Evaluation of Data Submitted in APPA's 2003 Distribution System Reliability & Operations Survey

by

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EVALUATION OF DATA SUBMITTED IN APPA's 2003 DISTRIBUTION SYSTEM RELIABILITY & OPERATIONS SURVEY

Introduction

"Power system reliability is measured in terms of the ability of a power system to provide electricity to end users."

— "Optimizing Power Quality and Reliability Initiatives," *Transmission & Distribution World,* February 2004

The 2003 APPA Reliability and Operations Survey evaluates how well public power systems are providing service to their end-use customers. This was accomplished by posing survey questions that covered eight areas:

1. Outage Tracking
2. IEEE – P1366
3. Sustained Outages
4. Momentary Outages
5. Outage Restoration
6. Power Quality
7. Work Force Issues
8. System Operation

Circulation Statistics

The survey was circulated to APPA's membership that maintains distribution systems, and yielded a total of 179 respondents. The 2003 survey had an increase of 53 responses from the 2001 survey. The respondents represent 49 percent of all the customers that public power systems serve. The 49 percent is a decrease of three (3) percent from the 2001 survey. The responding utilities ranged in customer-meter size from 434 to 1.4 million. When categorizing the

respondents according to customer-meter size and comparing that to the 2001 survey, there was a substantial increase in the less than 4,000 customer-meters category. Geographically, the respondents are in 37 of the 50 states and two U.S. territories.

