
$\text{NewCons}_{i,j}$	=	new average annual fuel consumption caused by implementing compliance option i at unit j
$\text{NewPrice}_{i,j}$	=	weighted average price of compliance option i's new fuel blend at unit j
$\text{OldCons}_j$	=	current average annual fuel consumption for unit j
$\text{OldPrice}_j$	=	weighted average price of current fuel blend at unit j

Equation 9-2 refers to a single year of calculations. STARRSS Version 1 performs its unit operation calculations in a single, average-year context. Year-by-year changes in fuel prices are incorporated into the program's calculations. In calculating a compliance option's incremental fuel costs, STARRSS first calculates the affected unit's average fuel consumption over the study period for both the base case and "change case" situations. The calculation of the base case fuel consumption is shown in Equation 9-1 on page 162; the calculation for the unit's fuel consumption after a compliance option has been implemented is shown in Equation 9-3 on the next page. STARRSS then uses these single, average-

year values in calculating incremental fuel costs for the affected unit for each year of the study period (using Equation 9-2). Since STARRSS allows the user to specify as many as three different fuels in a unit's existing and/or new fuel blend, the program uses the weighted average prices in all fuel price calculations. The program then takes the stream of the annual fuel costs calculated from Equation 9-3 and discounts them back to the *Base Year*.

$$\text{NewCons}_{i,j} = \text{NewCapFact}_{i,j} * \text{Cap}_j * \frac{8760 \text{ hrs}}{\text{year}} * \text{NewHtRate}_{i,j} \quad (9-3)$$

where:

$$\begin{aligned} \text{NewCons}_{i,j} &= \text{average annual fuel consumption after} \\ &\quad \text{implementing compliance option } i \text{ at unit } j \\ \text{NewCapFact}_{i,j} &= \text{unit } j\text{'s average annual capacity factor after} \\ &\quad \text{implementing compliance option } i \\ \text{Cap}_j &= \text{unit } j\text{'s existing capacity} \\ \text{NewHtRate}_{i,j} &= \text{unit } j\text{'s average heat rate after} \\ &\quad \text{implementing compliance option } i \end{aligned}$$

The *New Capacity Factor* for a unit at which a compliance option is implemented is a direct single-year user input on the *Edit/Define Compliance Options* screen. STARRSS assumes that the value that the user inputs for this data item represents a long-term estimate (i.e., constant value over time) of how the affected unit is expected to operate. If the user leaves the *New Capacity Factor* at zero, STARRSS assumes that the unit's utilization will not change and therefore uses the unit's current capacity factor in the above calculation.

The capacity of a unit can be affected by the implementation of a compliance option. For example, scrubbing a unit can cause a unit's capacity to be derated. However, the ***Capacity Deration*** data item (that is specified on the *Edit/Define Compliance Options* screen) **does not affect the STARRSS fuel consumption calculations**. For fuel consumption calculations, STARRSS uses the same unit capacity for both the base case and change case. A unit is derated by the adoption of a compliance option, frequently because some of the unit's capacity is required to power more equipment (such as with the installation of scrubbers). Such a circumstance translates into a reduction in net generation but not fuel consumption. The unit has less power that it can supply to the transmission grid, but its fuel consumption is unchanged (all else being equal). If a compliance

option is expected to reduce a unit's fuel consumption, the user should indicate this through specifying an improvement in the unit's boiler efficiency.

A generating unit's boiler efficiency can be affected by the implementation of a compliance option, particularly if a utility decides to burn a different type of fuel than what the boiler was originally designed to burn. On the *Edit/Define Compliance Options* screen, the user can specify a *Heat Rate Multiplier*. This data item is used to adjust an affected unit's heat rate (i.e., boiler efficiency) when a specific compliance option is implemented at the unit. The default value is 1.000; higher values will increase the new heat rate that is used in Equation 9-3 and translate into a decrease in boiler efficiency; lower values indicate an improvement in boiler efficiency.

**Step 7: Calculate Present Value of Variable O&M Costs**

STARRSS calculates the existing value of the increased variable O&M costs at a unit similar to the fuel cost calculation. These costs are meant to reflect non-fuel-related unit-specific operating cost, such as increased water consumption, waste disposal, and consumption of new products (e.g., limestone). They should not include the costs of additional power that may be required for certain compliance options. Replacement power costs are calculated in Steps 8 and 9.

A compliance option's non-fuel-related incremental variable O&M costs are calculated as the difference between the product of the new projected unit generation and the new variable O&M cost (specified on a \$/MWH basis) and the product of the current unit generation and the current variable O&M cost. Equation 9-4 below displays this in mathematical terms.

$$VO\&MCost_{i,j} = (NewGen_{i,j} * NewVO\&M_{i,j}) - (OldGen_j * OldVO\&M_j) \quad (9-4)$$

where:

$VO\&MCost_{i,j}$  = incremental variable O&M cost of implementing compliance option i at unit j

$NewGen_{i,j}$  = new average annual generation caused by implementing compliance option i at unit j

$NewVO\&M_{i,j}$  = new variable O&M cost (in \$/MWH) at unit j after implementing compliance option i

$$\begin{aligned}\text{OldGen}_j &= \text{current average annual generation at unit } j \\ \text{OldVO\&M}_j &= \text{current variable O\&M cost (in \$/MWH) at unit } j\end{aligned}$$

Equation 9-4 refers to a single year of calculations. Although STARRSS Version 1 performs its unit operation calculations in a single, average-year context, the year-to-year changes in annual price data are not averaged; instead, they are explicitly represented in a STARRSS analysis.

Current "base case" variable O&M costs are input on a unit-specific basis and are expressed in \$/MWH of net generation. They are escalated throughout the length of the study by the *Variable O&M Escalators* on the *Tax Rate, Escalation Rate and Cost of Capital* screen.

Each compliance option's *Increased Non-Fuel Variable O&M Cost* data item is found on the *Edit/Define Compliance Options* screen, is expressed in the same \$/MWH terms, and is escalated by the same schedule of escalators. This data item serves as a direct adder to the unit's current "base case" variable costs. In calculating a compliance option's incremental variable O&M costs, STARRSS first calculates the affected unit's average annual generation over the study period for both the base case and "change case" situations. The calculation of the base case generation is shown in Equation 9-5 below.

$$\text{OldGen}_j = \text{CapFact}_j * \text{Cap}_j * \frac{8760 \text{ hrs}}{\text{year}} \quad (9-5)$$

where:

$$\begin{aligned}\text{OldGen}_j &= \text{base case average annual expected generation at unit } j \\ \text{CapFact}_j &= \text{base case average annual capacity factor for unit } j \\ \text{Cap}_j &= \text{capacity for unit } j\end{aligned}$$

The calculation of the new projected annual average generation is similar to Equation 9-5 except that a *New Capacity Factor* is used (if a non-zero value is input for this data item on the *Edit/Define Compliance Options* screen). If a compliance option's *New Capacity Factor* is left at zero, then STARRSS assumes

that there will be no change in the unit's utilization and therefore uses the unit's current capacity factor in the above calculation. Also, if the user specifies a *Capacity Deration*, the unit's capacity will be adjusted. For example, a 4% deration would cause STARRSS to multiply the unit's capacity by 96% ( $= 100\% - 4\%$ ) in calculating a unit's new projected net generation.

STARRSS then uses the single, average-year values for base case and new generation in calculating incremental variable O&M costs for the affected unit for each year of the study period (using Equation 9-4). The program then takes the stream of the annual variable O&M costs and discounts them back to the *Base Year*.

**Step 8:            Calculate Present Value of Replacement Capacity Costs**

STARRSS calculates the present value of the costs (or benefits) of replacement capacity for any compliance option that causes a deration (or increase in capacity) at a generating unit. Similar to the calculations for fuel or variable O&M costs, the program calculates the annual stream of replacement capacity costs for an option by multiplying the yearly system marginal capacity cost (as input on the *Marginal Capacity Cost* screen) by the difference between the affected unit's new capacity and its original capacity. Derations result in positive costs; capacity increases result in negative costs (i.e., benefits). STARRSS then discounts the stream of costs back to the *Base Year*.

**Step 9:            Calculate Present Value of Replacement Energy Costs**

STARRSS calculates the present value of the costs (or benefits) of replacement energy for any compliance option that causes a change in a generating unit's output. Through a process that is virtually identical to the calculation of replacement capacity costs (described above), STARRSS multiplies the yearly system marginal energy cost (as input on the *Marginal Energy Cost* screen) by the difference between the affected unit's new generation (as described above in Step 7) and its original "base case" generation (as calculated in Equation 9-5). Decreases in generation result in positive replacement energy costs; increases in generation result in negative costs (i.e., benefits). STARRSS then discounts the stream of costs back to the *Base Year*.



### **9.1.3 Calculation of Impacts of Individual Compliance Options**

The "impact" of a compliance option refers to its annual average reduction in SO<sub>2</sub> emissions.

#### **Incremental Conservation Programs and Renewable Projects**

STARRSS calculates the emissions reduction impacts from incremental conservation programs or renewable projects by multiplying the program's *Expected Energy Savings* for each year by the program's *System Marginal SO<sub>2</sub> Emissions* (both entered on the *Incremental Conservation/Renewables* screen).

#### **Generating-Unit-Specific Compliance Options**

STARRSS calculates impacts for each generating-unit-specific compliance option in the following way.

##### **Step 1: Calculate Unit's Base Case Emissions**

For the unit which the compliance option affects, STARRSS multiplies the original annual fuel consumption (as calculated in Equation 9-1) by the sulfur content/emissions rate of the current fuel (or fuel blend). The program then adjusts these uncontrolled emissions for any existing pollution control systems by multiplying the emissions by one minus the existing system's removal efficiency.

##### **Step 2: Calculate Unit's New Emissions**

STARRSS then calculates the unit's new level of emissions if the compliance option were to be implemented. The program multiplies the new annual fuel consumption (as calculated in Equation 9-3) by the new fuel blend's sulfur content/emissions rate. Even if the option does not entail fuel-switching (and hence the base case and new fuel's sulfur content are the same), the fuel consumption of the unit may change (because of differences in boiler efficiency and unit utilization). The outcome of this calculation is then adjusted for any new pollution control systems. When the unit does not have an existing pollution control system, the new emissions are multiplied by one minus the new system's removal efficiency. If the unit already has a system, then an adjustment must be made for both systems by multiplying by one minus the existing system's removal efficiency and one minus the new system's removal efficiency.

### **Step 3: Calculate Effects on Other Units Emissions**

If the generating unit's capacity or capacity factor will be changed by the option, then STARRSS will calculate the emissions impact at other power plants that would be caused by increased or decreased generation from this unit. The program will calculate the difference between the unit's original annual generation and the new annual generation and multiply this differential by the value of the compliance option's *System Marginal SO<sub>2</sub> Emissions* data item. In the case of a reduction of the unit's generation, this term will be positive -- reflecting the additional emissions that will occur elsewhere because other units will have to increase generation to compensate. If the individual unit experiences an increase in generation, this will back down other units and reduce their emissions.

### **Step 4: Calculate Total Annual Impact**

Calculate the total annual impact for the compliance option using Equation 9-6 below:

$$\text{Impact}_i = \text{RegEmiss}_j - \text{NewEmiss}_{i,j} - \text{OthrEmiss}_j \quad (9-6)$$

where:

Impact <sub>i</sub>	=	total annual impact for compliance option i
RegEmiss <sub>j</sub>	=	base case annual emissions from generating unit j
NewEmiss <sub>i,j</sub>	=	new annual emissions from generating unit j after implementing compliance option i
OthrEmiss <sub>j</sub>	=	emissions impacts at other generating units caused by changes in generation at unit j

### **Step 5: Calculate Bonus Allowance Effect**

Scrubbing, repowering, and conservation compliance options can generate bonus allowances for a utility. STARRSS calculates the theoretical allocation of bonus allowances for each eligible compliance option based on the provisions in Title IV of the CAAA. The program adjusts the allocation of the bonus allowances

by the associated user-specified ***Bonus Allowance Supply Percentages*** (on the ***Allowance Parameters*** screen). This is the anticipated total allocation. STARRSS divides the option's bonus allowance allocation by the number of years of the study to determine the annualized allocation that will be used in STARRSS Version 1's single-year analyses. This annualized number is added to the appropriate compliance option's emissions reduction impact. All unitized cost (\$/ton) calculations in STARRSS use this "modified" impact in the denominator to reflect the benefits of bonus allowances.

STARRSS uses simplified processes to capture the effects of bonus SO<sub>2</sub> allowances on the selection of particular compliance options. For each compliance option, STARRSS will calculate the total bonus allowance impact, divide that total by the number of years in the study, and add that total to the SO<sub>2</sub> reducing impact associated with the compliance option. To disable the calculation of bonus allowances for any option, the user must set the ***Bonus Allowance Supply Percentage*** in the ***Allowance Parameters*** selection of the ***System-level Info*** submenu to zero for all forecasts.

### **Phase I Extension Bonus Allowances**

The CAAA allocates Phase I Extension Bonus Allowances for Phase I-affected units that use technology achieving 90% or greater SO<sub>2</sub> removal efficiency (i.e., scrubbers). Phase I extension bonus allowances have two components: one allows the unit to delay installation of qualifying technology until January 1, 1997, and another provides extra incentive allowances for reducing emissions below the Phase II standard of 1.2 lbs. SO<sub>2</sub>/MBtu.

In STARRSS, the first component of the Phase I Extension Bonus is calculated for each unit using equation 9-7:

$$\text{Bonus Part 1} = (\text{RegEmiss}_j - \text{NewEmiss}_{i,j}) * 2 \quad (9-7)$$

where:

RegEmiss<sub>j</sub> = regular (uncontrolled) annual emissions from generating unit j without a scrubber

NewEmiss<sub>i,j</sub> = annual emissions from generating unit j resulting from implementing scrubber compliance option i

The difference is multiplied by two because that is the number of years (1995 and 1996) over which the extension bonus allowances are granted.

By using the difference between the units expected emissions with and without a scrubber for the two years 1995 and 1996, the bonus allowances allow the utility to continue operating several units at their current emission levels until 1997. In the CAAA, the unit using scrubber technology is designated the "control unit," while the units that would receive extra allowances freed up by the control unit are designated the "transfer units." By allocating bonus allowances to control and transfer units, EPA permits the utility to delay installation of the scrubber until 1997.

The second component of the Phase I Extension Bonus is calculated for each unit using equation 9-8 and represents those bonus allowances that are allocated for the years 1997 - 1999:

$$\text{Bonus Part 2} = (\text{BasPhaseII}_j - \text{NewEmiss}_{i,j}) * 3 \quad (9-8)$$

where:

$\text{BasPhaseII}_j$  = basic phase II allowance allocation (Baseline Heat \* 1.2 lbs SO<sub>2</sub>/MBtu) for generating unit j

$\text{NewEmiss}_{i,j}$  = annual emissions from generating unit j resulting from implementing scrubber compliance option i

The difference is multiplied by three because it is the number of years (1997 - 1999) over which the bonus allowances are granted. This component of the bonus allowances in effect rewards the unit for achieving an emission rate lower than 1.2 lbs/MBtu three years before the Phase II deadline.

### **Repowering Extension Bonus Allowances**

Repowering Extension Bonus Allowances allow a utility system to cover increased emissions at other generating units while an affected unit undergoes a repowering construction period. For each year of the repowering construction period after 2000 (up to a maximum of three years), bonus allowances are allocated according to equation 9-9:

$$\text{Repowering Bonus} = \text{RegEmiss}_j - \text{Emiss1.2}_j \quad (9-9)$$

where:

$\text{RegEmiss}_j$  = regular (uncontrolled) annual emissions from generating unit j before repowering

$\text{Emiss1.2}_j$  = annual emissions at the Phase II emission limitation (i.e. unit's Baseline Heat \* 1.2 lbs SO<sub>2</sub>/MBtu) for generating unit j

This bonus allows the utility to replace the generation lost at the repowering unit with compensating generation at an emissions rate no greater than 1.2 lbs/MBtu. If the unit's emissions are lower than the unit's basic Phase II allocation, no bonus is awarded.

#### **Conservation/Renewable Energy Bonus Allowances**

The CAAA provides a Conservation/Renewable Energy Bonus Allowance reserve for utilities engaging in qualifying energy-saving conservation activities. STARRSS calculates bonus allowances from this reserve using equation 9-10:

$$\text{Con/Renew Bonus} = \text{ExSave}_i * .002 \quad (9-10)$$

where:

$\text{ExSave}_i$  = Expected savings over the applicable period for program i, in MWh (or expected generation provided by renewable energy project i)

The .002 factor converts verified savings from MWhs to allowances at a rate of 4 lbs SO<sub>2</sub>/MWh (the conversion multiplier stipulated in the CAAA).

For utilities with Phase I-affected units, only the 1992 - 1994 energy savings will be considered in the above equation; for Phase II-affected utilities, only the 1992 -1999 energy savings will be considered.

#### **9.1.4 Calculation of Allowance Transactions**

STARRSS compares the utility's emissions reduction target with the sum of the annual impacts and annualized bonus allowance allocations for all compliance options in a strategy. For a shortfall, STARRSS "fills the gap" with allowance purchases. If the sum of the impacts and bonus allowances exceeds the target reduction then STARRSS sells the excess allowances.

The program determines the costs or revenues from allowance transactions by pricing a stream of annual allowance transactions over the length of the study. Effectively, STARRSS Version 1 assumes that the calculated average-year volume will be purchased/sold in every year of the study. The program multiplies this annual trading volume by each year's allowance price (buying or selling) to develop a stream of annual costs or revenues. STARRSS takes in consideration the size of the annual transactions and modifies the buying/selling price depending on the *Purchase Price Premium* or *Sale Price Discount* (see page 53). The program then discounts this stream of costs or revenues back to the *Base Year*.

#### **Trading Limitations**

If the amount of allowances sold exceeds the user-specified allowance sales limit (as entered on the *Allowance Parameters* screen), then STARRSS will not give the strategy any credit/revenues for those allowances that are over the limit.

In the opposite case, if the amount of allowances that the utility must purchase is greater than the user-specified limit, the program will still purchase them (since the utility still must comply). However, STARRSS will "flag" all allowance transactions that exceed the selling or buying limits by placing an asterisk next to the transaction values on the output reports.

In Version 1, STARRSS determines the trading limits by taking the average value of the yearly limits over the study period.

#### **9.1.5 Calculation of Total Cost of Compliance**

Prior to calculating the total cost of a compliance strategy, STARRSS will determine the present value of any applicable compliance option linkages (see page 104). The capital cost savings are assumed to occur in the *In-Service Year* of the latest compliance option. The operating cost savings are assumed to occur only during those study years that all of the compliance options in the linkage are active.

The last step in the process is the calculation of a strategy's total cost of compliance. This is merely the sum of all of the individual compliance option costs, plus the allowance transaction

costs (which will be negative if the utility is an allowance seller), minus any cost savings because of applicable compliance option linkages.

#### 9.1.6 Calculation of Unitized Costs

In addition to the total present value of compliance costs, STARRSS displays unitized costs (i.e., \$/ton) on a number of output reports.

To convert the present value of total cost for a compliance option into a unitized cost, the levelized value must be calculated first. If the discount rate remains constant over the study period, the levelized value can be calculated by using Equation 9-11 below.

$$\text{LevVal}_{xx} = \frac{(\text{PresVal}_{xx} * \text{DiscRate})}{(1 - (1 + \text{DiscRate})^{-\text{LOS}})} \quad (9-11)$$

where:

$\text{LevVal}_{xx}$	=	levelized value of the present value of total costs in year 19xx
$\text{PresVal}_{xx}$	=	present value of total costs in year 19xx
$\text{DiscRate}$	=	discount rate (utility's cost of capital)
$\text{LOS}$	=	length of study (in years)

If the user has input a discount rate that changes from year to year, a more complicated equation (that uses a string of discount factors) must be used to calculate the levelized cost of compliance.

To calculate an option's or strategy's unitized cost of compliance (in \$/ton), the levelized cost of compliance simply is divided by the average annual impact (in tons of SO<sub>2</sub> reduced).

## 9.2 FULL OPTIMIZATION

The STARRSS Full Optimization process considers every possible combination of "active" compliance options (i.e., those options that the user has selected for the optimization). For example, assume that a user has defined two compliance options for a utility system, one each at the utility's two affected units. The utility's current annual emissions are 250,000 tons/year. However, it has only been allocated 150,000 allowances/year, thereby necessitating the reduction of 100,000 tons/year (or the purchase of allowances to cover any excess emissions). Option #1 will reduce system emissions by 70,000 tons, and Option #2 will reduce emissions by 60,000 tons. If the Full Optimizer is executed, STARRSS will develop four compliance strategies:

- 1) Purchase 100,000 allowances
- 2) Implement Option #1 only and buy 30,000 allowances
- 3) Implement Option #2 only and buy 40,000 allowances
- 4) Implement both options and sell 30,000 allowances

The Full Optimizer will evaluate all of these possible combinations based on the mean forecast for all of the STARRSS data items. During the optimization process, STARRSS will not perform multiple iterations for each possible strategy because this would take too long. Instead, the Full Optimizer calculates a single present value of the cost of each possible strategy. All of the STARRSS inputs are temporarily set to their mean value (i.e., the weighted average of the triple forecasts) when the program calculates each possible strategy's present value of compliance costs.

The Full Optimizer will discard any strategies that violate the user-specified allowance trading limits (on the *Allowance Parameters* screen). However, this does not mean that the user will never see the limits exceeded by optimal strategies. As is pointed out below, STARRSS submits its strategies to the multiple-scenario evaluation process. Therefore, a strategy may remain within the allowance trading limits when evaluated under the mean forecast assumptions but exceed the limits when opened up to the variability of the multiple-scenario.

In the Full Optimizer, STARRSS ranks the strategies in a master list that can hold as many as 255 strategies. STARRSS continues to develop new combinations of compliance options even if the list fills up. However, if a compliance strategy does not have a low enough cost to make it on the list, it is discarded. The Full Optimizer continues this process until it has considered all possible strategies. This could involve evaluating billions of strategies. For example, if a utility system has 10 affected units, and if each unit has 9 different possible



compliance options, then there are 10 billion different combinations of options. The number of possible strategies is given by Equation 9-12 below.

$$\text{Possible Number of Strategies} = (\text{Number of Options} + 1)^{(\text{Number of Units})} \quad (9-12)$$

Obviously, the full-enumeration approach can translate into an enormous number of options to consider. As noted above, STARRSS does not attempt to save all of these strategies in the computer's memory. As described above, STARRSS instead develops a master list of at most 255 strategies. In opting to do, the program takes one shortcut. The economy of scale cost savings that are modelled in the database through the Compliance Option Linkages (see page 104) are not considered in the cost of a strategy until all possible strategies have been enumerated and the top 255 strategies are on the master list. At that point, the cost savings of all linkages are deducted from the total cost of any strategies that contain the specific compliance option combinations that are modelled as linkages. The list is then resorted.

If the user has modelled a compliance linkage that entails considerable cost savings, it is possible that a strategy that includes this cost-saving combination of options may not make it onto the master list. Conceivably, if the cost savings were tremendous, that strategy may have been the least-cost plan. The user should remain aware of this limitation of the Full Optimizer and should evaluate such cost-saving combinations as user-specified strategies if the optimization process appears to overlook such measures.

Ultimately, the user determines the number of strategies that will be more fully evaluated from the master list of 255. The *Number of Strategies to be Evaluated/Saved* (see page 119) is the data item through which the user controls the size of this top set of plans. That number of strategies will be taken from the top of the list of 255 and run through the standard multiple-scenario evaluation process. After the top plans have been evaluated, they are displayed in the STARRSS output reports in ascending order of expected cost. The least-cost plan is not necessarily the most desirable. The user must also consider the level of risk (i.e., potential variation in cost) that is associated with each strategy, along with non-quantifiable issues that can bear on the selection of an appropriate compliance strategy.

### 9.3 HEURISTIC ALGORITHMS

In the event that a user defines an optimization problem that is so large that a full enumeration of all possible compliance strategies would be too time-consuming, two alternative methodologies are provided. These methodologies employ heuristic algorithms in the development of a set of "good" compliance strategies. In mathematical terminology, the problem of determining the least-cost compliance strategy for a utility is "NP-complete." In other words, the optimal solution cannot be determined through any short-cuts; the only way to be sure one has found the least-cost compliance strategy is to fully enumerate all of the possible strategies and see which one is the cheapest. Therefore, there is no guarantee that any

methodology which bypasses the full enumeration approach will find the optimal plan. However, true optimization is not critical within STARRSS. The main target of the STARRSS optimization methodology is to develop a set of good compliance plans which can then be exposed to a variety of future economic and operational uncertainties. True optimization can only be performed in a world of fixed underlying assumptions. What appears to be the optimal strategy under the mean forecast assumptions within STARRSS could have a higher expected cost than other strategies under variable conditions. Therefore, the STARRSS heuristic algorithms quickly compile a set of low-cost, diverse compliance plans; the true test of each of these plan's "optimality" will occur during STARRSS' full scenario analysis.

For both heuristic algorithms, STARRSS allows the allowance trading constraints (specified on the *Allowance Parameters* screen) to be violated. However, in the case of purchase violations, it prices the additional allowances at \$999/ton; for sales violations, it prices the excess allowances (over the sales limit) at \$0/ton. This arrangement permits the program to consider strategies that may marginally violate the trading limits (when evaluated under the mean forecast assumptions) but are still worthy of consideration.

### **9.3.1 Heuristic #1: Multiple Scenario Hill Climbing**

The first heuristic uses a three-step process to generate each strategy, the steps of which will be described below:

- Step #1: Scenario generation
- Step #2: Hill climbing optimization
- Step #3: Mean-forecast re-evaluation

**Scenario Generation:** The scenario generation step is the same process that occurs in the strategy evaluation process described in section 9.1; one of the three forecasts for each data item in the database is chosen, describing a possible scenario. The entire optimization that takes place in step two will attempt to minimize costs *under this scenario*; Heuristic #1 is the only optimizer which considers multiple scenarios.

**Hill Climbing:** Hill climbing is an established optimization technique in Operations Research. It is analogous to a climber trying to find the highest point on a mountain. If the shape of the mountain is fairly regular, the climber can easily find the top simply by choosing the steepest direction in which to take each step. The climber knows he or she is at the top of the mountain when a step further in any direction would lead the climber downhill. In Heuristic #1, "steps" are substitutions of one compliance option for another at any one unit (including doing nothing at all as an option). A random strategy is chosen as a starting point, and the substitution that results in the greatest cost reduction in the overall strategy is taken at each step.

Note that this algorithm is not guaranteed to come up with the optimal solution every time. The assumption in the analogy is that the mountain is fairly regular in shape; if it has more than one distinct peak, the climber could end up at a "false summit" (i.e., a peak that is not the highest. Similarly, Heuristic #1's hillclimbing will sometimes find a strategy which is not the least cost, but from which any single substitution would produce a more expensive strategy.

Heuristic #1 attempts to circumvent this possibility by repeating the hillclimbing process four times within each scenario iteration, using four randomly generated strategies as starting points; this is analogous to four climbers starting at different places and climbing the same mountain with the hope that at least one would reach the true summit.

The heuristic algorithm is also protected against false summits by the use of multiple scenario iterations; each scenario corresponds to a slightly different "landscape" for the hillclimber to traverse. If the scenarios are significantly different, a false summit is unlikely to fool the climber, or even exist at all, in every single iteration.

Re-Evaluation: The least cost of the four (or fewer) strategies the hillclimber finds is re-evaluated under the mean forecast assumption, and sorted into the final list of strategies according to this measure of its cost. The rationale behind re-evaluation is that if a strategy which has a low cost in some arbitrary scenario is not somewhat competitive in the mean forecast scenario, then it is not really viable.

#### Tradeoffs between Heuristic #1 and Full Enumeration

Heuristic #1 can be much faster than full enumeration, generates strategies that have been developed under scenarios other than the mean forecast, and considers compliance option linking every time it evaluates the cost of a strategy. If there are significant linkage benefits in the database, Heuristic #1 could outperform the Full Enumerator. On the other hand, under certain circumstances, Heuristic #1's strategies may not measure up to the Full Enumerator's strategies, especially when allowance purchase and sales limits are strict enough to constrain the search; these situations are more likely to yield false summits.

#### **9.3.2 Heuristic #2: Varying Prioritization**

The second heuristic's process is more complex and is especially designed for compliance strategy optimization. While both Heuristic #1 and #2 develop sets of compliance plans that are optimal or near-optimal, preliminary analyses have shown that Heuristic #1 is a little better on average. However, under certain circumstances, Heuristic #2 does better.

The general flow of the second heuristic process involves two distinct algorithms: the Main Algorithm and the Market Algorithm. The Main Algorithm generates strategies that consist of emissions-reducing actions at every unit where compliance options are specified; in many cases,

this results in strategies that involve the significant overcontrol of emissions and the sale of many allowances. Each strategy is then passed to the Market algorithm for possible improvement. The Market Algorithm explores the possible benefits that may be achieved through allowance transactions. If the marginal compliance options are more expensive than the allowance purchase price in the marketplace, then the Market Algorithm will back these options out of the plan and sell fewer (or purchase more) allowances. Once the Market Algorithm can no longer economically back options out of the plan, it will begin to explore the possibility of adding options whose cost is cheaper than the allowance sale price in the marketplace, thereby overcontrolling emissions and selling the excess allowances.

### **Main Algorithm**

The Main Algorithm generates all of the compliance plans on which the Market Algorithm works. It assures that the basic "building blocks" for a low-cost compliance strategy will be compliance options with low unitized (\$/ton) costs, large impacts (total tons of SO<sub>2</sub> emissions reduced), or a combination of both. In other words, a low-cost strategy may entail implementing low-cost/low-impact options at all affected units or medium-cost/high-impact options at only a few units. Regardless, it is unlikely that a sound strategy will involve many options that are both high-cost and low-impact.

Therefore, the primary objective of the Main Algorithm is to select a variety of good sets of compliance options for the Market Algorithm to work on. As can be seen in the following example, this may not mean selecting the least-cost options for each affected unit.

Assume that a utility must reduce its annual emissions by 30,000 tons of SO<sub>2</sub>. The utility has three affected units. The following table presents the compliance options available for each unit along with the levelized \$/ton cost and expected impact (tons reduced) of each of those options:

<u>Unit</u>	<u>Compliance Options</u>			
	FUEL SWITCH		SCRUB	
	<u>\$/ton</u>	<u>tons</u>	<u>\$/ton</u>	<u>tons</u>
BIGCOAL 1	400	10,000	500	30,000
BIGCOAL 2	550	10,000	700	30,000
BIGCOAL 3	600	10,000	800	30,000

In this case, selecting the cheapest compliance options (fuel switching) at all of the units would not be the least-cost strategy. Such a plan would cost \$15.5 million/year<sup>6</sup> on a levelized basis, whereas a decision to scrub BIGCOAL 1 (and meet the utility's compliance requirements with that one action) would be cheaper, costing only \$15 million/year<sup>7</sup>.

Heuristic #2's Main Algorithm therefore must consider not only a compliance option's unitized cost (\$/ton) but also the amount of SO<sub>2</sub> reductions that the option can achieve. What characterizes a compliance option as being "good" is both its low cost and its high impact. Based on this fact, STARRSS must rank the utility's compliance options on more than just cost (\$/ton). Since the Main Algorithm must produce multiple compliance plans, a procedure was designed that allows the algorithm to establish a variety of rankings, instead of just one. These rankings will be in ascending order and will be based on what will be called the minimization factor, or "M-factor." The M-factor is a numeric value which is calculated for each compliance option based on the following formula:

$$\text{M-factor} = (k_1)(\$/\text{ton}) + (k_2)(E_1)(1/\text{tons}) + (k_3)(E_2)(\$/\text{ton})(1/\text{tons})$$

where:            \$/ton refers to each compliance option's unitized cost; 1/tons is the inverse of each compliance option's emission reduction impact; k<sub>1</sub>, k<sub>2</sub>, and k<sub>3</sub> are weighting factors that sum to 100%; and E<sub>1</sub> and E<sub>2</sub> are equalization coefficients (and will be addressed later in this section).

Heuristic #2's approach is referred to as a Varying Prioritization approach since it establishes a variety of different rankings of compliance options (30 different rankings, to be exact) where each ranking prioritizes the options with a different weighting of the options' unitized costs, impacts, or a combination of the two.

As a start, STARRSS will set k<sub>1</sub> = 100% (and thus, the other two weighting factors will be 0%). Therefore, the M-factors for all of the utility's compliance options will be the options' unitized costs (\$/ton). Ranking the options in ascending order will place those options with the lowest \$/ton cost at the top of the list. STARRSS will start at the top and begin its selection process, moving all the way down the list. Obviously, as STARRSS moves down the list, it must keep track of which generating units each compliance option affects since two options cannot be chosen for the same generating unit. Therefore, whenever STARRSS selects an option, it temporarily deactivates any subsequent options in the list that also apply to the same generating unit.

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<sup>6</sup> \$15.5 million/year = [\$400 x 10,000] + [\$550 x 10,000] + [\$600 x 10,000]

<sup>7</sup> \$15 million/year = \$500 x 30,000

Each M-factor ranking will "spawn" several compliance plans based on multiple rounds of selection. These multiple selection rounds will be addressed below. For the time being, the important issue is the M-factor ranking.

After STARRSS has developed one or more compliance strategies from the above M-factor ranking (where  $k_1 = 100\%$ ), the weighting factors are changed. Obviously if  $k_1$  were set to 0% and  $k_2$  were set to 100%, it is likely that the M-factor ranking would change substantially. With the full weight being placed on the second term in the M-factor calculation, those options with the largest impact (i.e., tons of  $\text{SO}_2$  reduced) would have the smallest values for the inverse of the impact (1/tons) and would therefore be at the top to the list.

Incidentally, the inverse of the impact is used in the M-factor calculation for the following reason. As was stated earlier, "good" compliance options can have either **low** \$/ton costs and/or **high** impacts. Therefore, if STARRSS is to appropriately combine an option's characteristics (and select the options with the lowest M-factors), the inverse of the impact must be used. Thus, a large impact translates into a smaller M-factor and therefore a better ranking of the option.

As the  $k_2$  weighting factor is increased, the benefits of large-impact compliance options begin to compete with (and ultimately overshadow) the benefits of options that merely have low unitized costs. With a different ranking in place, STARRSS can now repeat the selection process, starting at the top of the list and picking the lowest M-factor options for all of the utility's units. This reranking is performed 30 times with various values of  $k_1$ ,  $k_2$ , and  $k_3$ . Each time that this reranking produces a fundamentally different list, a different set of options will be selected.

The third term in the M-factor calculation is merely a combination of the first two. Effectively, this term is a type of cost-benefit ratio, in that it measures how large an option's unitized cost is in relation to the option's impact. Obviously, the lower this value is, the more attractive is the compliance option. If  $k_3$  is left at 0%, then this cost-benefit term will not affect the M-factor. However, increasing the value of  $k_3$  will cause those options with favorable cost-benefit ratios to rise in the ranking.

The M-factor calculation involves two other coefficients: the equalization coefficients,  $E_1$  and  $E_2$ . These coefficients put the three terms in the calculation on "equal footing." Realizing that 1) the unitized costs for most compliance options are in the hundreds of dollars per ton, and that 2) the impacts are generally in the thousands or tens of thousands of tons, one can see that the terms in the calculation are mismatched. Since the second term is the inverse of the impact, its value will usually be around 0.001 or 0.0001 (1/1000 or 1/10000, respectively), while the first term will be in the 100s. Thus, the first term could be six orders of magnitude larger than the second. If the M-factor calculation is not adjusted for this magnitude differential, the overall process will still work; however,  $k_1$  will have to drop to 0.0001% (and  $k_2$  will have to rise to 99.9999%) before any meaningful changes will occur in the ranking of compliance

options. In order to bring the weighting factors into a more appropriate range, equalization coefficients will be used to "equalize" the effects on the M-factor from the three terms in the calculation.

The equalization coefficients are calculated at the beginning of the Main Algorithm -- during a preliminary analysis of the utility's compliance options. The coefficients are based on the mean value (across all options) of each of the terms in the M-factor calculation and are calculated in the following manner:

$$E_1 = \frac{\text{Mean of \$ / ton}}{\text{Mean of 1 / tons}} = (\text{Mean of \$ / ton}) \times (\text{Mean of tons})$$

$$E_2 = \text{Mean of tons}$$

For example, if the average value of the unitized costs for all compliance options was \$500/ton and the average impact was 10,000 tons, then  $E_1$  would be 5,000,000 and  $E_2$  would be 10,000.