Figure 1

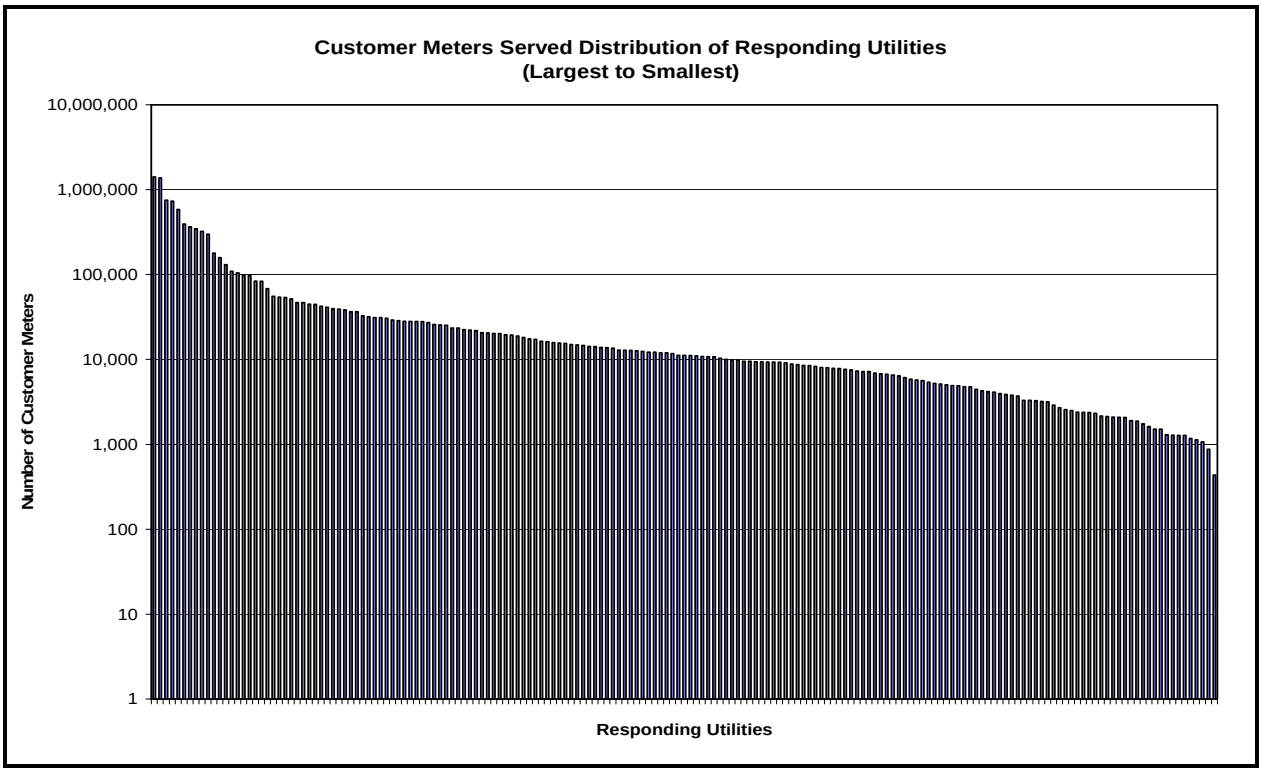
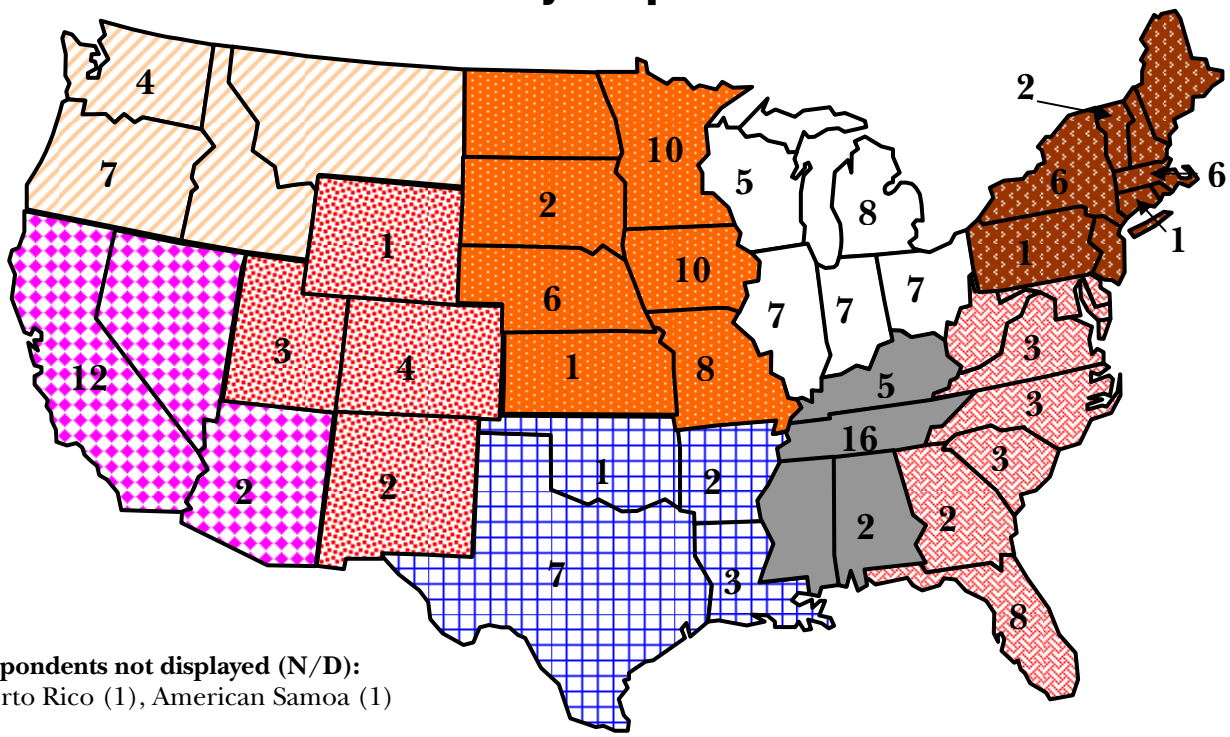


Figure 2 on the following page shows the state and regional breakdown of survey responses.