Having explained how all three M-factor terms are placed on equal footing, how then are the weighting factors ( $k_1$ ,  $k_2$ , and  $k_3$ ) calculated? STARRSS has a table of values for the weighting factors, in which each row of values is used to define each ranking (or reranking) of the compliance options. The following chart shows the table of k-values:

<u>Ranking #</u>	$k_1$	$k_2$	$k_3$
1	100	0	0
2	85	0	15
3	70	0	30
4	55	0	45
5	40	0	60
6	25	0	75
7	10	0	90
8	0	0	100
9	85	15	0
10	70	15	15
11	55	15	30
12	40	15	45
13	25	15	60
14	10	15	75
15	0	15	85
16	70	30	0
17	55	30	15
18	40	30	30
19	25	30	45
20	10	30	60
21	0	30	70
22	55	45	0
23	40	45	15
24	25	45	30
25	10	45	45
26	0	45	55
27	40	60	0
28	25	60	15
29	10	60	30
30	0	60	40

Each particular row of k-values "seeds" a new ranking of the utility's compliance options. Within the context of a single ranking, several compliance plans could be developed. Round I of the selection process was described earlier: basically, the top options are picked until an option has been chosen for every unit. Anytime that STARRSS encounters an option for a generating unit that has already been addressed by a previously selected option, the program will skip the new option. Obviously, this is justified by the fact that the "challenger" (i.e., the new option) has a less favorable M-factor than the "incumbent" (i.e., the already-selected option). However, the M-factor is not the ultimate measure of optimality; it is merely a mathematical construct for temporarily ranking compliance options, and a close face-off between



a challenger and an incumbent may be worth investigating further. Bumping the incumbent and replacing it with the challenger could actually produce a better compliance strategy. For this reason, five "rounds" will be performed for each ranking. After developing the list of compliance options from the "master" ranking, STARRSS will search for any challenger option that has an M-factor that is close to an incumbent's (less than 5% higher, to begin with). If it finds such a challenger, STARRSS will replace the incumbent and thereby create a new compliance strategy. STARRSS then returns to the master strategy again to investigate other swaps. This swapping arrangement will continue until another four variations on the original compliance strategy are developed. If STARRSS gets to the bottom of the list before it has developed five variant strategies, the cut-off percentage is doubled, and STARRSS returns to the top of the list to continue the process.

A variant of this multiple-rounds process (where marginally higher M-factor options can replace incumbents) is used to solve the non-compliance problem; this situation occurs when STARRSS reaches the bottom of the ranking before it achieves compliance. The rankings that put very little emphasis on an option's impact (focusing instead on \$/ton) can result in a strategy of completely low-impact options that will not bring the utility into compliance. In this case, a modified round is performed, where a challenger is assessed not only on its M-factor (and how it compares to the incumbent) but also on how much additional impact (in tons of SO<sub>2</sub> reduction) that it achieves relative to the incumbent. Since the solution to this problem involves finding more tons, challengers that provide less impact are skipped immediately. During this modified round, the challenger-incumbent M-factor percentage is allowed to rise until enough challengers with positive impact contributions have bumped their incumbents and covered the shortfall.

All compliance strategies that are developed within the Main Algorithm and which at a minimum meet the utility's compliance requirements are stored in a single list. The present value of the total cost of each strategy is calculated before it is put on the list. This cost is merely the summation of each selected compliance option's cost (\$/ton x tons reduced), minus the linkage benefits between any selected options, plus the revenue or minus the cost of any allowance transactions required to bring the strategy into compliance. If the master list grows too large during the heuristic process (more than 255), the strategies that have the highest costs are dropped from the list. At this point, each strategy is passed to the Market Algorithm for possible improvements.

### **Market Algorithm**

The Market Algorithm takes the individual compliance strategies that are produced by the Main Algorithm and explores ways in which the total cost of compliance can be reduced through economically beneficial allowance transactions. STARRSS will first remove any uneconomical allowance sales by removing options from the strategy whose unitized costs (\$/ton) are higher than the levelized sale price of allowances. After exhausting options which cost more per ton

than allowances, STARRSS will examine the list of "unused" compliance options for possible additions to the strategy's portfolio; if the selling price of allowances is higher than the cost of one or more of these options, STARRSS will add these options to the strategy, sell the excess allowances at a profit, and reduce the overall cost of compliance.

Specifically, the Market Algorithm will function in the following manner. First, the compliance strategy's options are ranked in ascending order according to their unitized costs. STARRSS begins by temporarily removing the most expensive option and replacing it with allowances. If the cost of the strategy decreases, STARRSS drops the option from the strategy. The program works its way up the list towards cheaper options until it finds an option which it is not economical to drop.

At this point the Market Algorithm prepares to add compliance options to the strategy by sorting the list of "unused" options, again according to unitized cost. Starting with the cheapest item on this list, and moving towards the most expensive, STARRSS will compare the cost of the strategy with and without each option, and add the option to the strategy if the increased allowance sales (or reduction in allowance purchases) can economically justify it. When it reaches the first option whose inclusion would not reduce the cost of the strategy, the option is not added to the strategy, and the strategy is inserted into a final list of strategies to be passed on to the evaluator. The length of this list is determined by the *Number of Strategies to be Evaluated/Saved* data item on the *Develop STARRSS Strategies* screen.

#### **Allowance Trading Limits and Option Cost Irregularities**

The costs of strategies and options used internally in both heuristic processes described above are modified somewhat to handle special situations. If a strategy considered at any point would involve buying more allowances than the limit set by the user, the excess allowances are automatically priced at a million dollars per ton. This circumvents cumbersome and inappropriate program logic that would discard compliance strategies that marginally violate the allowance purchase constraint. As it stands, the internal costs for strategies that significantly violate that limit become very high, and those strategies are inevitably discarded. Similarly, allowance sales beyond the user-specified limit are priced at zero dollars per ton. This discourages STARRSS from continuing to consider more and more options to overcontrol emissions for the purpose of allowance sales that exceed the allowance sales constraint.

Finally, compliance options with zero or negative impact and positive cost are assigned extremely high M-factor values (to discourage their selection), and options with positive impact and negative cost are assigned extremely low negative M-factor values (to encourage their selection). The user should note that **these special cost calculations are never reflected in the reported costs**. They are used internally by the heuristics and discarded before the final list of strategies that have been developed are submitted to the evaluator for analysis.

## 10.0 CUSTOMIZED DATABASES

STARRSS is delivered to all government agencies with one customized database for each utility that comes under that agency's jurisdiction. The set of delivered databases will also include complete databases for any multi-state holding companies and power pools to which individual operating companies under the agency's jurisdiction belong. Deliveries to utilities will include each recipient's specific database. Deliveries to all other organizations will include a "generic" database.

### DISCLAIMER

**THESE DATABASES ARE MEANT TO PROVIDE USERS WITH A HELPFUL STARTING POINT FOR MODELLING SPECIFIC UTILITIES. HOWEVER, ALL OF THE VALUES IN THE DATABASES MUST BE CHECKED FOR ACCURACY. NEITHER EPA NOR RCG/HAGLER, BAILLY IN ANY WAY GUARANTEES THE VALIDITY OR ACCURACY OF THE INFORMATION.**

Although some of the information in STARRSS can be reliably estimated from historical data (such as unit capacities, allocated allowances, etc.), much of the STARRSS input data involves forecasts that the user must develop (e.g., allowance price forecasts, fuel price forecasts, etc.).

For many of these data items, illustrative values have been entered into the delivered databases solely for the purpose of helping the user become acquainted with the system, and allowing the user to run the program immediately upon delivery. Had these inputs been left at zero, executing the program would have produced nonsensical results.

As mentioned above, the user should verify all information in the delivered databases. To prioritize which information most needs checking and modification, the inputs in these databases are divided into two categories: 1) forecasts that use illustrative values (and therefore should be changed immediately), and 2) historical information that came from published sources. The remainder of this chapter clarifies which data entries are purely illustrative and which are from published sources.

All inputs in the delivered utility-specific databases cover only the Medium Forecast (with an associated low/medium/high probability distribution of 0%/100%/0%). No ranges or probabilities are predicted for any of the data items. Such an arrangement fails to take advantage of STARRSS' multi-scenario analysis features. **The user is therefore encouraged to develop ranges and to input low, medium, and high forecasts for as many data items as possible, thereby capturing the benefits of STARRSS' multi-scenario methodology.**

## 10.1 ILLUSTRATIVE DATA

The following is a list of STARRSS data inputs for which no attempt was made to produce or predict accurate information. The values listed are the illustrative values entered in the databases. **These are not suggested values. They should be changed to reflect the specific circumstances of the utility being modelled.** Table 10-1 shows the data inputs for which the user will need to develop specific forecasts.

**Table 10-1. STARRSS Data Items Containing Illustrative Values**

DATA ITEM	ILLUSTRATIVE VALUE(S)
Allowance Price Forecasts Purchase Price (1995) Sale Price (1995)	\$500 (escalated at 5%) \$400 (escalated at 5%)
Utility Marginal Energy Costs (1992) Utility Marginal Capacity Costs (1992)	\$50/MWH (escalated at 5%) \$100/kW (escalated at 5%)
Utility Cost of Capital Utility Return on Equity Equity Percent of Capital	10% 12% 50%
Escalation Rates Capital Costs Variable O&M Costs Fixed O&M Costs	5% 5% 5%
Effective Tax Rate	34%

## 10.2 PUBLISHED HISTORICAL INFORMATION

Each delivered database has been customized with information pertaining to a specific utility. All of the unit-specific information in the delivered databases has been drawn from published sources of historical information. The majority of the data was extracted from reference 2 (hereafter referred to as "the CQF Report"), reference 3 (hereafter referred to as the "NADB"), and reference 4 (hereafter referred to as "the UDI Report"). These sources provide estimates of unit operating characteristics, fuels, and allowance allocations.

### 10.2.1 Unit Information

STARRSS Version 1 delivered databases of operating utilities, holding companies, or power pools include only those units within the system affected by the Clean Air Act (ie. those units which receive allowances). Table 10-3, at the end of this chapter, shows the units included in each of the databases for this STARRSS delivery. This section lists the data items defined for units in these databases, and describes the data sources and methods used to derive the information.

- ▶ Unit Name and Number: The unit name and number label was altered from the NADB label to fit a 10-character field.
- ▶ Capacity (MW): The values entered for capacity represent the unit's 1989 summer net dependable capacity as provided by NADB.
- ▶ Heat Rate: The values entered for heat rate represent the unit's 1989 generator full load heat rate (in Btu/kWh) as provided by NADB.
- ▶ Variable Operation & Maintenance Costs: The UDI report lists Variable O&M costs for all of the major coal-fired U.S. plants. Not all coal-fired plants had this information available, however. Variable O&M costs were given at the plant level only, and do not account for differences between units that may result from differing ages or the presence of pollution control equipment. UDI presented the 1990 variable O&M costs, which were escalated to 1992 dollars using the General Purpose Machinery and Equipment category of the Producer Price Index (U.S. Bureau of Labor Statistics, March, 1992).
- ▶ Capacity Factors: Where possible, unit capacity factors reported in the UDI report were used in STARRSS. For units not covered in the UDI report, capacity factors were calculated by dividing the baseline heat input by the potential heat input (calculated from NADB), yielding an average capacity factor for the years 1985-1987. Any estimated capacity factor exceeding 90% was reset

to 90%. Table 10-6 at the end of this chapter lists the units in the delivered database whose capacity factors were calculated using information from NADB.

- ▶ Fuel Used: The fuel information was compiled by cross-referencing historical information contained in the UDI and CQF reports. Price forecast information comes from EIA macroeconomic forecasts for the next 20 years. The derivation of fuel price and sulfur content will be explained in greater detail in the next section.
- ▶ Flue Gas Desulfurization Efficiency: Historic FGD SO<sub>2</sub> removal efficiency information from the UDI report was included for those affected units with pre-existing FGD equipment.
- ▶ Baseline Heat: The values entered for baseline heat represent the boiler-generator average total heat input for the years 1985-1987 (in Trillion Btus) as provided by NADB.
- ▶ Phase I Allowances: Phase I allowance calculations are relatively straightforward. Table A of section 404 of the Clean Air Act Amendments of 1990 (Title IV) gives the basic allowance allocation for units at 110 generating facilities. These allowance allocations are adjusted by the creation of the 2.8% EPA Allowance Sales and Auction Reserve. In addition, Section 404(a)(3) allocates 200,000 Phase I allowances on a pro rata basis to units in Ohio, Illinois, and Indiana. The calculation of Phase I allowance allocations for units included in the delivered databases is shown in Table 10-4, at the end of this chapter (note that units are listed according to their holding company affiliation; Table 10-2 lists utility holding companies and their operating subsidiaries).
- ▶ Phase II Allowances: Phase II allocations are somewhat more complex. After basic allowances are assigned according to the provisions of section 404 (according to the category each affected unit falls in) adjustments are made to account for the following factors:
  - The ratchet factor necessary to achieve the 8.9 million ton national emissions cap;
  - Bonus allowances allowing qualified units to run at a 60% capacity factor (total bonus pool ratcheted to 530K);
  - Withholding of allowances for the Conservation and Repowering Reserve;
  - Withholding of allowances for the EPA Sales and Auction Reserve;

and,

- Addition of miscellaneous bonus allowances to qualifying units (e.g. units in "clean" states, selected units in ten states with high reduction obligations, etc.).

STARRSS Version 1 databases include allowance allocations for units through the year 2009. Allowance allocations change slightly after that year, as several bonus pools and reserves expire. Furthermore, allowances in STARRSS are allocated by generating unit rather than by boiler. This will result in no change in allocation for units with a one-to-one boiler-generator configuration. For multi-header boilers, STARRSS assigns allowances to each generator by multiplying the total number of allowances assigned to the multi-header configuration by the generator's share of the multi-header configuration's total capacity. This results in no net change in overall allowance allocations, although some allocations may appear different from available data which lists allowance allocations by boiler. The precise calculation of allowance allocations (by boiler) for units included in this database delivery is given in Table 10-5, at the end of this chapter (note that units are listed according to their holding company affiliation; Table 10-2 lists utility holding companies and their operating subsidiaries).

Finally, for utility systems with a partial interest in jointly-owned units, several unit characteristics were pro-rated according to percentage ownership, as given in the UDI report. Pro-rated characteristics include the capacity, baseline heat, Phase I allowances, and Phase II allowances. For example, if a utility system owned 10% of a 900MW unit with a baseline of 10 trillion Btus, and 2000 Phase II allowances, it would show up on the STARRSS affected unit list as a 90MW unit with a baseline of a trillion Btus and 200 Phase II allowances. Although it makes sense to assume that a utility with a 10% share of a unit controls 10% of the unit's allowances, this may not necessarily hold true, and should be verified to the extent possible.

#### **10.2.2 Fuel Information**

Included in each STARRSS database is fuel information defined for each unit. **Of all of the historical, unit-related information contained in the STARRSS delivered databases, this is the most subject to error, and must therefore be scrutinized closely.** The fuel price and emissions rate information was drawn primarily from the Department of Energy/Energy Information Administration's Cost and Quality of Fuels for Electric Utility Plants - 1990 (CQF). Information from U.S. Coal Plant Statistics 1990 (UDI) was also used. The fuels defined in delivered databases represent preliminary information indicating the types of fuels burned at units within the system and historical cost information. The basic process employed was to:

- 1) assess the sulfur content of fuels by examining the fuel or multiple fuels that were delivered to each affected plant during 1990;
- 2) examine and report the spot price of this fuel or fuel blend in 1990; and,
- 3) apply the EIA fuel price forecast escalation rates to derive 20-year fuel price forecasts.<sup>1</sup>

Section 8.2.3 will outline the process used to derive the fuel quality information, Section 8.2.4 will describe the sources used for fuel price information, and Section 8.2.5 will suggest a research design for incorporating more accurate fuel information.

## Fuel Sulfur Content

### Coal

The "Origin of Coal Received by Company and Plant" table (Table 36) of the CQF report lists the origin and quality of coals received at every coal-fired plant in the United States in 1990. The UDI report devotes a table ("Table 1: Age & Status of U.S. Coal-Fired Units by NERC Region") to the current status of coal-fired units, which includes the 1990 average sulfur content of the boiler fuel. By cross-referencing these tables, a profile of the quality of fuel burned at each unit could be derived. In particular, cross-referencing the UDI and CQF reports revealed whether different units within a given plant burned the same coal, the same coal blend, or different coals during 1990.

Calculation of fuel burn emission rate (in lbs. SO<sub>2</sub>/MBtu) depends on three pieces of information: coal heat content (in Btus/lb. coal), coal sulfur content (by percent weight), and the conversion factor for sulfur to sulfur dioxide (2 lbs. SO<sub>2</sub>/lb. Sulfur).<sup>2</sup>

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<sup>1</sup> The same set of escalators were used for all coals, regardless of regional or other differences. Different forecast escalators were used for oil and natural gas.

<sup>2</sup> The calculation proceeds as follows:

$$1/(\text{Heat Content}) * (\text{Sulfur Content \%})/100 * 2 * 10^6 = \text{Emission Rate (lbs./MBtu)}$$

The conversion factor of two assumes that virtually all of the coal's elemental sulfur is oxidized to SO<sub>2</sub> during combustion. The 10<sup>6</sup> factor simply converts Btus to MBtus. Combining all of the constants leads to the following simplified equation:

$$20,000/(\text{Heat Content}) * (\text{Sulfur Content \%}) = \text{Emission Rate (lbs./MBtu)}$$

where 20,000 = 2 \* 10<sup>6</sup>/100. This equation was used to calculate emission rates from the information provided by the CQF report.



In many instances, units burn a blend of fuels rather than a single fuel. The delivered databases, however, do not define fuel blends; instead, fuel blends are reported as a single fuel with aggregate fuel quality and price. Furthermore, in some cases, an analysis of the CQF report indicated that fuel blends at some units included only a subset of all the fuels received at the plant. In these cases, the average sulfur content reported in the UDI report was used as a benchmark to infer which of the received coal types were most likely blended. Based on this determination, a weighted average heat content, sulfur content, and delivered cost was calculated for the fuel blend. Again, these estimates only partially capture the actual fuel situation utilities face for the affected units on their systems.

The fuel names or labels used in the delivered databases are designated according to the plant burning the fuel, and the fuel burn emission rate. For example, a fuel label might read "BIGCOAL-MS". This label denotes a medium sulfur coal burned at the "BIG COAL" plant. For fuel labelling purposes, the following ranges were used to designate a coal as low, medium-, or high-sulfur:

<u>Fuel Type</u>	<u>Emission Rate (lbs./MBtu)</u>
Low Sulfur (LS)	less than 1.2
Medium Sulfur (MS)	1.2 - 2.5
High Sulfur (HS)	greater than 2.5

In addition, where space permitted, a designator indicating the fuel's state of origin was included in the label. A fuel label of this type might read "BCOALMS-AL", signifying a medium sulfur coal from Alabama burned at the "BIG COAL" plant. Naturally, the user is free to adopt his/her own labelling conventions in the process of defining fuels.

## Oil

For units burning significant amounts of oil during 1990, price and quality information from Table 43 ("Quantity, Average Delivered Cost, and Quality of Fossil-Fuel Receipts by Company and Plant") of the CQF report served as the reference for the quality of petroleum burned at the unit. The fuel burn emission rate was calculated in a similar fashion to that described for coal.<sup>3</sup>

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<sup>3</sup> Oil heat and sulfur content is not as conveniently reported as it is for coal. The average heat content of oils were calculated using cost information provided in cents/MBtu and \$/Bbl as follows:

$$1/(\text{Btu Cost}) * (\text{Barrel Cost}) * 100 = \text{Heat Content (MBtu/Bbl)}$$

Using conversion rate of 42 gallons/Bbl and 5.8 lbs/gallon, along with sulfur content by weight reported in the CQF report allowed the derivation of oil burn emission rate, in lbs SO<sub>2</sub>/MBtu.

The fuel labelling convention for oil indicates the fuel and the plant at which the fuel was burned. For example, an oil-burning unit might have a fuel label reading "OIL-SMLLOIL", indicating an oil burned at the "SMALL OIL" unit.

### **Natural Gas**

As with oil, Table 43 of the CQF report was used to determine whether or not a significant amount of natural gas was burned at a particular unit. The SO<sub>2</sub> emission rate for natural gas was assumed to be zero for STARRSS analysis purposes, so no derivation of fuel quality was necessary.

The fuel labelling convention for natural gas indicates the fuel and the plant at which the fuel was burned. For example, a natural gas-burning unit might have a fuel label reading "GAS-TURBN1", indicating natural gas burned at the "TURBINE 1" unit. Note that many gas burning units also burn significant quantities of oil. STARRSS delivered databases do not reflect this common situation.

### **"Current" Fuel Prices**

The "Receipts and Average Delivered Cost of Coal by Type of Purchase, Company, and Plant" table (Table 42) of the CQF report lists the aggregate delivered cost of spot and contract coal on a plant-by-plant basis in 1990. Since contract prices may reflect negotiated agreements from five or ten years ago (when coal prices were much higher), the contract deliveries were not considered to be representative of the current or projected market. Therefore, where possible, the spot price of coal delivered to a plant was used to denote the current fuel cost (1992).<sup>4</sup> However, in some cases, plants made no spot purchases, or made small spot purchases unrepresentative of the fuel burned at the plant. In these cases, the average contract price was used instead of the spot price. For units burning a subset of the aggregate fuels, the spot price, contract price, and the average delivered cost for the specific fuel (or fuel blend) burned at the unit were compared to determine the most representative price for the fuel.

For oil and natural gas, the average delivered cost reported in Table 43 of the CQF report was used for the fuel cost at units burning oil or natural gas. Again, for units burning both oil and natural gas, only one fuel was defined; the user will need to define blends of oil and natural gas where appropriate.

While fuel prices currently input in the STARRSS databases will allow the user to run STARRSS and to conduct preliminary screening exercises, the usefulness of these prices is extremely limited in a formal evaluation of a utility's compliance plan. In particular, historical

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<sup>4</sup> As spot coal prices have not changed much between 1990 and 1992, the 1990 CQF values were not inflated or otherwise adjusted.

prices from a single year cannot capture the contract situation a utility faces for a given plant or unit. Whether the 1990 price for coal at a unit reflects the beginning of a long-term contract or the expiration of a contract has significant consequences for a utility's evaluation of the economics of fuel switching or blending. The fuel contract situation of a unit also effects the long-run costs the utility faces when it implements compliance options that change the amount of fuel consumed at that unit. Furthermore, for units burning petroleum, 1990 prices were influenced by singular events (ie. Iraq's seizure of Kuwait). Therefore, a fuel price forecast based on a single-year analysis of average spot prices or delivered costs may significantly distort the costs of any compliance option that changes a unit's fuel consumption.

### Fuel Price Growth Rates

The STARRSS data inputs include separate national fuel price growth rates for coal, oil, or natural gas. These price projections come from DOE/EIA's Annual Outlook for U.S. Electric Power, 1991: Projections Through 2010 (July 1991). These price projections make no distinction between regions of the country or between fuel qualities.

#### 10.2.3 Research Recommendations

The user should acquire more detailed information to accurately portray the fuel situation and options of a utility plant or unit. This information may include:

- ▶ volume, quality, F.O.B. mine price and transportation costs of spot coal purchases;
- ▶ volume, quality, F.O.B. mine price and transportation costs of contract coal purchases;
- ▶ details of current coal contracts, including:
  - expiration date;
  - price escalation methodology (or expectations of future price escalation) and,
  - market price reopener provisions; and
- ▶ volume, quality, F.O.B. mine price and transportation costs of alternative coal supply options being considered by the utility for future coal supplies (spot and contract).

Use of these data items should put the user in a good position to model both the utility's current fuel situation and the economic basis for fuel-based compliance activities.

Note that even if the same coal is burned at several plants within a utility system, the delivered price for that coal will vary depending on the cost of transportation to each plant, and market

conditions prevailing at the time each coal contract was entered into. Coals must therefore be modelled on a plant-by-plant basis.

Finally, for a STARRSS analysis, if the user knows he/she will not define a compliance option for a particular unit, the user need not obtain more accurate fuel price information for that unit, although the user must still verify fuel sulfur content information. Because STARRSS models compliance costs on an incremental basis, accurate prices are not necessary if they will not be compared to costs for new fuels. However, STARRSS will still need to know the affected unit's emissions (and therefore fuel quality) to determine the overall system SO<sub>2</sub> reduction obligation.

### 10.3 TABLES: DELIVERED DATABASE INFORMATION

The following tables are samples of customized tables that are included in a formalized delivery of STARRSS. Each direct recipient of STARRSS (e.g., state regulatory commissions) receives a set of customized tables that contain information for all of the databases that are included in the recipient's delivery.

#### SAMPLE TABLES

**Table 10-2. Holding Company and Operating Utility Systems Included in STARRSS Delivered Databases.**

#### Sulfur Power & Light Company

**Table 10-3. Units Included in STARRSS Delivered Databases.**

#### SULFUR POWER & LIGHT

Unit Name	Capacity (MW)	Heat Rate	Baseline	Calculated	Allowances	
			Heat (TBTUs)	SO <sub>2</sub> Emis. (tons)	PhaseI	PhaseII
BIGCOAL 1	650.0	10000	26.700	75293	36500	14000
BIGCOAL 2	650.0	10000	27.300	84761	37000	14500
MEDCOAL 1	350.0	10500	32.320	44656	44000	17500
MEDCOAL 2	350.0	10600	32.800	46244	44500	18000
MEDCOAL 3	350.0	10400	32.860	44424	45000	18000
MEDCOAL 4	350.0	10400	32.260	7984	0	17500
SMALLOIL 1	50.0	13800	0.370	77	0	200
SMALLOIL 2	50.0	13600	0.640	115	0	330
SMALLOIL 3	80.0	13500	1.040	171	0	600

**Table 10-4. Phase I Allowance Calculations for Units in Delivered Databases.**

Plant Name	Boiler Number	Gen. Number	Basic Phase I	Sec. 404 Additions	Total Phase I	EPA 2.8% Reserve	Final Phase I
SULFUR POWER & LIGHT BIGCOAL	1	1	37522	0	37522	1022	36500

**Table 10-5. Phase II Allowance Calculations for Units in Delivered Databases.**

Plant Name	Boiler Number	Gen. Number	Basic Phase II	Ratcheted Phase II	Cons./Repower Adjustment	2.8% Sales/Auc. Adjustment	Sec. 405 Addition	Final Phase II
SULFUR POWER & LIGHT BIGCOAL	1	1	15985	14532	140	392	0	14000

**Table 10-6. Units in Delivered Databases For Which NADB Was Used to Calculate Capacity Factors.**

Plant Name	Number
SULFUR POWER & LIGHT BIGCOAL	2

**Table 10-7. Jointly-owned Units Appearing in Delivered Databases.**

Plant Name and Unit Number	Ownership Percentage
SULFUR POWER & LIGHT BIGCOAL	2 50.00

## 11.0 DESCRIPTIONS OF COMPLIANCE OPTIONS

This chapter provides a rudimentary description of some of the many compliance options that are available to utilities as they develop Clean Air Act compliance strategies. Specifically, the chapter is divided into four basic sections:

- (1) Pollution Control Technologies
- (2) Fuel Switching
- (3) Conservation and
- (4) Other Compliance Activity

Although the majority of this chapter is dedicated to describing pollution control technologies, this does not mean technological options are more important or are preferable over the other options. It is simply that many of the other options are difficult to summarize in a general fashion. Typically, their cost-effectiveness and viability are very dependent on the specific utility or generating unit being analyzed. This is also the case with technological options, but more literature exists upon which to base general descriptions.

In the Pollution Control Technology section, each subsection describes the general process for each pollution control technology, the primary strengths and weaknesses utilities will consider for each process, and approximate cost and performance information. Because sulfur reducing technologies have evolved dramatically in the last few years, even these generic cost and performance parameters can only be broadly estimated. The site-specific nature of pollution control retrofits further complicates efforts to gauge compliance option costs. Nevertheless, this chapter attempts to provide a range of information on which users can base their expectations for one set of common assumptions control costs and performance.

STARRSS users may develop more specific cost and performance estimates from other sources. For example, actual bids by pollution control equipment vendors could be used if available. Also, the Air and Energy Engineering Research Laboratory has published another PC compatible software system capable of producing more specific and reliable cost estimates for sulfur and SO<sub>2</sub> removal systems. This software, the Integrated Air Pollution Control System, Version 4.0, user's guide, technical documentation, and programmer's maintenance manual (EPA/600/7-90/022a,b,c, and d) can be obtained from the National Technical Information Service (specify PB91 506469) for \$80.00. Research is underway to update this software and documentation.

## **11.1 POLLUTION CONTROL TECHNOLOGIES**

Pollution control technologies may be divided into four broad categories which are discussed in the following sections:

- ▶ Precombustion Coal Treatment will discuss general cost and removal information for physical and chemical coal cleaning options (page 206);
- ▶ Combustion Treatment will review the most popular repowering and boiler SO<sub>2</sub> removal technologies, and discuss their relative strengths and weaknesses (pages 207 through 209). Technologies reviewed include:
  - Atmospheric Fluidized Bed Combustion (AFBC)
  - Pressurized Fluidized Bed Combustion (PFBC)
  - Integrated Gasification Combined Cycle (IGCC)
  - Furnace Sorbent Injection (FSI)
- ▶ Flue Gas Desulfurization (scrubbing or FGD), will review and provide cost information and relative strengths and weaknesses for a variety of FGD processes (pages 209 through 226); and,
- ▶ Reagent Additives, will discuss additives commonly used in conjunction with FGD systems to improve removal efficiency (pages 226 through 227). Reagent additives reviewed include:
  - Dibasic Acid (DBA)
  - Thiosulfate

Precombustion coal treatment involves either washing or chemical treatment of coal to remove sulfur. Combustion options modify the design of the boiler to improve SO<sub>2</sub> removal efficiency. In some cases, combustion options also improve the efficiency and reliability of the boiler. FGD uses sodium- or calcium-based reagents to remove SO<sub>2</sub> from post combustion flue gases, while fuel switching often involves modifications to boilers and/or coal handling equipment to permit burning a lower sulfur fuel.

Coal cleaning falls into two categories: physical coal washing and chemical coal cleaning. The low cost of physical coal washing makes it an attractive option, although sulfur removal efficiency also tends to be low. Chemical coal cleaning processes aim to remove greater amounts of sulfur, but none of the processes has yet proven cost-effective. Development of commercially viable chemical cleaning processes is likely to be five to ten years away.

Combustion treatment options use a variety of combustion processes, often combined with calcium-based reagents directly in the furnace, to reduce SO<sub>2</sub> emissions from the coal

combustion gases. Except for FSI and new duct sorbent injection techniques now under development (not discussed herein), the high capital costs of boiler retrofits for combustion options renders them non-competitive with other SO<sub>2</sub> removal processes. There are, however, benefits to combustion options aside from SO<sub>2</sub> control; improved boiler efficiency and improved reliability keep the cost of power at modified boilers lower than conventional systems with pollution control retrofits. As a result, utilities have utilized combustion options mainly with boilers at or near retirement, where the largest efficiency gains could be realized.

The maturing of flue gas desulfurization technologies has led to a variety of control options which have a fairly similar range of overall control costs. The most appropriate FGD option or set of options for a utility system will depend on site-specific factors associated with retrofitting its units and the amount of SO<sub>2</sub> reduction the system needs to achieve to ensure continuous compliance. Other factors ranging from the supply and cost of reagents to the volatility of SO<sub>2</sub> allowance prices may also affect the utility's choice of FGD technologies.

Boiler retrofits for fuel switching carry considerably lower capital costs but more variation in costs from unit to unit. In some cases, no boiler modifications are needed for fuel switching. In general, initial concerns about the high volatility and moisture of low-sulfur western coals have diminished, reducing capital cost estimates for boiler retrofits to accommodate even these coals. The cost differential between fuels under consideration plays a much larger role in determining the economic viability of a fuel switch than capital costs associated with boiler modifications. Section 11.2 will discuss the economics of fuel-switching in greater detail.

#### **11.1.1 Precombustion Coal Cleaning**

##### **Physical Coal Cleaning**

During physical coal cleaning raw coal is tumbled, screened, and sorted into size classifications. Each size of coal in water is further acted upon by vibrating tables or froth flotation cells to physically separate pyritic sulfur bearing rock, shale, and other impurities from the coal. Although physical coal cleaning is a relatively inexpensive means of sulfur reduction, costs can vary considerably. The economics of physical coal cleaning tend to be plant and coal seam specific and coal seam. Washing coal with less than 1% sulfur content (by weight) is generally impractical. Capital costs for coal cleaning can range from 10-30 \$/kW, fixed O&M costs can vary from 0.6-6 \$M/yr, depending on the size of the plant, and variable O&M costs can range from 0.75-1 \$/MWh. Typical SO<sub>2</sub> removal efficiency ranges from 10-30%.



## **Chemical Coal Cleaning**

Most chemical coal cleaning efforts have used chemical reagents in a tub of pulverized coal. The reagents react with both organic and inorganic sulfur, and the mix is centrifuged to separate the coal from its impurities. These methods have proven costly, and none have been demonstrated commercially.

In perhaps the most promising precombustion method for coal cleaning, ethanol and ethanol vapors decompose and bind to coal, reacting with organic and inorganic sulfur in the coal. The by-products, elemental sulfur and acetaldehyde, are commercially saleable. The end product is a finely pulverized low sulfur coal that can be used directly in boilers (see, for example, *Compliance Strategies Review*, 3 February 1992). Initial estimates suggest that the 90% sulfur removal can be achieved at low cost using this process. Ohio researchers are seeking funding for a demonstration facility that would apply this process, but it has not yet seen demonstration or commercial use.

### **11.1.2 Combustion SO<sub>2</sub> Reduction Technologies**

This section will describe briefly three common combustion technologies that utilities may consider for Phase I or Phase II compliance. Two of these technologies involve extensive boiler retrofits, or repowering; in addition to improvements in unit efficiency, combustion technologies that repower an existing boiler may qualify the utility for bonus allowances from EPA and an extension in the unit's compliance deadline.

Combustion options treat coal directly in the unit boiler to reduce SO<sub>2</sub> emissions. In addition to SO<sub>2</sub> control, combustion options can provide other benefits: improved unit capacity, improved unit heat rate, and a high level of NO<sub>x</sub> reduction. Although retrofitting a boiler with a combustion technology tends to be much more expensive on a per kW basis than flue gas desulfurization options, the other benefits of improved efficiency and unit dispatch may offset the increased cost, particularly if the retrofit takes place at an older, less efficient boiler that the utility is considering for retirement. Many combustion options are eligible for funding through the Department of Energy's Clean Coal Technology program, further offsetting costs to the utility. For new facilities, combustion technologies and flue gas desulfurization technologies are estimated to be cost-competitive on a \$/kW basis.

### **Atmospheric Fluidized Bed Combustion**

Atmospheric Fluidized Bed Combustion (AFBC) injects powdered coal and limestone together into the boiler. Air pressure from combustion creates a "fluidized bed," in which the limestone reacts with SO<sub>2</sub> directly in the furnace. The waste by-product is a relatively stable calcium sulfate powder. Because AFBC uses low combustion temperatures, the process inhibits NO<sub>x</sub> formation. The process achieves SO<sub>2</sub> removal in the range of 90-95%, and NO<sub>x</sub> emission reduction of approximately 70-90%. Primary disadvantages to the AFBC

process include: high volume of waste production caused by high molar ratio of calcium to sulfur, and possible upgrades to electrostatic precipitators and fabric filters to accommodate increased ash and dust loading. Improvements in rated capacity and/or heat rate are boiler-specific.

### **Pressurized Fluidized Bed Combustion**

The Pressurized Fluidized Bed Combustion process (PFBC) represents an advanced AFBC process that economizes on unit size and waste disposal requirements. The advance features allow PFBC to operate at higher pressures, which improve efficiency and reduce the amount of reagent needed to achieve pollutant removal (relative to AFBC). PFBC carries somewhat higher capital costs than AFBC but can achieve greater improvements in the boiler's capacity, particularly if the boiler is near retirement. Utilities consider PFBC most appropriate as a repowering technology for older boilers.

### **Integrated Gasification Combined Cycle**

The Integrated Gasification Combined Cycle (IGCC) process gasifies the coal in a reactor. The gasified coal is then combusted in a gas turbine which powers an electric generator directly. The steam boiler can be used for recovery of heat from the gas turbine exhaust and deliver supplemental power through a steam turbine. IGCC achieves an SO<sub>2</sub> removal efficiency exceeding 95% and NO<sub>x</sub> reduction exceeding 90%. In some cases, IGCC substantially improves the capacity of the retrofitted boiler. The cost of retrofitting the gasification facility makes IGCC the most capital-intensive commercially viable repowering option.

### **Furnace Sorbent Injection**

Furnace sorbent injection uses powdered limestone (or other calcium-based sorbent) injected directly into the furnace. The limestone is calcined to calcium oxide, which then reacts with SO<sub>2</sub> and combustion air oxygen to form calcium sulfate. Furnace sorbent injection requires only limited boiler modifications, keeping capital costs low. The process is not therefore considered to be a "repowering" technology such as AFBC or IGCC. Table 11-1 (below) outlines the strengths and weaknesses of furnace sorbent injection, relative to flue gas desulfurization technologies (against which it is often compared). Although many power plants in Europe use furnace sorbent injection, only a few boilers in the United States have used the process, and then only at a demonstration scale (B&V, 1991).

**Table 11-1. Furnace Sorbent Injection strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Low capital cost	Low SO <sub>2</sub> removal efficiency
Low waste handling costs	Increased dust loading
	Limited domestic experience
Important Factors: The increase in dust loading associated with the furnace sorbent injection process may require a replacement or upgrade of the unit's electrostatic precipitator, resulting in increased capital costs. For retrofit cost assumptions, see Table 11-3 and discussion (page 210).	