Figure 2

Survey Respondents



Respondents not displayed (N/D):
Puerto Rico (1), American Samoa (1)

Region 1 – Wyoming, Colorado, New Mexico, Utah – *Total responses (10)*

Region 2 – Indiana, Illinois, Michigan, Ohio, Wisconsin – *Total responses (34)*

Region 3 – Minnesota, Iowa, Missouri, Kansas, Nebraska, North Dakota, South Dakota – *Total responses (37)*

Region 4 – Oklahoma, Arkansas, Texas, Louisiana – *Total responses (13)*

Region 5 – Maryland, Delaware, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida – *Total responses (19)*

Region 6 – Nevada, Arizona, California – *Total responses (14)*

Region 7 – Kentucky, Tennessee, Mississippi, Alabama – *Total responses (23)*

Region 8 – Maine, New Hampshire, Vermont, Connecticut, Rhode Island, Massachusetts, New Jersey, New York, Pennsylvania – *Total responses (16)*

Region 9 – Montana, Idaho, Washington, Oregon, Alaska – *Total responses (11)*

N/D **Region 10** – American Samoa, Federated States of Micronesia, Guam, Northern Mariana Islands, Palau, Puerto Rico, Virgin Islands – *Total responses (2)*

N/A **Region 11** – Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Nunavut, Ontario, Prince Edward Island, Quebec, Saskatchewan, Yukon – *Total responses (0)*

I. RELIABILITY

Overall Evaluation

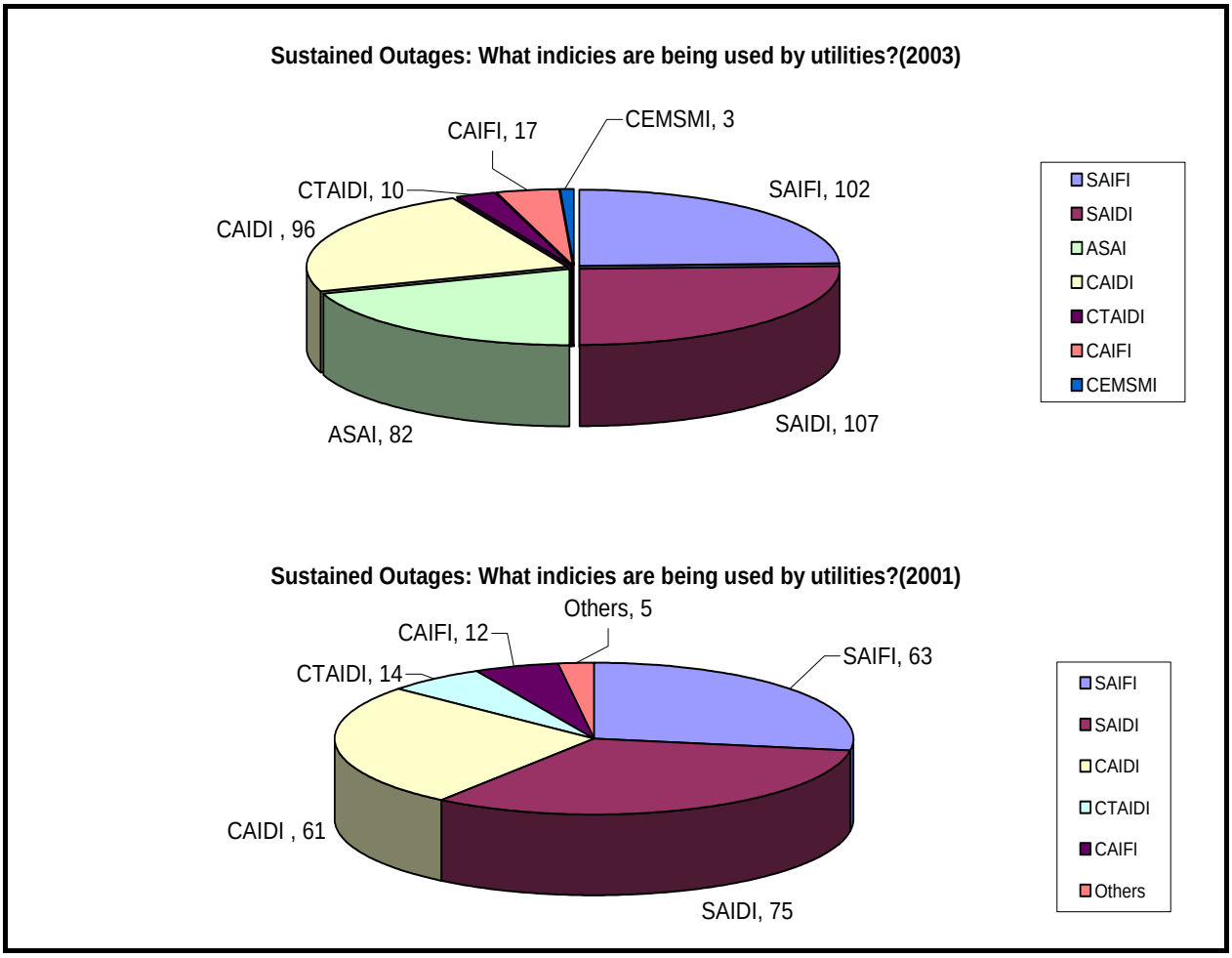
Sustained Outages

In the 2001 survey respondents were asked the types of reliability indices that they used. The responses indicated that most utilities used the System Average Interruption Duration Index (SAIDI) (59 percent) and System Average Interruption Frequency Index (SAIFI) (50 percent). With respect to the 2003 survey the same question was posed, and again System Average Interruption Duration Index (57 percent) and System Average Interruption Frequency Index (56 percent) were identified as the most used indices.

The 2003 survey included two additional indices that were not mentioned in the 2001 survey. They were the Average System Availability Index (ASAI) and the Customer Experiencing Multiple Sustain and Momentary Index (CEMSMI). ASAI was the fourth highly used index at 45 percent. However, the CEMSMI was the least used index at approximately two (2) percent.

Figure 3 graphically displays the number of utilities that use each type of index. Many utilities apply more than one index to their distribution system.

Figure 3



Each utility was asked to input their distribution utility statistics for each index for the period of January 1, 2002 – December 31, 2002. The statistics for each index were averaged and are represented in Table 1. When comparing **Table 1 and Table 2**, the results show a reduction in three of the five indices. SAIDI increased by 9.21 minutes and Customer Total Average Interruption Duration Index (CTAIDI) increased by 5.34 minutes. These differences could be attributed to the increased number of respondents.

Table 1. Overall Averages of Sustained Reliability Indices from January 1 – December 31, 2002

SAIFI (Interruptions per year)	SAIDI (Minutes per year)	CAIDI (Minutes)	CTAIDI (Minutes)	CAIFI (# of Sustained Interruptions)
3.24	65.09	65.91	23.15	2.10

Table 2. Overall Averages of Sustained Reliability Indices from January 1 – December 31, 2000

SAIFI (Interruptions per year)	SAIDI (Minutes per year)	CAIDI (Minutes)	CTAIDI (Minutes)	CAIFI (# of Sustained Interruptions)
4.68	55.88	91.03	17.81	10.67
Percentage change between 2000 and 2002				
–30%	+16%	–27%	+29%	–80%

Tables 3 and 4 on the next page are the averages of the sustained outage indices for responding utilities in the 2001 and 2003 surveys. A comparison of Table 3 and Table 4 shows that although customers are experiencing longer outages time wise there are fewer number of outages.