**Table 11-2. Furnace Sorbent Injection Cost Ranges<sup>1</sup>**

Capital Costs (\$/kW):	50 - 85
Fixed O&M Costs (\$/yr):	2.9 - 7.5
Variable O&M Costs (\$/MWh):	1.65 - 4.15
SO <sub>2</sub> Removal Efficiency (%):	50 - 60

### **11.1.3 Flue Gas Desulfurization Technologies**

The following section describes most of the FGD technologies utilities might consider during compliance planning. The section discusses each technology, describing the general process, listing strengths and weaknesses, and supplying ranges for costs the user may wish to use in developing compliance options for modelling in STARRSS.

<sup>1</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

As noted previously, the cost information is presented in broad ranges that attempt to capture most of the potential variability in FGD costs for typical medium-sized utility boilers. These cost estimates are based on an iterative risk analysis using baseline data from several studies of FGD technologies conducted by the Electric Power Research Institute (EPRI). All monetary values given represent 1992 dollars. Table 11-3 presents some typical values for parameters used in these type of analyses.

**Table 11-3. Parameters Used to Develop FGD Cost Estimates**

<b>PARAMETER</b>	<b>VALUE (RANGE)</b>
Plant Size (MW)	300
Plant Retrofit Factor	1.0
Plant Capacity Factor (%)	60 - 70
Plant Heat Rate (Btu/kWh)	9,500 - 10,500
Coal Higher Heating Value (Btu/lb)	10,000 - 11,500
Coal Sulfur Content by Weight (%)	2.0 - 3.2

Other values for these parameters will considerably alter the costs presented herein. Note that a retrofit factor of 1.0 was used to develop these cost estimates, reflecting essentially the cost of a new unit with a new power plant. This convention allows these cost estimates to be easily integrated with existing plant retrofit factors to provide a reasonable plant-specific range of cost estimates. Most available cost estimating studies present costs for a "typical" power plant with a "moderate" retrofit factor ranging from 1.3 to 1.6.

#### **Conventional Limestone**

In the conventional limestone scrubbing process, a limestone slurry circulates through a spray tower to absorb SO<sub>2</sub> and form a calcium sulfite/sulfate sludge. This process has fairly widespread commercial application in the United States. In addition, the process uses a cheap and abundant reagent, pulverized limestone (EPRI, 1984).

**Table 11-4. Conventional Limestone strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Use of abundant reagent	High power consumption
Extensive experience with process	High volume of waste
Used on a wide variety of coals	
<hr/>	
Important Factors:	Utilities have more experience with the conventional limestone process than with any other FGD system; therefore, subsequent discussions of the strengths and weaknesses of various FGD systems will use the conventional limestone FGD process as the basis for comparison.

**Table 11-5. Conventional Limestone Cost Ranges<sup>2</sup>**

Capital Costs (\$/kW):	135 - 220
Fixed O&M Costs (\$M/yr):	1.0 - 6.4
Variable O&M Costs (\$/MWh):	0.55 - 3.60
SO <sub>2</sub> Removal Efficiency (%):	90 - 92

#### **Limestone Forced Oxidation Without Gypsum Recovery**

The limestone/forced oxidation (LSFO) scrubber is a refinement of the conventional wet limestone scrubber. The LSFO process oxidizes the calcium sulfite/sulfate by-product to precipitate landfill gypsum from the reagent slurry that is discarded in landfill. The process has also demonstrated somewhat higher SO<sub>2</sub> removal rates than conventional limestone FGD systems (EPRI, 1984).

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<sup>2</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

**Table 11-6. Limestone Forced Oxidation strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Lower waste disposal costs	High power requirements
Used on a wide variety of coals	High volume of waste
Uses an abundant, low-cost reagent	
<hr/>	
Important Factors:	Because of LSFO's similarity to conventional FGD processes, utilities consider the risks associated with LSFO to be low. In addition, lower overall costs and higher SO <sub>2</sub> removal efficiency have made LSFO the most popular FGD technology to date for Phase I retrofits.

**Table 11-7. LSFO Cost Ranges<sup>3</sup>**

Capital Costs (\$/kW):	125 - 205
Fixed O&M Costs (\$M/yr):	1.4 - 7.1
Variable O&M Costs (\$/MWh):	0.75 - 3.95
SO <sub>2</sub> Removal Efficiency (%):	90 - 95

#### **Limestone Forced Oxidation With Gypsum Product Recovery**

Adding a "pre-scrubber" and auxiliary waste handling equipment to the LSFO scrubber described above produces commercial grade gypsum instead of gypsum waste. The pre-scrubber removes chlorine and other impurities that would otherwise end up in the gypsum by-product and degrade it (UE&C, 1991).

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<sup>3</sup> Cost estimates based on values from Radcliffe, "FGD Economics", *EPRI Journal*, December, 1990.

**Table 11-8. Limestone Forced Oxidation/by-product strengths and weaknesses**

STRENGTHS	WEAKNESSES
Use of abundant reagent	High power requirements
Reduced waste disposal costs	Higher capital costs
Produces marketable by-product	Need high level of control of impurities
Important factors: The economic viability of the gypsum production process depends on a readily accessible market for wallboard gypsum. The process may require ESP upgrades for improved dust control.	

**Table 11-9. LSFO/by-product Cost Ranges<sup>4</sup>**

Capital Costs (\$/kW):	130 - 215
Fixed O&M Costs (\$M/yr):	1.0 - 6.9
Variable O&M Costs (\$/MWh):	0.60 - 3.80
SO <sub>2</sub> Removal Efficiency (%):	90 - 95

**Saarberg-Hoelter (SHU)**

The SHU process uses a wet limestone and formic acid slurry reagent to achieve 90% removal of SO<sub>2</sub> from flue gases. The formic acid increases the degree of limestone utilization, and reduces lime and gypsum scaling. The waste product consists primarily of dewatered landfill gypsum. Developed in Germany, the process has not yet seen utility-scale application in the United States. Five units in Europe apply the SHU process, although none of the units burn high-sulfur coals of the kind typically used in the United States (B&V, 1991).

<sup>4</sup>Cost estimates based on values from Radcliffe, "FGD Economics," EPRI Journal, December, 1990.

**Table 11-10. Saarberg-Hoelter strengths and weaknesses**

STRENGTHS	WEAKNESSES
High reagent utilization	Higher cost of formic acid
Use of abundant reagent (limestone)	Little domestic experience
Lower waste disposal costs	Low pH causes corrosion problems
Important factors:	
Utilities have not applied the SHU process to high sulfur coals, so actual removal efficiency may be uncertain. The availability of formic acid in large quantities and at an economically feasible price may also be uncertain.	

**Table 11-11. Saarberg-Hoelter Cost Ranges**

Capital Costs (\$/kW):	Not Available
Fixed O&M Costs (\$M/yr):	Not Available
Variable O&M Costs (\$/MWh):	Not Available
SO <sub>2</sub> Removal Efficiency (%):	90 - 92

### **Chiyoda-121**

The Chiyoda scrubber uses a jet bubbling reactor to remove SO<sub>2</sub> and create commercial grade gypsum. As with the Limestone/gypsum product process, the Chiyoda process requires pre-scrubbing equipment to remove chlorine and residual fly ash that would otherwise degrade the gypsum product. The Chiyoda process has not been used commercially in the United States, although it has been used successfully in Japan. The Chiyoda process uses limestone more efficiently than conventional processes, and reduces capital and maintenance costs (EPRI, 1984).



**Table 11-12. Chiyoda-121 strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
High reagent utilization	Little domestic experience
Use of abundant reagent	
Produces saleable by-product	
<hr/>	
Important Factors: The Southern Company has successfully demonstrated the Chiyoda process, but it has not been implemented at a commercial scale facility.	

**Table 11-13. Chiyoda-121 Cost Ranges<sup>5</sup>**

Capital Costs (\$/kW):	125 - 205
Fixed O&M Costs (\$M/yr):	1.2 - 6.6
Variable O&M Costs (\$/MWh):	0.65 - 3.70
SO <sub>2</sub> Removal Efficiency (%):	90 - 92

#### **Pure Air**

The Advanced Flue Gas Desulfurization (AFGD) system proposed by Pure Air (a joint venture of Air Products and Chemicals, Inc., and Mitsubishi Heavy Industries America, Inc.) essentially uses a forced oxidation wet limestone FGD system and incorporates advanced design features to improve reliability and reduce capital costs. The Pure Air process uses pre-crushed limestone as the reagent, and a single absorber module to remove 90-95% of SO<sub>2</sub> from the flue gases. The high degree of reliability of the single absorber eliminates the need for a spare absorber, reducing capital costs. As part of DOE's Clean Coal Technology Program, Pure Air will demonstrate the AFGD process at Northern Indiana Public Service

<sup>5</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

Company's Bailly Station. A single absorber will clean the flue gases for a combined total of 528 MW, starting in 1995 (U.S. DOE, 1989).

**Table 11-14. Pure Air Advanced FGD strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
High reliability	Limited domestic experience
Lower O&M Costs	Higher reagent costs
Produces saleable by-product	
<b>Important Factors:</b> Currently, most FGD manufacturers promise to cut out the spare absorber from their systems, minimizing the capital cost advantage claimed by Pure Air. Higher reagent costs result from the need to pre-crush limestone; these costs may be negligible in some cases.	

**Table 11-15. Pure Air Advanced FGD Cost Ranges<sup>6</sup>**

Capital Costs (\$/kW):	110 - 175
Fixed O&M Costs (\$/yr):	1.6 - 6.6
Variable O&M Costs (\$/MWh):	0.90 - 3.65
SO <sub>2</sub> Removal Efficiency (%):	90 - 95

### **Lime**

Wet lime flue gas desulfurization systems use essentially the same process as limestone FGD systems. Using lime instead of limestone as the reagent provides several advantages,

<sup>6</sup> Cost estimates based on values from Radcliffe, "FGD Economics," EPRI Journal, December, 1990.

including: increased reagent utilization, higher SO<sub>2</sub> removal efficiency (92%-96%), and better turn-down capabilities. However, the significantly higher unit cost of lime largely offsets these advantages. Lime also has a greater tendency to scale. Utilities have extensive experience with lime FGD systems, making it a proven process (B&V, 1991).

**Table 11-16. Conventional Lime strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Extensive industry experience	High power consumption
High removal efficiency	Expensive reagent
Used with wide range of coals	Increased scaling
<b>Important Factors:</b> Lime FGD systems have slightly better removal efficiency than their limestone counterparts, although this advantage is offset by considerably higher costs; lime can cost 3-6 times as much as limestone.	

**Table 11-17. Conventional Lime Cost Ranges**

Capital Costs (\$/kW):	135 - 220
Fixed O&M Costs (\$/yr):	2.9 - 9.0
Variable O&M Costs (\$/MWh):	1.05 - 4.25
SO <sub>2</sub> Removal Efficiency (%):	92 - 96

### **Magnesium Enhanced Lime**

The Magnesium promoted lime scrubber uses a slurry of approximately 95% pure lime (CaO) and 5% magnesium oxide (MgO) as the reagent. Dravo, Inc. markets this reagent as a product called Thiosorbic Lime. The magnesium oxide reacts with SO<sub>2</sub> to form

magnesium sulfite, which reacts further with SO<sub>2</sub> to form magnesium bisulfite. In addition, the lime in the slurry will also react with SO<sub>2</sub> to form calcium sulfite. The high degree of reactivity of this solution leads to a high SO<sub>2</sub> removal efficiency (98%). The process requires more water extraction equipment for the waste products than conventional limestone processes, and the reagent costs are higher than limestone (UE&C, 1991).

**Table 11-18. Magnesium Enhanced Lime strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
High reagent utilization	Expensive reagent
High removal efficiency	High waste disposal costs
Reduced corrosion due to higher pH	

**Important Factors:** The very high removal efficiency of this process substantially reduces control costs of this option on a \$/ton removed basis, offsetting the expense of the reagent.

**Table 11-19. Magnesium Enhanced Lime Cost Ranges<sup>7</sup>**

Capital Costs (\$/kW):	100 - 170
Fixed O&M Costs (\$M/yr):	2.9 - 9.0
Variable O&M Costs (\$/MWh):	1.65 - 5.20
SO <sub>2</sub> Removal Efficiency (%):	96 - 98

<sup>7</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

## Lime Spray Drying

The lime spray drying process uses a spray dryer as the contacting device for the flue gas and hydrated lime reagent (CaO). Reagent is pumped to the spray dryer and sprayed as a fine mist into the absorber where it mixes with the flue gas. Water is evaporated by the heat of the flue gas while SO<sub>2</sub> is absorbed. A dry calcium sulfite/sulfate powder forms as the flue gas cools. A baghouse or electrostatic precipitator collects the resulting dry solid and fly ash (EPRI, 1990).

**Table 11-20. Lime Spray Drying strengths and weaknesses**

STRENGTHS	WEAKNESSES
Low capital cost	Expensive reagent
Low power requirements	Low SO <sub>2</sub> removal efficiency
	High volume of waste

Important Factors: Cost values given here assume a fabric filter is installed with the lime spray drying system. SO<sub>2</sub> removal efficiency tends to drop to the low range for coals with greater than 2% sulfur content by weight.

**Table 11-21. Lime Spray Drying Cost Ranges<sup>8</sup>**

Capital Costs (\$/kW):	95 - 160
Fixed O&M Costs (\$M/yr):	1.2 - 5.9
Variable O&M Costs (\$/MWh):	0.70 - 3.30
SO <sub>2</sub> Removal Efficiency (%):	75 - 85

<sup>8</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

### **Lurgi Circulating Fluidized Bed**

This process routes post-combustion flue gas through a circulating fluidized bed of hydrated lime which reacts with SO<sub>2</sub> to achieve a high removal efficiency (95-97%). The reagents recycle continually through the fluidized bed, allowing for a high rate of reagent use. Lurgi systems have operated in Europe since 1980, and one 100 MW lignite unit in the United States has operated since 1987. Only one supplier, who holds the patent, offers the Lurgi process. The process costs more than other dry FGD processes but its low reagent and capital costs and proven process results in lower costs over the life cycle of the installation (B&V, 1991).

**Table 11-22. Lurgi Circulating Fluidized Bed strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Low capital cost	High reagent cost
Low waste handling costs	Limited domestic experience
High reagent utilization	Only one vendor for process
<b>Important Factors:</b>	
The high rate of reagent utilization largely offsets the reagent's cost, making Lurgi CFB an extremely cost-effective option on a levelized basis. Increased dust loading may require an electrostatic precipitator upgrade or replacement.	

**Table 11-23. Lurgi CFB Cost Ranges<sup>9</sup>**

Capital Costs (\$/kW):	85 - 140
Fixed O&M Costs (\$M/yr):	2.4 - 7.4
Variable O&M Costs (\$/MWh):	1.40 - 4.15
SO <sub>2</sub> Removal Efficiency (%):	95 - 97

### **Soda Ash**

In the soda ash scrubbing process, a sodium carbonate solution is dispersed in the flue gas stream via spray nozzles. The soda ash reacts with SO<sub>2</sub> in the flue gas to form sodium sulfite bisulfite and sulfate compounds. As with the lime or limestone scrubbing process soda ash generally costs more than lime or limestone the process has higher reagent costs. Disposal of the soluble waste product is also potentially more costly and/or environmentally less desirable. (B&V, 1991).

**Table 11-24. Soda Ash strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Low energy requirements	High reagent cost
Low capital costs	High waste disposal cost
Important Factors:	The economic viability of the soda ash process depends on the availability of low cost supplies of soda ash and a scarcity of calcium reagents.

<sup>9</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

**Table 11-25. Soda Ash Cost Ranges<sup>10</sup>**

Capital Costs (\$/kW):	Not Available
Fixed O&M Costs (\$M/yr):	Not Available
Variable O&M Costs (\$/MWh):	Not Available
SO <sub>2</sub> Removal Efficiency (%):	90

**Dual-Alkali**

The dual alkali process uses two SO<sub>2</sub> removal reagents: lime or limestone and soda ash. A soda ash solution is used to absorb the SO<sub>2</sub> from the flue gas thereby taking advantage of its superior SO<sub>2</sub> removal chemical kinetic properties. Lower cost lime or limestone reagents are used to regenerate the soda ash solution from the sodium sulphite, bisulfites, and sulfates resulting from removal of the SO<sub>2</sub> from the flue gas. In a recirculating tank, the calcium reagent regenerates sodium sulfite and a relatively minor amount of soda ash make-up is required to balance the soda ash lost in the calcium sulfate/sulfite waste generated. Dual-alkali systems currently serve six large utility boilers in the United States (B&V, 1991).

**Table 11-26. Dual-Alkali strengths and weaknesses**

STRENGTHS		WEAKNESSES	
High reagent utilization		High reagent cost	
Utility experience with process		High waste disposal cost	
Important Factors:    The SO2 removal efficiency of the dual alkali process tends toward the high range for high sulfur coals (greater than 3% sulfur content by weight).			

<sup>10</sup> Cost estimates based on values from Radcliffe, "FGD Economics", *EPRI Journal*, December, 1990.



**Table 11-27. Dual-Alkali Cost Ranges<sup>11</sup>**

Capital Costs (\$/kW):	115 - 190
Fixed O&M Costs (\$M/yr):	1.7 - 7.5
Variable O&M Costs (\$/MWh):	1.00 - 4.10
SO <sub>2</sub> Removal Efficiency (%):	85 - 95

### **Wellman-Lord**

The Wellman-Lord process uses an aqueous sodium sulfite solution as the primary contact reagent for incoming flue gas. The sodium sulfite is converted to sodium bisulfite which can be easily regenerated by simply heating the solution. The regeneration stage reproduces the sodium sulfite solution and a concentrated stream of SO<sub>2</sub> gas that is sent to a sulfur recovery stage. The process removes 90% or more of flue gas SO<sub>2</sub>, and can produce marketable sulfuric acid, or by reaction with natural gas elemental sulfur. Eight utility coal-fired boilers with a combined capacity of 2100 MW use the Wellman-Lord process (B&V, 1991).

**Table 11-28. Wellman-Lord strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
High reagent utilization	High capital cost
Produces marketable sulfur	High waste disposal cost
High energy requirement	
<b>Important Factors:</b> The utility industry has not given much consideration to the Wellman-Lord process because of its high capital costs and process complexity.	

<sup>11</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

**Table 11-29. Wellman-Lord Cost Ranges**

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Capital Costs (\$/kW):	Not Available
Fixed O&M Costs (\$M/yr):	Not Available
Variable O&M Costs (\$/MWh):	Not Available
SO <sub>2</sub> Removal Efficiency (%):	90 - 95

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**Dowa**

The Dowa process uses a dual alkali system similar to that outlined previously, except the primary reagent is an aqueous slurry of aluminum sulfate and aluminum oxide (A/203) instead of soda ash. The resulting aluminum sulfite/sulfate mixture is then oxidized to aluminum sulfate and regenerated. As with the dual alkali process, lime or limestone regenerates the primary reagent and precipitates gypsum waste. No U.S. utility has used the Dowa process, although TVA successfully demonstrated the process at its 10 MW Shawnee Test Facility in 1982 (B&V, 1991).