Table 3. Typical Reliability Index for Publicly Owned Utilities (2003 Reliability Survey)

	SAIFI (Per year)	SAIDI (Minutes per year)	CAIDI (Minutes)
Average of top 25%	0.16	7.81	22.69
Average of top 25 – 50%	0.59	33.24	50.79
Average	3.24	65.09	65.91
Average of 50% – 75%	1.12	61.98	68.81
Average of bottom 25%	10.52	160.87	121.36

Table 4. Typical Reliability Index for Publicly-Owned Utilities (2001 Reliability Survey)

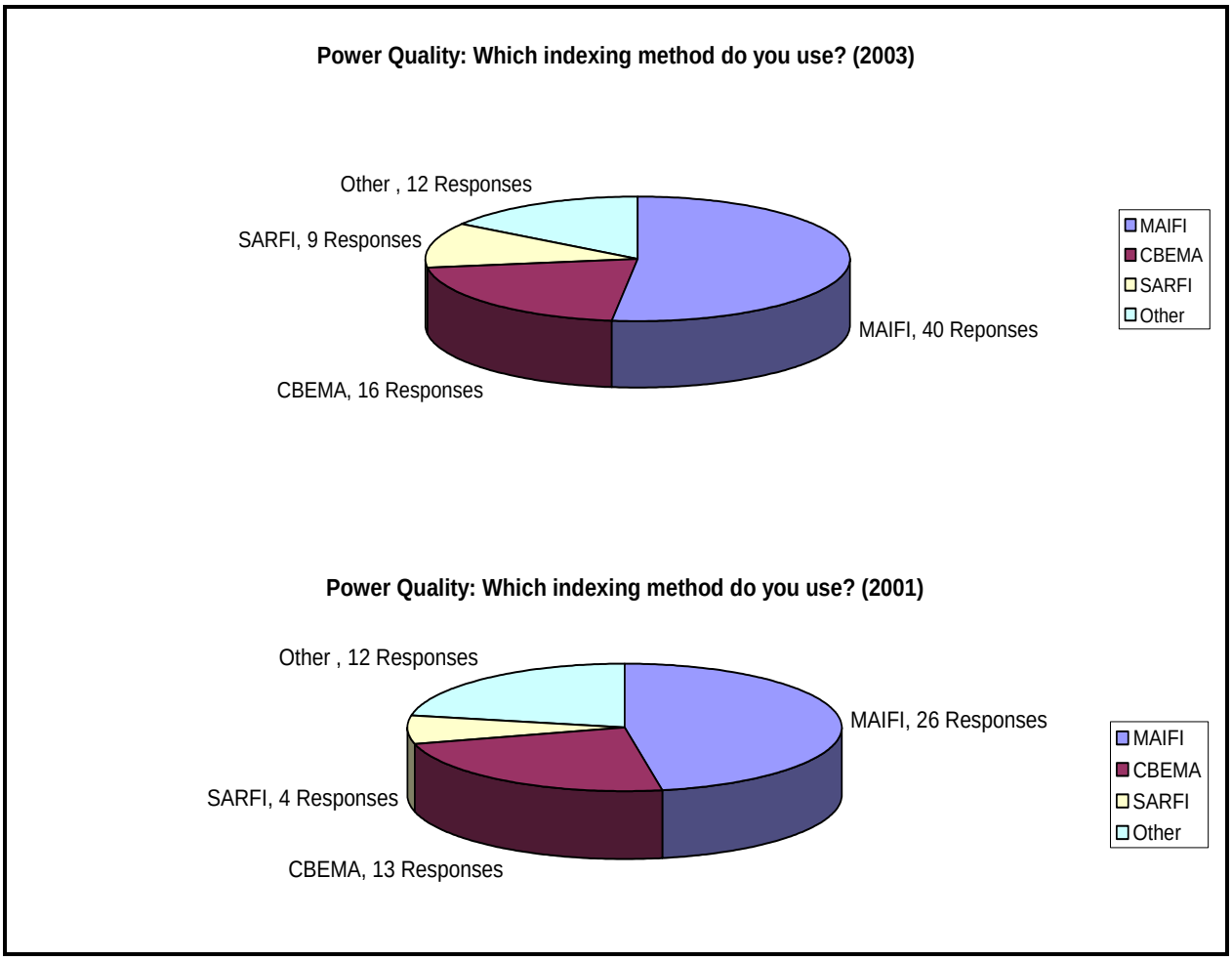
	SAIFI (Per year)	SAIDI (Minutes per year)	CAIDI (Minutes)
Average of top 25%	0.27	5.63	29.43
Average of top 25 – 50%	0.71	27.98	58.07
Average	4.68	55.88	91.03
Average of 50% – 75%	1.21	55.04	78.58
Average of bottom 25%	17.23	126.44	215.97

Momentary Outages

Additional indexing methods used by responding utilities are Momentary Average Interruptions Frequency Index (MAIFI), Computer Business Equipment Manufacturers Association curve (CBEMA), System Average RMS Variation Frequency Index (SARFI), and "Other." Some of the "Other" indices used were SAG Energy Index and ITTC.

Figure 4 displays the number of utilities that are currently using these momentary outage indices and the number of utilities that identified using the same momentary indices in the 2001 survey. The majority of the utilities are still using MAIFI, CBEMA, and Other.

Figure 4



The 40 utilities that acknowledge using MAIFI included their MAIFI statistics for the period of January 2002 – December 2002. In this 2003 survey, the overall average MAIFI (based on interruption lasting less than five minutes) was 21.17 interruptions per year. This is an increase of 18.49 yearly interruptions in comparison to the 2001 survey MAIFI data.

Tables 5 and 6 display the MAIFI averages regionally and by number of customer meters.

Table 5

Region	MAIFI (# of interruptions <5 minutes)
Region 1	0.744
Region 6	0.747
Region 8	1.5
Region 2	1.86
Region 10	2.01
Region 3	2.36
Region 4	4.22
Region 9	7.00
Region 5	9.01
Region 7	146.88

Table 6

Customer Meters	MAIFI (# of interruptions <5 minutes)
40,001 to 100,000	0.74
0 to 4,000	3
More than 100,000	3.33
4,001 to 10,000	3.53
10,001 to 20,000	3.63
20,001 to 40,000	75.38

Regional Evaluation

Shifting from a national to a regional view of reliability, we evaluated the data based on APPA's regional breakdown of the U.S. For a breakdown of the states and territories in the APPA regions, refer to Figure 2 on page 3.

Table 7 displays the sustained outage indices that are being used in each of the 10 regions. In each of the regions, municipal systems are predominately using the three major indices: SAIFI, SAIDI, and CAIDI. Some utilities are implementing CTAIDI, CAIFI, and others, but not as frequently as SAIFI, SAIDI, and CAIDI.

Table 7

Region	SAIFI	SAIDI	ASAI	CAIDI	CTAIDI	CAIFI	CEMSMI
Region 1	**6**	**5**	**5**	**6**	**3**	**3**	**0**
Region 2	**18**	**21**	**15**	**18**	**2**	**3**	**2**
Region 3	**20**	**21**	**20**	**20**	**0**	**2**	**0**
Region 4	**11**	**11**	**7**	**10**	**2**	**2**	**0**
Region 5	**8**	**8**	**7**	**7**	**0**	**2**	**0**
Region 6	**8**	**8**	**3**	**5**	**0**	**2**	**0**
Region 7	**15**	**16**	**15**	**16**	**3**	**3**	**1**
Region 8	**7**	**6**	**5**	**7**	**0**	**0**	**0**
Region 9	**7**	**9**	**5**	**5**	**0**	**0**	**0**
Region 10	**2**	**2**	**0**	**1**	**0**	**0**	**0**

Averages for the three major indices (**SAIDI, CAIDI, and SAIFI**) were calculated for each APPA region. **Tables 8–10** on the following pages rank the regions and show a comparison to the 2001 statistics.