**Table 11-30. Dowa strengths and weaknesses**

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STRENGTHS	WEAKNESSES
High reagent utilization	High reagent cost
Reduced equipment erosion	High waste disposal cost
	Limited domestic experience

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| Important Factors: | Although Dowa has been used in Japan, the primary application has been to industrial boilers, rather than utility boilers. |

**Table 11-31. Dowa Cost Ranges**

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Capital Costs (\$/kW):	Not Available
Fixed O&M Costs (\$M/yr):	Not Available
Variable O&M Costs (\$/MWh):	Not Available
SO <sub>2</sub> Removal Efficiency (%):	90

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**Magnesium Oxide**

This process uses a magnesium hydroxide slurry to absorb flue gas SO<sub>2</sub>. The magnesium sulfite resulting from the reaction is then calcined in an off-site process to regenerate the absorbent and to extract concentrated SO<sub>2</sub> for the production of marketable sulfuric acid or elemental sulfur. This recovery allows for a very high rate of reagent utilization and produces a marketable by-product. Three magnesium oxide systems currently operate on U.S. utility boilers with an SO<sub>2</sub> removal efficiency of 90% or greater (B&V, 1991).

**Table 11-32. Magnesium Oxide strengths and weaknesses**

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<b>STRENGTHS</b>	<b>WEAKNESSES</b>
High reagent utilization	High reagent cost
Produces marketable sulfuric acid	High energy requirements

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**Important Factors:** The degree of control needed to operate the Magnesium Oxide process efficiently (including the smooth management of the off-site processing and delivery of regenerated reagent) is a disadvantage compared to options in which the process is controlled entirely on-site.

**Table 11-33. Magnesium Oxide Cost Ranges**

Capital Costs (\$/kW):	Not Available
Fixed O&M Costs (\$M/yr):	Not Available
Variable O&M Costs (\$/MWh):	Not Available
SO <sub>2</sub> Removal Efficiency (%):	90 - 98

#### **11.1.4 Reagent Additives**

##### **Dibasic Acid (DBA)**

The addition of dibasic acid to the recirculation tank enhances the performance of limestone forced oxidation FGD systems. Dibasic acid prevents a substantial drop in pH during the SO<sub>2</sub> absorption process, which increases the absorption capability (removal efficiency) of the limestone reagent. However, dibasic acid contaminates the resulting gypsum waste, making the waste unsuitable for use as a commercial grade gypsum by product. (UE&C, 1991).

**Table 11-34. Limestone/Dibasic Acid strengths and weaknesses**

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
Higher SO <sub>2</sub> removal	Higher reagent cost for DBA
	High waste disposal cost
	Limited Use

Important Factors: To date, Dibasic Acid has been used solely to improve removal efficiencies in systems that had fallen below removal efficiency expectations. DBA has not seen use in a new or retrofit FGD system.

**Table 11-35. Limestone/DBA Cost Ranges<sup>12</sup>**

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Capital Costs (\$/kW):	130 - 215
Fixed O&M Costs (\$M/yr):	1.4 - 7.1
Variable O&M Costs (\$/MWh):	0.80 - 3.95
SO <sub>2</sub> Removal Efficiency (%):	92 - 95

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### **Thiosulfate**

Thiosulfate has the effect of minimizing the oxidation of sulfite to sulfate thereby preventing gypsum scaling in the absorber and promotes a less contaminated calcium sulfite crystal precipitate that is more easily dewatered increasing the utilization of the limestone reagent. In the spray tower, emulsified elemental sulfur reacts with limestone to form calcium sulfite and thiosulfate; the thiosulfate ion further reacts with CaCO<sub>3</sub> (limestone), increasing the amount of Ca available to react with SO<sub>2</sub> in the flue gas. The waste product consists primarily of a calcium sulfite sludge. The thiosulfate process increases utilization level of the reagent, reducing costs to purchase reagent and the volume of waste produced. Many new systems can use thiosulfate, and vendors have modified several existing limestone systems to use thiosulfate. The performance of thiosulfate tends to be site-dependent, however (UE&C, 1991).

## **11.2 FUEL SWITCHING COMPLIANCE OPTIONS**

### **Natural Gas Co-Firing**

In natural gas co-firing, coal and natural gas burn simultaneously in a single steam generator. Because natural gas emits virtually no SO<sub>2</sub> when burned, the addition of natural gas reduces boiler SO<sub>2</sub> emissions. The amount of SO<sub>2</sub> reduction depends on the proportion of natural gas in the boiler fuel, although boilers designed to burn coal can handle more than a 10% blend of natural gas in the fuel mix a greater proportion of natural gas is rarely used due to cost and technical factors. The use of natural gas reduces maintenance and unit unavailability costs and can improve the rated capacity of previously derated units. Natural gas co-firing also reduces boiler NO<sub>x</sub> emissions. Capital costs of gas co-firing vary greatly,

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<sup>12</sup> Cost estimates based on values from Radcliffe, "FGD Economics", EPRI Journal, December, 1990.

and depend on the natural gas supply facilities the plant has already installed; for plants with significant prior investment, capital costs can be as low as \$5/kW, while for plants with no prior investment, capital costs can exceed \$50/kW. The price of natural gas supply determines the bulk of the operation and maintenance costs for co-firing (B&V, 1991).

### **Coal Switching/Blending**

The cost of coal switching or blending varies greatly from unit to unit. In their original design, utilities build boilers to maximize the performance of a particular coal. Key coal characteristics utilities design the boilers for include: ash content, ash softening temperature, moisture content, grindability, and sulfur content. Utility planners consider sulfur content the least important of these factors; a coal that closely matches the ash content, moisture content, ash softening temperature, and grindability of the current coal will usually be suitable for fuel switching. For example, because low-sulfur Appalachian coals match the characteristics of many mid-western high-sulfur coals, Appalachian coals have been in relatively high demand for fuel switching.

Most fuel switches will require some capital modifications. Low sulfur coals produce lower concentrations of SO<sub>3</sub> that will tend to adsorb on the particulate and affect the resistivity of the flyash, decreasing electrostatic precipitators. Fuel switches therefore usually require an ESP upgrade or replacement. In addition, the lower sulfur coals can cause slagging, plugging, and fouling in a boiler designed to use other coals with different ash softening temperature characteristics. Several test burns have suggested that these problems are not as formidable as first believed.

Not surprisingly, the price of candidate coals for fuel switching play a larger role in determining the viability of a fuel switch option than how well it matches the coal the boiler was designed for. High demand and increasing prices for eastern low-sulfur coals, along with easing concerns about using western coals, has led many utilities to consider western coals. The cost differential between western and eastern low-sulfur coals is great enough that in many cases it is more cost-effective to modify the boiler to burn western low-sulfur coal than to pay a stiff premium for eastern low-sulfur coals.

The delivered price of coal also has an important site-specific component: the diversity of transportation options available to the utility plant. If a plant coal yard has a single rail spur as its sole source of delivery, then the railroad company servicing the rail may command a higher price for delivery than if a plant has multiple rail spurs or is close to a barge unloading point. In the east and northeast, where rails lines are extensive, transportation costs will not play a large role in fuel costs. A plant's decision to buy western coal, however, will likely depend more on transportation costs than on the mine mouth cost of the coal itself.

### 11.3 CONSERVATION COMPLIANCE OPTIONS

While it is unlikely that utilities will rely heavily on conservation to meet their reduction obligations, most utilities will factor gains from demand-side management into their compliance option portfolio. Conservation carries three distinct benefits from a compliance planning perspective:

- 1) Aggressive demand-side management efforts, particularly those that curtail base load energy generation, will reduce SO<sub>2</sub> emissions, proportionately reducing the need for a utility system to expend emission allowances to cover those emissions;
- 2) Even DSM action that does not curtail generation can reduce the rate of load growth which, in addition to avoiding the cost of new generation, reduces the need to cover new generation out of the utility system's pool of emission allowances; and,
- 3) If conservation programs meet statutory requirements, those programs may qualify the utility to receive bonus allowances from EPA's Conservation and Renewable Energy Reserve.

Section 404(g) of the Clean Air Act Amendments creates the Conservation and Renewable Energy Reserve by deducting 30,000 allowances/year from national totals from the years 2000 to 2009, for a total reserve of 300,000 allowances. Allowances allocated from the reserve by EPA may be used any time after they are allocated.

The two criteria a utility conservation program must meet to qualify for allowances from the reserve are:

- ▶ The utility must have in place a commission-approved least cost plan (or integrated resource plan) that explicitly considers demand-side as well as supply-side resources; and,
- ▶ The utility's rate structure must guarantee net income neutrality for investments in demand-side management measures. Examples of net income neutrality mechanisms are measures that increase the return on rate base for utilities engaging in DSM, or an electric revenue adjustment mechanism such as that used in California. The Department of Energy certifies that the applicant's regulatory authority is, in fact, employing a net income neutrality mechanism.

Once the applicant meets these criteria, they receive allowances at the rate of 4 lbs SO<sub>2</sub>/MWh of energy saved. Note that qualified renewable energy sources may also receive allowances from the Reserve at the rate of 4 lbs SO<sub>2</sub>/MWh generated.

STARRSS uses a simple process to compare marginal control costs and allowance prices specified by the user to determine if a new conservation program is justified as part of an effort to meet the overall reduction target. The STARRSS program will consider both the SO<sub>2</sub> reduction impact and the bonus allowance impact of any conservation program the user specifies.

#### **11.4 OTHER COMPLIANCE ACTIVITY**

This section briefly discusses a variety of non-standard compliance options that utilities can undertake to reduce SO<sub>2</sub> emissions on their system. In some cases, STARRSS Version 1 is limited in its ability to model these options as discrete and comparable to other compliance options because full system dispatch modelling is not yet available. For these cases, this section will also include suggestions on how to model these compliance options using STARRSS.

##### **Reduced Utilization**

Reduced utilization is a specific Phase I compliance option provided by the Clean Air Act Amendments. A utility wishing to reduce the generation of a Phase I-affected unit (thereby reducing that unit's SO<sub>2</sub> emissions) must provide EPA with two types of information:

- the amount of reduction in use at the unit, expressed as the difference between the projected annual heat input and the Baseline Heat Input ("Baseline"), in Btus; and
- the source of compensating generation (or factors accounting for reduction in utilization, if applicable).

If the source of compensating generation emits no SO<sub>2</sub> (such as nuclear or hydroelectric generation), then the utility need only demonstrate that the increase in generation at these units will fully compensate the reduction in utilization at the Phase I-affected unit (using the affected unit's current heat rate as the benchmark value to convert kWhs to Btus). Alternatively, if the utility expects conservation programs or other system-wide factors to result in reduced utilization, the utility may specify these factors, subject to EPA's year-by-year review.

However, in the case where the compensating unit is a fossil-fired Phase II-affected unit, the compensating unit becomes a Phase I-affected unit and receives Phase I allowances equal to



its Baseline times the lesser of its actual or allowable SO<sub>2</sub> emissions rate (if the compensating unit has a zero Baseline, it receives no allowances).

A utility pursuing reduced utilization must therefore consider carefully which compensating unit it wishes to use; some units may receive a more advantageous allowance allocation, or be emitting at a low enough rate to reap substantial compliance benefits from a reduced-utilization/compensating unit option.

### **Suggested Approach for STARRSS Modelling of Reduced Utilization**

Modelling a reduced utilization compliance option in STARRSS is relatively straightforward but may require the user to perform some side calculations to determine some STARRSS inputs. Structuring a reduced utilization compliance option actually requires only two inputs in the Define Compliance Options screen. First, the user enters the projected New Capacity Factor of the unit reducing utilization. The resulting costs and emissions reductions are tracked in STARRSS using the inputs for the fuel the unit will burn under the new compliance option and the marginal energy costs to replace the lost generation.

The second input that the user must define is the System Marginal SO<sub>2</sub> Emissions rate associated with reducing utilization. This input should reflect the net emissions rate (in lbs SO<sub>2</sub>/MWh) of the compensating unit(s). Accordingly, if the compensating unit is non-fossil based, or if the reduction in utilization is attributed to a system-wide load reduction, this input should be zero. If the compensating unit is a Phase II-affected unit, the user must calculate the marginal SO<sub>2</sub> emissions rate according to Equation 11-1 below:

$$\text{System Marginal SO}_2 \text{ Emissions (lbs/MWh)} = [(E_c - A_c) / G_r] * 2000 \text{ lbs/ton} \quad (11-1)$$

where:

- $E_c$  = compensating unit c's projected emissions (in tons of SO<sub>2</sub>), calculated as the product of the unit's projected heat input times the unit's projected SO<sub>2</sub> emissions rate (in lbs/106 Btu);
- $A_c$  = compensating unit c's Phase I allowances, calculated as the product of the compensating unit's Baseline times the lesser of the unit's 1985 SO<sub>2</sub> rate or the unit's SO<sub>2</sub> limit (in lbs./106 Btu) under SIP or other regulations; and,
- $G_r$  = the difference in generation resulting from reduced utilization at reducing unit r, calculated as the difference between the MWh's generated at the reducing unit's Baseline, and the projected MWhs of generation.

The 2000 multiplier converts tons of SO<sub>2</sub> into lbs. Note that if further compliance activities are performed at either the reducing unit or the compensating unit (such as a fuel switch along with a reduction in utilization), costs to perform these activities must be reflected in the same compliance option as the inputs for reduced utilization. **Because STARRSS can only consider one option for each unit in compliance strategy development, combinations of compliance options must be modelled as a single composite compliance option.**

#### **Phase I Substitution Units**

Utilities may find that certain Phase II-affected units on their system can more easily comply with Phase I reduction obligations than their Phase I units. In this event, the Act contains provisions allowing utilities to substitute Phase II-affected units for their Phase I-affected units, effectively transferring all or a portion of the Phase I-affected unit(s) reduction obligation to the Phase II unit(s). In a Phase I Substitution Plan, a utility must submit to EPA the following information:

- 1) the calculated reduction obligation of the proposed Phase I unit;
- 2) the calculated reduction obligation of the proposed Phase II substitution unit (under SIP or other regulations);
- 3) the proposed reduction to be achieved at the Phase I unit due to compliance activity;
- 4) the proposed reduction to be achieved at the Phase II unit due to compliance activity; and,
- 5) satisfactory demonstration that the sum of the proposed reductions (items 3 and 4 above) equals or exceeds the sum of required SO<sub>2</sub> emissions reductions (items 1 and 2 above).

Note that multiple Phase I units and substitution units may be included in a single Phase I Substitution Plan. If EPA determines that the proposed substitution plan will not result in a net emissions increase, it will approve the substitution plan and allocate allowances to units in the plan as follows:

- the Phase I unit(s) in the plan will receive allowances equal to their basic allowances plus the difference between the unit's reduction obligation and the proposed amount of reductions due to compliance activity;
- the substitution units in the plan will receive allowances equal to their current emissions (or allowable emissions under SIP, if less) less the difference

between the Phase I unit's reduction obligation and the Phase I unit's proposed amount of reductions due to compliance activity.

### **Suggested Approach for STARRSS Modelling of Substitution Plans**

STARRSS is not well equipped to compare a proposed substitution plan discretely to other compliance options, because substitution plans involve compliance options at different facilities that must take place concurrently as well as changes to basic data (i.e. allowance allocations) that are not typically reflected in the Edit/Define Compliance Options screens. The best way to evaluate a substitution plan is to create a separate .SDB file for the utility system under consideration, incorporating the changes to allowance allocations and proposed compliance options. Allowance allocations may be changed in the View/Edit Affected Units screen, and units governed by an approved substitution plan can have their options "fixed" (i.e. evaluated regardless of other compliance activity) in the Define Active Compliance Options step of the Develop STARRSS Strategies screen. Comparing the results of runs on the original database to the results of runs on the database modified to reflect a substitution plan should provide the user with an indication of how the substitution plan is affecting the utility's efforts to achieve least-cost compliance with its SO<sub>2</sub> reduction obligations.

### **Efficiency Improvements**

Efficiency improvements considered by utilities typically fall into two categories: improvement of the boiler heat rate, and improvement of pollution control device efficiency.

By replacing old steam seals in the turbine or worn components elsewhere in the system, utility engineers can improve the unit's heat rate, thereby reducing the amount of SO<sub>2</sub> emitted for an equal level of generation. Although this process constitutes part of a generating unit's standard maintenance, compliance requirements may cause utilities to evaluate efficiency improvements as a marginal SO<sub>2</sub> compliance activity, particularly at older boilers. This can be modelled in STARRSS by designating a compliance option that reduces the Heat Rate Multiplier (on the Edit/Define Compliance Options screen).

A second possibility considered by many utilities with FGD-equipped units on their system is the improvement of the FGD system's SO<sub>2</sub> removal efficiency. This can often be achieved through implementation of a tighter process control, the addition of larger amounts of reagent, or the use of reagent additives (as discussed in Section 11.1.4). FGD efficiency improvements can remove significant amounts of SO<sub>2</sub> at relatively low cost, making such improvements a worthwhile marginal compliance activity. Such possibilities can be modelled in STARRSS by designating new compliance options with SO<sub>2</sub> Removal Efficiencies (on the Edit/Define Compliance Options screen) for units that already have existing scrubbers (as designated on the Affected Units Operating Factors screen).

## **Clean Energy Additions**

The addition of hydroelectric, gas-fired, or renewable energy units to a utility's system can reduce the need for generation at affected units and subsequently reduce system-wide SO<sub>2</sub> emissions. Furthermore, renewable energy resources may qualify the utility for bonus allowances in a manner similar to that for conservation programs (Section 11.3) -- at a rate of 4 lbs SO<sub>2</sub>/MWh of energy generated by the renewable resource. If a utility anticipates a reduction in generation by its Phase I-affected units below 1985 levels, it is encouraged to file a Reduced Utilization plan with EPA.

## **Unit Retirement**

The Clean Air Act Amendments have also led to greater consideration of unit retirement for older SO<sub>2</sub>-emitting units on many utility systems. Obviously, the retirement of an affected unit frees up that unit's allowances for use on the rest of the utility's system and covers the emissions of new fossil units. Note, however, that if a Phase I unit is targeted for retirement, the utility may need to account for the replacement of that unit's generation and file a Reduced Utilization plan with EPA. If the generation of the utility's Phase I units as a whole (subtracting the retired unit) still exceeds their 1985 generation (including the retired unit), no reduced utilization test is necessary.