Table 8. System Average Interruption Frequency Index (SAIFI)

2003		Percentage Change from 2001 to 2003
Region 9	.30 interruptions per year	–65%
Region 1	.52 interruptions per year	–99%
Region 6	.69 interruptions per year	–26%
Region 3	.85 interruptions per year	–9%
Region 5	1.27 interruptions per year	–84%
Region 8	1.92 interruptions per year	+42%
Region 7	2.27 interruptions per year	–22%
Region 10	3.97 interruptions per year	+30%
Region 2	7.50 interruptions per year	+525%
Region 4	9.2 interruptions per year	+464%

Table 9. System Average Interruption Duration Index (SAIDI)

2003		Percentage Change from 2001 to 2003
Region 2	29.88 minutes per year	+146%
Region 9	30.88 minutes per year	–41%
Region 6	39.15 minutes per year	+15%
Region 3	50.13 minutes per year	+68%
Region 1	55.68 minutes per year	–0.62%
Region 8	61.48 minutes per year	+101%
Region 5	62.28 minutes per year	–8%
Region 4	92.45 minutes per year	+58%
Region 7	126.11 minutes per year	+3513%
Region 10	234.50 minutes per year	+104%

Table 10. Customer Average Interruption Duration Index (CAIDI)

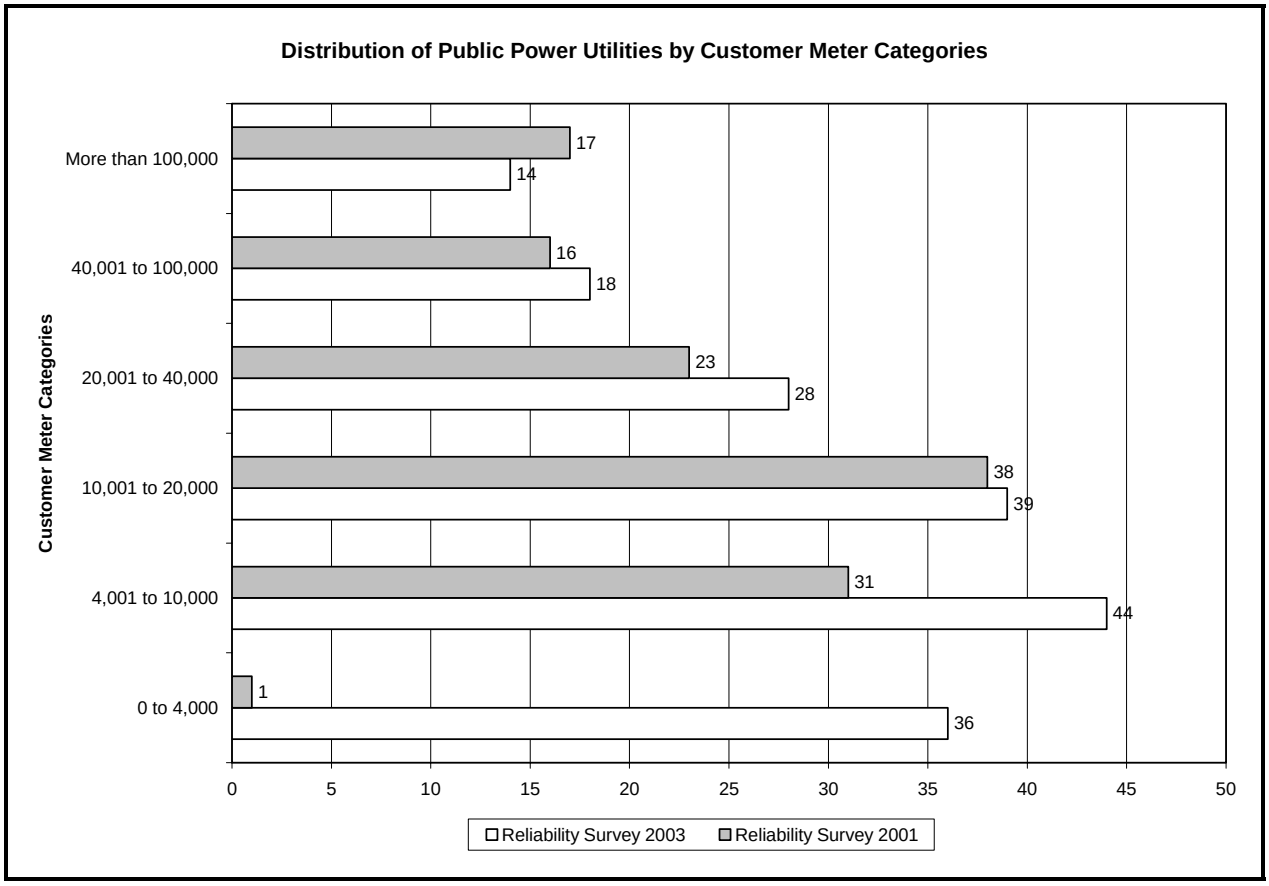
2003		Percentage Change from 2001 to 2003
Region 10	**41.98 minutes**	**–21%**
Region 4	**50.22 minutes**	**–88%**
Region 8	**50.98 minutes**	**+34%**
Region 3	**55.64 minutes**	**+24%**
Region 5	**57.04 minutes**	**+16%**
Region 2	**63.65 minutes**	**–22%**
Region 7	**67.17 minutes**	**+56%**
Region 1	**79.54 minutes**	**+91%**
Region 6	**101.29 minutes**	**+97%**
Region 9	**132.72 minutes**	**+116%**