A retirement option (as opposed to a base case planned retirement) can be modelled in STARRSS by specifying a compliance option with a Start Date that immediately follows the proposed retirement year, a New Capacity Factor of 0.1%, and an appropriate value for the System Marginal SO<sub>2</sub> Emissions (all on the Edit/Define Compliance Options screen).

# APPENDIX A

## STARRSS DATA REQUIREMENTS

### Affected Generating Unit Information:

- 1) Utility Ownership Percentage(s)
- 2) Summer Net Capacity (MW)
- 3) \*Expected Long-Range Capacity Factor(s)
- 4) Average Heat Rate (BTU/kWh)
- 5) \*Current Variable O&M Cost (*Base Year* \$/MWH)
- 6) Expected Retirement Year (if before *End Year*)
- 7) Fuel/Fuel Blend Burned By The Unit<sup>1</sup>

### Fuel Information:

- 8) Sulfur Content (Lbs of SO<sub>2</sub>/mmBTU)
- 9) \*Delivered Price Forecast (1995-*End Year*, cents/mmBTU)

### Utility Information:

- 10) \*System Marginal Energy Cost Forecast (1995-*End Year*, \$/MWH)
- 11) \*System Marginal Capacity Cost Forecast (1995-*End Year*, \$/kW)
- 12) Cost of Capital Forecast (*Base Year-End Year*)<sup>2</sup>
- 13) Effective Tax Rate
- 14) Escalation Rate Forecasts (*Base Year-End Year*) for:
  - a) Capital Costs
  - b) Variable O&M Costs
  - c) Fixed O&M Costs

\*The user can define three forecasts for these data items (High, Medium, Low). The user also should designate his or her estimate of the likelihood that the forecast will occur by specifying a probability percentage for each forecast, the percentages for all three forecasts must sum to 100%.

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<sup>1</sup> The user must designate a name for each fuel (such as the name of the supplier or the location where it was mined) and, in the case of units that burn a blend of fuels, the percentage that each fuel represents in the blend (by mmbtu).

<sup>2</sup> The utility's latest allowed return on ratebase will suffice if a forecast is not available.

**Conservation Information:**

- 15) \*Energy Savings Forecast For Planned Conservation (*Base Year-End Year*, MWH)

**Allowance Market Information:**

- 16) \*Allowance Market Price Forecast (*Base Year-End Year*, \$/allowance)

**Compliance Option Information:**

**New Conservation Programs**

For each program:

- 17) \*Energy Savings Forecast For New Conservation Program (*Base Year--with an escalation rate for future years' savings*, MWH)
- 18) \*Expected SO<sub>2</sub> Emissions Reduction From Conservation Program (Lbs/MWH)
- 19) \*Expected Annual Program Costs (*Base Year--with an escalation rate for future years' costs*, \$/MWH)
- 20) \*Expected Annual Avoided Costs (*Base Year--with an escalation rate for future years' avoided costs*, \$/MWH)

**Fuel Switching Options**

For each fuel switching/blending option at each affected generating unit:

- 21) New Fuel Blend
- 22) \*Capital Costs (in *Base Year* \$M)
- 23) \*Increased Non-Fuel Variable O&M Costs (in *Base Year* \$/MWH)
- 24) \*Increased Fixed O&M Costs (in *Base Year* \$M/yr)
- 25) \*Additional Costs [if any] (in *Base Year* \$M/yr)
- 26) \*Capacity Deration (%)
- 27) \*New Capacity Factor [if unit will be operated differently]
- 28) \*Expected SO<sub>2</sub> Emissions Impact From Decreased/Increased Generation (Lbs/MWH)

\*The user can define three forecasts for these data items (High, Medium, Low). The user also should designate his or her estimate of the likelihood that the forecast will occur by specifying a probability percentage for each forecast; the percentages for all three forecasts must sum to 100%.

### Pollution Control Technology Options

For each technology option at each affected generating unit:

- 29) \*Capital Costs (in *Base Year* \$M)
- 30) \*Increased Variable O&M Costs (in *Base Year* \$/MWH)
- 31) \*Increased Fixed O&M Costs (in *Base Year* \$M/yr)
- 32) \*Additional Costs [if any] (in *Base Year* \$M/yr)
- 33) \*Capacity Deration (%)
- 34) \*New Capacity Factor [if unit will be operated differently]
- 35) \*Expected SO<sub>2</sub> Emissions Impact From Decreased/Increased Generation (Lbs/MWH)
- 36) \*SO<sub>2</sub> Removal Efficiency

**\*The user can define three forecasts for these data items (High, Medium, Low).** The user also should designate his or her estimate of the likelihood that the forecast will occur by specifying a probability percentage for each forecast; the percentages for all three forecasts must sum to 100%.

## DESCRIPTION OF STARRSS DATA REQUIREMENTS

### Unit Information

Data items #1 and #2 (Ownership Percentage and Summer Net Capacity) are fairly self-explanatory. The third item, Capacity Factor, should represent an estimate of a unit's future utilization. The best information would be annual projections from the *Base Year* through the *End Year*, presumably taken from a long-range "base case" that may have been filed. Ideally, the user should obtain or develop three forecasts (High, Medium, and Low scenarios) that represent all of a utility's units' annual capacity factors for High, Medium, and Low load growth scenarios (excluding DSM impacts). It should be emphasized that this is the ideal. If the user is only able to estimate a single long-term capacity factor for each unit, that will suffice.

The fourth item, Average Heat Rate, should represent the generating unit's efficiency based on its average capacity utilization. Therefore, it does not necessarily have to be the full load rate if the unit tends to operate at lower capacity levels most of the time.

Item #5, Variable O&M Costs, is self-explanatory. Item #6, Expected Retirement Year, is only needed if the user expects the unit to be retired before the end of the study.

### Fuel Information

The user must define what fuel or fuel blend each unit burns. Defining a fuel requires three pieces of information: a unique fuel name, the expected uncontrolled SO<sub>2</sub> emissions rate (in Lbs/mmBTU), and price forecasts. The user is free to define as many fuels as he or she likes. A unit in STARRSS may burn a blend of up to three fuels. If such is the case, the user merely specifies each fuel's percentage of the unit's fuel blend (on an mmBTU basis).

Similar to the generating unit capacity factors, three fuel price forecasts can be specified for each fuel. The user must at least specify the 1992 delivered prices and an expected growth rate. If detailed forecasts are available, the user can represent three delivered price forecasts (High, Medium, and Low) for each fuel for each year of the study.

### Utility System Information

Utility-specific system marginal energy and capacity costs are input in much the same fashion as fuel price forecasts. These energy and capacity costs are used to calculate the cost of replacement power and therefore should reflect generation costs only (i.e., no transmission or distribution costs).



For present value calculations and escalation of costs, the user must provide cost of capital and cost escalation rates. For each utility, please specify the company's current allowed rate of return (i.e., cost of capital). If the user has a financial forecast of how this might change, that forecast may be input; otherwise, the user can assume that the utility's cost of capital will not change from year to year. In STARRSS, the user can also specify assumptions about nominal escalation rates for 1) capital costs, 2) variable O&M costs, and 3) fixed O&M costs.

### Conservation Information

Since certain qualified conservation measures employed after 1991 may make a utility eligible for bonus allowances, the user should specify a forecast of each utility's expected level of conservation savings. This forecast should be in MWHs from 1992 through 1994. If such information is not readily available, the utility possibly has an estimate of the number of bonus allowances it expects to receive from the Conservation and Renewable Energy Bonus Allowance Reserve.

### Allowance Market Information

The user can specify three forecasts (High, Medium, and Low) for both buying prices and selling prices in the emerging allowance market. This allows the user to model a bid-ask spread; in illiquid markets it is common to see significantly different buying and selling prices.

### Compliance Option Information

The remainder of STARRSS inputs pertain to potential compliance options for a utility (such as increased conservation) and for specific generating units (such as fuel switching, co-firing, scrubbing, etc.). The critical values for the latter would be the estimates of capital costs, increased operating costs, operational changes (e.g., capacity derates or changes in utilization) and SO<sub>2</sub> removal impacts. For fuel switching, the user must identify a possible fuel type that could be utilized by a particular unit; any estimates for capital costs (e.g., for retrofitted fuel handling systems) or increased operating expenses can also be specified.

## APPENDIX B

### STARRSS WARNING MESSAGES

The following is a complete compilation of the warning messages that a user could encounter in using the system. For this appendix, the warning messages appear on the left-hand side of the page in bold italics; the explanations of the messages are on the right-hand side. The messages are arranged in alphabetical order, except for those that begin with a name. For example, the user will find the explanation for the message "***BIGCOAL 3: WETFGD1 is active outside of BIGCOAL 3's lifetime***" under <Unit Name> toward the end of the appendix.

***A fatal memory error occurred. Reduce the size of the database in use or obtain more memory. See also the Warnings appendix in the STARRSS documentation.***

This message could mean one of two things: (1) there is not enough memory for the size of the program, the database, and the temporary storage needed for execution, or (2) the database is incomplete in some way (e.g., there are no options defined, or no fuels, or no units). After making sure the second alternative is not the problem, the user has the option of eliminating memory-resident software or reducing the size of the database (by removing unneeded units, options, fuels, linkages, and conservation/renewable programs). See page 3-14 for more suggestions for reducing a database's memory requirements.

***Allowance sale price exceeds purchase price in (High/Medium/Low) forecast***

In Version 1, this refers to the present value of the stream of prices for a given allowance price forecast, not just to any single year's price. If the present value of allowance sales prices exceeds that of allowance purchase prices STARRSS will still evaluate plans, but it cannot capture profits from "arbitraged" allowances.

***A maximum of 5 units may be linked***

STARRSS limits the number of units in any given linkage to five. Linked units will usually be units at a single plant for which there are economies of scale in construction, supply delivery, etc.

***A maximum of 5 units may be redundant***

STARRSS limits the number of units in any given redundancy definition to five. Redundant units are units which are to be considered identical for the purposes of preliminary analysis; it is unlikely that units at two different plants would be considered identical, or that there would be more than five affected units at a single plant.

***Bad Fuel Blend at Unit <Unit Name>***

***Blend Adds up to <Percentage>***

The fuel blend specified on the *Affected Unit Operating Factors* screen must add up to 100%.

***Bad New Fuel Blend at Option <Unit Name>: <Option Name>***

***Blend Adds up to <Percentage>***

The fuel blend specified on the Edit/Define Compliance Options screen must add up to 100%.

***Base year for Phase I run must be 1995 or earlier***

Phase I of the Clean Air Act Amendments begins in 1995.

***Base year for Phase II run must be 2000 or earlier***

Phase II of the Clean Air Act Amendments begins in 2000.

***Can't copy to a redundant unit***

When a unit is redundant, its list of options are copies of the compliance options belonging to the primary unit of the redundancy. Although the unit may have "dormant" options that become visible when the unit is removed from the redundancy, the user cannot copy to this list while the unit is redundant.

***Can't delete last unit***

There must be at least one unit defined in the database at all times. If only one unit remains in the database, the user will not be allowed to delete it.

***Can't delete: name in use by unit <Unit Name>, for example***

A compliance option name cannot be deleted if there is an option at any unit which uses that name. Delete all options which use the name before trying to delete the name from the list.

***Can't display the report -- <File Name> is unreadable***

Although reports can generally be displayed from a previous execution of STARRSS, if certain files have been deleted or tampered with, the user will have to re-run the evaluator or optimizer and regenerate the report files.

***Can't open file <File Name>***

***Can't read file <File Name>***

***Can't write to file <File Name>***

The file mentioned has either been deleted from the disk, is in a different directory, or has had its "permissions" changed by the user or another program.

***Can't run a zero-year study***

The *Number of Years* field on the *Execution Parameters* screen must be set to one or more years.

***Can't start the graphics system: check the BGI directory listed on the report parameters screen***

There should be a drive and directory (e.g. c:\starrss\bgi) listed on the *Report Parameters* screen which contains the <File Name>.BGI files. These are the graphic interface files that were delivered with the main system.

***Capacity factor at unit <Unit Name> must be defined on or before <Year>***

Starting in 1995 for a Phase I run, or 2000 for a Phase II run, there must be a capacity factor specified for every unit, on the *Affected Unit Operating Factors* screen, page 2. Use the Fill function there (Ctrl-F) to see which years remain unspecified.

***Capacity factors are not defined for any units***

Normally unspecified capacity factors are assumed to be zero, but if no capacity factors are specified anywhere in the database there is no point in continuing with execution. This warning might mean that the *Base Year* on the *Tax Rate, Escalation Rates, and Cost of Capital* screen was moved forward, and all the capacity factors were only specified for the old base year.

***Fatal Error: The database is too large to be loaded***

STARRSS tried to load a database that was too large for the available memory and was unable to recover from the error. Try eliminating memory-resident software, obtaining more RAM, or using a smaller database.

***Fuel <Fuel Name> is in use at unit <Unit Name>; not deleted***

Fuels cannot be deleted if they are referenced anywhere else in the database. In this case, the reference is on page one of the *Affected Unit Operating Factors* screen for this unit. Delete all other references before deleting the fuel itself.

***Fuel <Fuel Name> is used by option <Unit Name>: <Option Name>; not deleted***

Fuels cannot be deleted if they are referenced anywhere else in the database. In this case, the reference is on page one of the Edit/Define Compliance Options screen for this option. Delete all other references before deleting the fuel itself.

***File <File Name> has been corrupted***

STARRSS tried to read from this file but found inconsistencies. Either the user or another program tampered with the file, or STARRSS' execution was aborted while writing to this file originally. Re-run the previous evaluation or optimization.

***File <File Name> is an invalid database***

STARRSS tried to read this file as a database but found inconsistencies. Either the user or another program tampered with the file, STARRSS' execution was aborted while writing to this file originally, or it was not actually a database file to begin with.

***Header file <File Name> is missing! Showing report anyway...***

STARRSS reads from two files to display a report; the report itself and a "header" file containing information such as the reduction target and the name of the utility. If STARRSS cannot find the header file (a file with extension .HDR) it will display the report without the header. However, the header file is not really necessary, and STARRSS can display the report even if it has been deleted for some reason.

***H,M & L probabilities for pointer <Pointer Number> must add to 100%***

***--- Adjusting probabilities to low=0, med=100, high=0***

The three rightmost values in each row of the *Probabilities Associated with Forecasts* screen are complimentary probabilities and must add up to 100%. Because it is impossible to exit from the Probabilities screen with inconsistent values, the database file has probably been tampered with.

***Internal error; preserve the file zbackup.sdb and contact RCG/Hagler, Bailly for further assistance.***

This warning message indicates an internal calculation error, or possibly a corrupted database file. Please preserve any further information the message gives, as well as the database ZBACKUP.SDB so Hagler, Bailly can more easily locate the problem.

***Life of conservation or renewable <Program Name> does not overlap study years***

***--- program removed from strategy <Strategy Number> (<Strategy Name>)***

The "study years" begin in 1995 for a Phase I run or 2000 for a Phase II run (see the *Execute* menu), and the length of the study is specified in the *Execution Parameters* screen. The *Incremental Conservation/Renewables* screen specifies the start year and lifetime of the conservation or renewable program are specified. The two ranges should overlap.

***Life of linkage <Linkage Name>'s options do not overlap***

***--- linkage disabled***

The "study years" (see above for definition) and the lifespan of all the options listed for this linkage (*Option Life* and *Start Year* on page one of the *Edit/Define Compliance Options* screen) must have some range of years in common. For example, a five-year option starting in 1995 and a five-year option starting in 2001 cannot be linked, since presumably there is no economy of scale for non-concurrent options. Such a link will simply be ignored by the evaluator, but this warning will always be given.

***Life of option <Unit Name>: <Option Name> does not overlap study years  
--- option removed from strategy <Strategy Number> (<Strategy Name>)***

The "study years" (see above for definition) and the lifespan of this option (given by the *Option Life* and *Option Start Year* on page one of the *Edit/Define Compliance Options* screen) must overlap. For example, an option of switching fuels for two years beginning in 1995 should not be part of a strategy in a Phase II run, which doesn't begin analysis until 2000.

***Life of option <Unit Name>: <Option Name> is zero***

Option Life, specified on page one of the Edit/Define Compliance Options screen, is the number of years over which the option will be active; in STARRSS it must be active for a minimum of one year.

***Linkage <Linkage Name>'s option <Unit Name>: <Option Name> not found  
--- linkage disabled***

The linkage includes an option that is not in the database. Define the option for the unit, or remove the option's mention in the linkage.

***Link <Link Number> contains duplicate units.***

A linkage represents an economy of scale associated with choosing two options at the same time. Since only one option can be chosen at a given unit, two options at the same unit cannot be linked. For example, there might be economy of scale savings associated with switching to the same new coal at BIGCOAL1 and BIGCOAL2.



***No database has been loaded yet. Please select the Load command from the Files menu to load a database.***

A database can't be built from scratch. To build a new database, load in an existing database and modify it appropriately. This message will appear when trying to enter a screen when STARRSS is first invoked, or after a failed attempt to load a corrupted or missing database.

***No help available for this screen***

See the appropriate section of this manual for further assistance.

***No legal compliance plans could be created***

If the optimizer fails to create any legal plans, it means either that there weren't enough high-impact options flagged as "active" on the *Define Active Compliance Options* screen (which can be found by first entering the *Develop STARRSS Strategies* screen), or that the allowance transaction limits are set too stringently on the *Allowance Parameters* screen.

***None of the strategies are active***

At least one of the strategies on the *Summarize and Execute* screen must be marked with a check for any execution to occur.

***No plans have been saved.***

If the *Number of Plans to Save* parameter on the *Develop STARRSS Strategies* screen is set to zero, none of the plans generated will be saved and evaluated afterwards.

***No report has been generated (<File Name> not found)***

This report is not available for viewing; re-run the evaluator or optimizer to generate the desired report again.

***No strategies were generated***

This message is generated when the second heuristic process has been unable to generate any strategies. If this happens, use the first heuristic or the full enumeration optimizer instead.

***Number of Iterations for Heuristic #1 must be at least 1***

Change the *Number of Iterations for Heuristic #1* to a number greater than zero.

***Only <Number> legal compliance plans could be created***

The *Number of Plans to Save* parameter was higher than the number of possible combinations of active options specified in the *Define Active Compliance Options* screen. Make more options active or lower the number of plans to save.

***Only 14 strategies can be simultaneously graphed***

There is only room on the left side of the screen for 14 strategy labels. Remove some of the check marks from the list of plans to be graphed.

***Option <Unit Name>: <Option Name> has an incorrectly defined fuel  
--- using zero cost and sulfur content for new fuel***

The fuel blend specified on the *Edit/Define Compliance Options* screen must add up to 100%.

***Option <Unit Name>: <Option Name> is overridden by redundancy <Redundancy Number>***

The secondary units of a redundancy share the options of the primary unit, with identical costs and impacts. Any options that were previously entered for secondary units remain in "limbo" until the redundancy is deleted. This warning message is a reminder of that.

***Out of memory -- can't save the <Number> changes to this form***

Changes to a filled-style form are only entered in the database when the user presses the <Escape> key. If the computer happens to run out of memory at exactly this point in time, the most recent changes to this particular page might be lost. If this happens, you are too close to the memory limits of the machine, and you should either reduce the size of the database, obtain more RAM, or remove some memory-resident programs to give STARRSS more room to work with.

***Overflow in filled values of allowance purchase prices***

***Overflow in filled values of allowance sale prices***

***Overflow in filled values of fuel <Fuel Name>***

***Overflow in filled values of marginal capacity costs***

***Overflow in filled values of marginal energy costs***

If you go to the form in question and type Ctrl-F, some of the prices, most likely on the last page, will be filled as a row of stars, indicating that the price has grown too large. Reduce the original prices or the growth rates until the stars no longer appear.

***Phase I only lasts for 5 years. The length of the study for this***

***Phase I run is currently set to <Number> years.***

***Continue execution anyway?***

Phase I of the Clean Air Act Amendments extends from 1995 through 1999. Since version 1 of STARRSS can only evaluate one Phase at a time, a 20-year run starting in 1995 tells STARRSS to assume that Phase I allocations will extend for 20 years instead of 5. This is allowed but not recommended.

*Phase II units may not be included in Phase I runs.  
Deactivate options at unit <Unit Name>.*

*Phase II units may not be included in Phase I runs.  
Remove <Unit Name> from strategy <Strategy Number>.*

Reducing emissions at a Phase II affected unit does not influence Phase I compliance, and cannot therefore be considered a part of a Phase I compliance strategy.

*Print file already exists: Append or overwrite?*

When performing an evaluation or optimization or upon pressing F2 while viewing a report, a file formatted for printing is written; this message lets you choose whether to append the new pages of information to the end of the file, or to erase the file and start from the beginning.

*Probability pointer <Pointer Number> MUST sum to 100%*

The three rightmost values in each row of the Probabilities Associated with Forecasts screen are complimentary probabilities and must add up to 100%. Because it is impossible to exit from the Probabilities screen with inconsistent values, the database file has probably been tampered with.

*Program <Program Name> has positive cost and increases emissions*

The evaluation proceeds normally when a conservation or renewable program has a positive cost, yet increases SO<sub>2</sub> emissions, but a message appears warning that the situation is not ideal.

*Program <Program Name> has zero cost*

The evaluation proceeds normally when a conservation or renewable program has zero cost, but this message alerts the user to this unusual situation.

***Redundance <Redundance Number> has only one unit***

Redundance is a way of indicating that two or more units should be considered identical for the purpose of preliminary analysis.

***Running the evaluator with this many strategies and iterations AND with the detailed flag on will create a huge disk file.***

The primary purpose of the detailed information flag is to verify that costs and bonuses are being computed in the way the user expects. Therefore one or two iterations are probably sufficient for a detailed examination of these values.

***Running the optimizer with the detailed information flag set to a value greater than 1 writes detailed information about the optimization process to the file <File Name>.DET. Its use is not recommended.***

The detailed output of the optimizers is not documented and is primarily intended for software development and verification at Hagler, Bailly.

***Set the Help Directory field in the Report Parameters screen to the directory where the file 'STARRSS.HLP' is located.***

STARRSS reads from this help file every time the user presses the <F1> key.

***Strategy ## (<Strategy Name>) has no options or programs  
--- Evaluating it as a do-nothing strategy***

The optimizers will sometimes suggest a strategy of allowance purchases and nothing else; the warning message is sent, but it is evaluated anyway.

*Strategy ##, conser./renew <Program Name> has zero impact*

*--- Using 9999.99 as marginal cost*

*Strategy ##, option <Unit Name>: <Option Name> had zero impact*

*--- Using 9999.99 as marginal cost*

STARRSS will evaluate options that have a cost but no impact; this, however, results in an undefined value for dollars per ton, so the arbitrary value of \$9999.99/ton is used.

*Study must begin after database start year (<Year>)*

If the database start year (on the Tax Rate screen) is later than 1995, the start year for evaluations or optimizations (on the Execution Parameters screen) must be set to 2000. The database start year cannot be set to 2001 or later.

*That file exists already: write over it?*

Replying "Y" will erase the old information written in that file and put the new information in its place. "N" will preserve the old information.

*The start and end years of the database, as specified on the Tax Rate screen, must start before <year> and end after <year>.*

This message indicates that the start year of the study (1995 for a Phase I run or 2000 for a Phase II run) is earlier than the start year of the database (taken from the Tax Rate, Escalation Rates, and Cost of Capital screen) or the end year of the study (the start year plus the study length as specified on the Execution Parameters screen) comes after the end year of the database (also on the Tax Rate screen). Extend the years on the Tax Rate screen or change the study period parameters.

***There are no choices among active options***

If only one choice (including choosing to do nothing!) is "active" for each option in the Define Active Compliance Options screen (accessed via the Develop STARRSS Strategies screen), then the optimizers have no work to do and will refuse to execute. Note that the active flags are all deactivated when the Phase I/Phase II flag is flipped (to prevent consideration of Phase II units in a Phase I run).

***There are no compliance options defined in this database***

***There are no strategies defined in this database***

***There are no units defined in this database***

Some forms cannot be entered without first defining objects in other screens.

***This operation may take more memory than you have available.***

Check the "Memory Available" table under the Files menu to see how much memory is available and how much is needed to perform various functions. The memory requirements are only estimates, and are generally on the high side, so execution may be possible even if the table indicates that it is not; but do so at your own risk -- remember that the database is always saved as "zbackup.sdb" at the start of an evaluation or optimization; in the event of a crash or program termination, zbackup.sdb will contain all the information the user had defined for the .sdb file prior to the crash.

***This report is too large to display at this time. Print the file <File Name> instead.***

The file name given in the warning message contains the report requested, although it is not formatted with page breaks, headers, or footers. Try saving the database then removing options to free up some memory.

***Undefined capacity factor at unit <Unit Name>***

You cannot exit from the Affected Unit Operating Factors screen if there is some unit without a capacity factor specified somewhere on page 2 or beyond.

***<Unit Name>: <Option Name> has a start date that is too late to qualify for Phase I Extension Bonus Allowances***

***--- skipping Phase I extension bonus allowance calculations***

If a pollution control technology option begins operation in 1998 or later for a Phase I affected unit, it will be ineligible for Phase I extension bonus allowances.

***<Unit Name>: <Option Name> has positive cost and increases emissions***

An example of this might be switching to a coal that has a higher sulphur content yet is more expensive than the baseline coal. This could happen in an apparently reasonable compliance option in a few scenarios where the costs came out high and the impact low.

***<Unit Name>: <Option Name> has zero cost***

The evaluation proceeds normally when a compliance option has zero cost, but this message alerts the user to this unusual situation.

***<Unit Name>: <Option Name> in strategy ## lies outside the study period.***

STARRSS will allow the user to specify strategies that cannot be evaluated under the currently specified execution phase, but the user will always be warned.

***<Unit Name>: <Option Name> is active outside of <Unit Name>'s lifetime***

This message means either the start year of the option precedes the commission date of the unit, or the start year plus the life of the option are greater than the retirement date of the unit.



***Unit <Unit Name> is in at least two redundancies***

Redundancies are sets of identical units. These sets cannot overlap.

***Unit <Unit Name> has an incorrectly defined fuel  
--- using zero cost and sulfur content for existing fuel***

The fuel blend specified on the Affected Unit Operating Factors screen must add up to 100%.

***Unit <Unit Name> has more than 256 options to consider***

The full enumeration optimizer won't work if more than 256 options are active at any one unit.

***Units cannot be deleted while there are redundancies, linkages, or user strategies defined. Please remove all of these structures from the database before deleting units.***

This rule avoids the confusion that could be caused if (for example) a unit were deleted but was still listed in a redundancy.

***You don't have graphics capability!***

This message indicates that whatever graphics capabilities the user's machine may have, they are not recognized or supported by the Borland C graphics subroutines that STARRSS uses.

***You must set the base and end years to something reasonable.***

The base year must be later than 1950, and the end year must be within 150 years of the base year.

# **APPENDIX C**

## **TROUBLESHOOTING**

This Troubleshooting appendix is meant to assist the user in solving operational problems that the user may encounter when using STARRSS. Potential problem areas have been broken down into the following general categories:

- ▶ **Invoking STARRSS**
- ▶ **Moving Around the System**
- ▶ **Changing Data Items**
- ▶ **Loading Files**
- ▶ **Evaluating**
- ▶ **Optimizing**
- ▶ **Reading Reports**
- ▶ **Reading Input Summaries**

## Invoking STARRSS

Problem	Explanation/Solution
"File not found"	STARRSS must be invoked from the directory where it has been placed. Change directory to that location before calling STARRSS. (e.g., CD C:\STARRSS)
"Cannot execute STARRSS.EXE"	There is not enough memory available to load the STARRSS executable. STARRSS requires 500,000 bytes of core memory. The user should eliminate unneeded memory-resident programs, or purchase more memory; however, STARRSS cannot make use of extended or expanded memory.
The program seems to be loaded into memory, but does not work properly.	Possibly the PC has an 8086 microprocessor. STARRSS is written for 80286 (or better) machines. It will not work on an 8086 or compatible.
The words, "STARRSS has been modified" appear on the banner page, and nothing else happens.	STARRSS copy-protection has been triggered somehow. This copy of the executable has been rendered unusable.
After the banner page, the words, "Can't open <File Name>" appear in a small window.	The user must have typed "STARRSS <File Name>," and <File Name> was not a valid STARRSS database.

## Moving Around the System

Problem	Explanation/Solution
The cursor cannot be positioned over some check marks.	Options belonging to a secondary unit in any redundancy are activated or deactivated depending on the options at the primary unit.
The user cannot exit the <i>Probabilities Associated with Forecasts</i> screen.	Each set of three probabilities must add up to 100% before the user can leave the screen.
The user cannot exit the <i>Affected Unit Operating Factors</i> screen.	Two specific data items must have values defined for them before the user can leave this screen. At least one capacity factor value must be defined; and a fuel or fuel blend that adds up to 100% must be defined.
The user cannot exit the <i>Edit/Define Compliance Options</i> screen.	A fuel or fuel blend adding up to 100% must be defined before the user can exit this screen.
The user cannot exit the <i>Generating Unit Redundance</i> screen.	The user will not be allowed to exit this screen if: two redundancies contain the same unit, any redundancy contains the same unit twice, or a redundancy contains only a primary unit.
Typing the name of a fuel on the <i>Fuels</i> screen does not bring up the cost and content data for that fuel.	Use the F2 key, while the cursor is on the fuel name, to move to a different fuel definition. Typing a name only changes the label on the current fuel.
STARRSS disappears and the user is presented with a DOS prompt.	The user may have accidentally selected "Temporarily Exit to DOS." Type "exit" to return to STARRSS.

(Continued)

## Moving Around the System (continued)

Problem	Explanation/Solution
Help screens are not available.	Go to page two of the <i>Reporting Parameters</i> screen and make sure the <i>Help Directory</i> references the directory that contains the file "STARRSS.HLP". If the user cannot locate the STARRSS.HLP file on his or her PC, the user should copy the file from the delivery diskette.
Graphical presentation of the results is not available.	Go to page two of the <i>Reporting Parameters</i> screen and change the <i>BGI Files Directory</i> to the directory that contains the graphical interface files. These are the files that were included on the delivery diskette which have the .BGI file name extension. If this does not work, graphics may be unavailable for this machine.

## Changing Data Items

Problem	Explanation/Solution
The name of a unit cannot be changed, even though the cursor is apparently over the correct field.	Unit names can only be changed on the <i>Display/Edit Affected Units</i> screen. Use the F2 key on a unit field to select between existing units.
The name of a fuel cannot be changed, even though the cursor is apparently over the correct field.	Fuel names can only be changed on the <i>Fuels</i> screen. Use F2 on a fuel field to select between existing fuels.
All of the checkmarks for a given unit cannot be turned off at once on the <i>Select Compliance Options</i> screen.	This is appropriate. The "Do Nothing" option must be activated if all of the other options are inactive.
Two checkmarks cannot be turned on at the same time on the <i>User Strategies</i> screen.	A strategy consists of no more than one option per unit. To model two options at once, construct a third option which is the combination of the first two.
The probability pointer on the <i>Allowance Sale Prices</i> screen cannot be changed.	This pointer is identical to the one on the <i>Allowance Purchase Price</i> screen; changing that pointer will change both.
The emissions field on the <i>Display/Edit Affected Units</i> screen is zero and cannot be changed.	<p>This is a calculated field; the user should check the unit's capacity, capacity factor, existing control technology, existing fuel blend, and fuel contents.</p> <p>Note that if the <i>Base Year</i> on the <i>Tax Rate</i> screen is set forward, every yearly value before the new <i>Base Year</i> in the system, including unit capacity factors, will no longer be available; this could cause a lot of values to go to zero.</p>
The <i>Existing Fuel Blend</i> on the <i>Define Compliance Options</i> screen cannot be changed.	The base fuel for each unit may be entered and edited on the <i>Affected Units Operating Factors</i> screen.

(Continued)

## Changing Data Items (continued)

Problem	Explanation/Solution
An item cannot be deleted.	Many values and structures in the database are interdependent; e.g., deleting a fuel that is in use by one or more units or compliance options could leave the database in a confusing state. To avoid this, references to an item must be removed before the item itself. Pop-up messages will provide guidance in this process.

## Loading Files

Problem	Explanation/Solution
No files are listed in the <i>Load</i> window.	There are no STARRSS databases (i.e., files with .SDB extensions) in the current directory; change to a different directory by typing S, then entering a new directory name.
The desired database is not listed in the <i>Load</i> window.	The file may be in a different directory. Change to the right directory (see above).
The database started to load, but there was an error.	Look up the error message in the Warnings appendix. Either STARRSS tried to load a file that was not a valid database, or not enough memory was available.
A STARRSS database has been renamed to something other than *.SDB, and it is therefore not listed in the <i>Load</i> window.	Type S, then enter the exact name of the file.



## Evaluating

Problem	Explanation/Solution
The evaluator's costs appear to be incorrect.	<p>1) Go to the <i>Input Summaries</i> section and verify that the inputs to the evaluator are correct.</p> <p>2) Examine the <i>Detailed Information File</i> (see the <i>Execution Parameters</i> discussion in section 7.0)</p>
A scrubber was not credited with bonus allowances.	<p>1) The <i>Technology Efficiency</i> field on the <i>Edit/Define Compliance Options</i> screen must indicate an efficiency of 90%, even if overrides are specified for the option, for bonus allowance calculations to be triggered.</p> <p>2) The EXISTING pollution control technology, defined on the <i>Affected Unit Operating Factors</i> screen, is irrelevant to bonus calculations.</p> <p>3) Bonus allowances may have been deactivated by values entered in the <i>Bonus Allowance Supply Percentage</i> table on the <i>Allowance Parameters</i> screen.</p>
The utility has no emissions.	<p>Use the <i>Input Summaries</i> to verify that appropriate values have been specified for the following:</p> <ul style="list-style-type: none"> <li>Each unit's capacity factors</li> <li>The base case and option fuel blends</li> <li>The fuel's SO<sub>2</sub> content</li> <li>The unit's capacity</li> <li>The unit's existing SO<sub>2</sub> removal technology efficiency</li> <li>The option's SO<sub>2</sub> removal efficiency</li> <li>The option's derate, capacity factor change, and emissions override values.</li> </ul>

## Optimizing

Problem	Explanation/Solution
Heuristic #1 only finds a single strategy.	Heuristic #1 searches for a single best strategy under each of a variety of scenarios. In some cases, it may judge a single strategy best under ALL scenarios. This single strategy may, on evaluation prove to have a relatively narrow distribution of costs (low risk).
Heuristic #1 does not find any strategies.	If the <i>Number of Iterations for Heuristic #1</i> field is set to zero, the Heuristic will do nothing.
The Optimizer finds fewer strategies than the number in the <i>Number of Plans to Save</i> field.	The Full Optimizer can only find as many strategies as there are combinations of activated options; the Heuristics will usually find even fewer.

## Reading Reports

Problem	Explanation/Solution
The best strategy turned out to be doing nothing but allowance purchases.	Check to see if the allowance prices are too low, or option prices, fuel prices, or escalation rates are too high.
The impact of some strategies is greater than the Reduction Target.	STARRSS tries to match each strategy's impact with the reduction target, but it may overcomply if the marginal compliance option overcomplies, and allowance sale limits prohibit the resale of all the extra allowances generated.
A strategy includes more allowance purchases than the permitted <i>Allowance Purchase Limit</i> .	STARRSS strategies will never undercomply; violation of purchase limits is always a last resort, and is flagged in the reports with an asterisk (*).
Two of the strategies generated by the optimizer are identical.	Look at the Detail Report -- different similar strategies may be given the same name.
The reports do not appear to pertain to the optimization or evaluation requested.	Check the date on the header of the reports; if there was an error during the execution then reports from a previous run may still be available.
No reports are available.	The evaluation or optimization failed for some reason and no reports were created.
Strategy A is cheaper than strategy B according to the Optimizer, but in the Evaluator B is cheaper than A.	The number of iterations for the Optimizers and the Evaluator may be set to different values.
The cost of Strategy A according to the Evaluator is different from the Optimizer's evaluation.	
Some reports are blank.	There will be no units listed in certain reports if the only strategy(-ies) evaluated consisted solely of allowance transactions.
The Optimizer's suggested plans are not very good ones.	Try a different Optimizer; each has its strengths and weaknesses.

## Reading Input Summaries

Problem	Solution
Some fields are "dashed out."	<p>1) Option cost and impact overrides may have been specified; dashes through other fields indicate that they will be ignored.</p> <p>2) Dashes can also indicate that there is no change from the base case situation.</p>
A unit's base case "SO <sub>2</sub> rate" is zero.	<p>Check the following:</p> <ul style="list-style-type: none"><li>The unit's capacity factor</li><li>The unit's base case fuel blend</li><li>The fuels' SO<sub>2</sub> content</li><li>The unit's capacity</li><li>The unit's existing SO<sub>2</sub> removal technology efficiency</li></ul>

## APPENDIX D

### UNIT CONVERSIONS

<u>To convert from</u>	<u>to</u>	<u>Multiply by</u>
barrel (bbl)	m <sup>3</sup>	1.590 E-01
Btu	joules	1.055 E+03
Btu/h	watts	2.928 E-01
ft <sup>3</sup>	m <sup>3</sup>	2.832 E-02
gallon	m <sup>3</sup>	3.785 E-03
lb	kg	4.536 E-01
ton	kg	9.078 E+02
ton	tonne	9.078 E-01

# APPENDIX E

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