Utility Size Evaluation

The respondents were categorized according to six customer-meter categories. In the 2001 survey the 0 to 4,000 customer-meter category had only one respondent, so for 2003 efforts were focused on getting more responses from this category. Responses increased by 3,500 percent in this category. Many of the other customer-meter categories experienced slight to moderate increases in responses except for the "More than 100,000," which decreased by three.

See **Figure 5** on the next page for a graphical representation of responses by customer-meter categories.

Figure 5



Below, **Table 11** is an evaluation of responses that indicated the use of sustained outage indices based on customer-meter categories.

Table 11

Customer-Meter Category	SAIFI	SAIDI	CAIDI	CTAIDI	CAIFI	ASAI
0 to 4,000	5	3	5	1	1	3
4,001 to 10,000	30	31	28	6	7	26
10,001 to 20,000	20	22	19	1	2	17
20,001 to 40,000	22	24	21	0	2	19
40,001 to 100,000	12	14	11	1	1	9
More than 100,000	13	13	11	1	3	8

According to the customer-meter breakdown, the indices that are widely used are SAIFI, SAIDI, and CAIDI. The tables below and on the next page, **Tables 12–14,** display the sustained outage indices according to customer-meter categories and the calculated averages of each category. Each table is ranked from least to most within the corresponding category.

Table 12

Customer-Meter Category	SAIFI (Interruptions per year)
40,001 to 100,000	.77
10,001 to 20,000	1.12
20,001 to 40,000	2.52
4,001 to 10,000	3.84
0 to 4,000	4.18
More than 100,000	8.22

Table 13

Customer-Meter Category	SAIDI (Minutes per year)
10,001 to 20,000	51.64
4,001 to 10,000	51.96
20,001 to 40,000	52.37
40,001 to 100,000	64.08
More than 100,000	114.06
0 to 4,000	179.58

Table 14

Customer-Meter Category	CAIDI (Minutes)
0 to 4,000	37.89
40,001 to 100,000	60.89
10,001 to 20,000	61.97
More than 100,000	64.81
4,001 to 10,000	67.45
20,001 to 40,000	78.21

How Are Utilities Defining Outages?

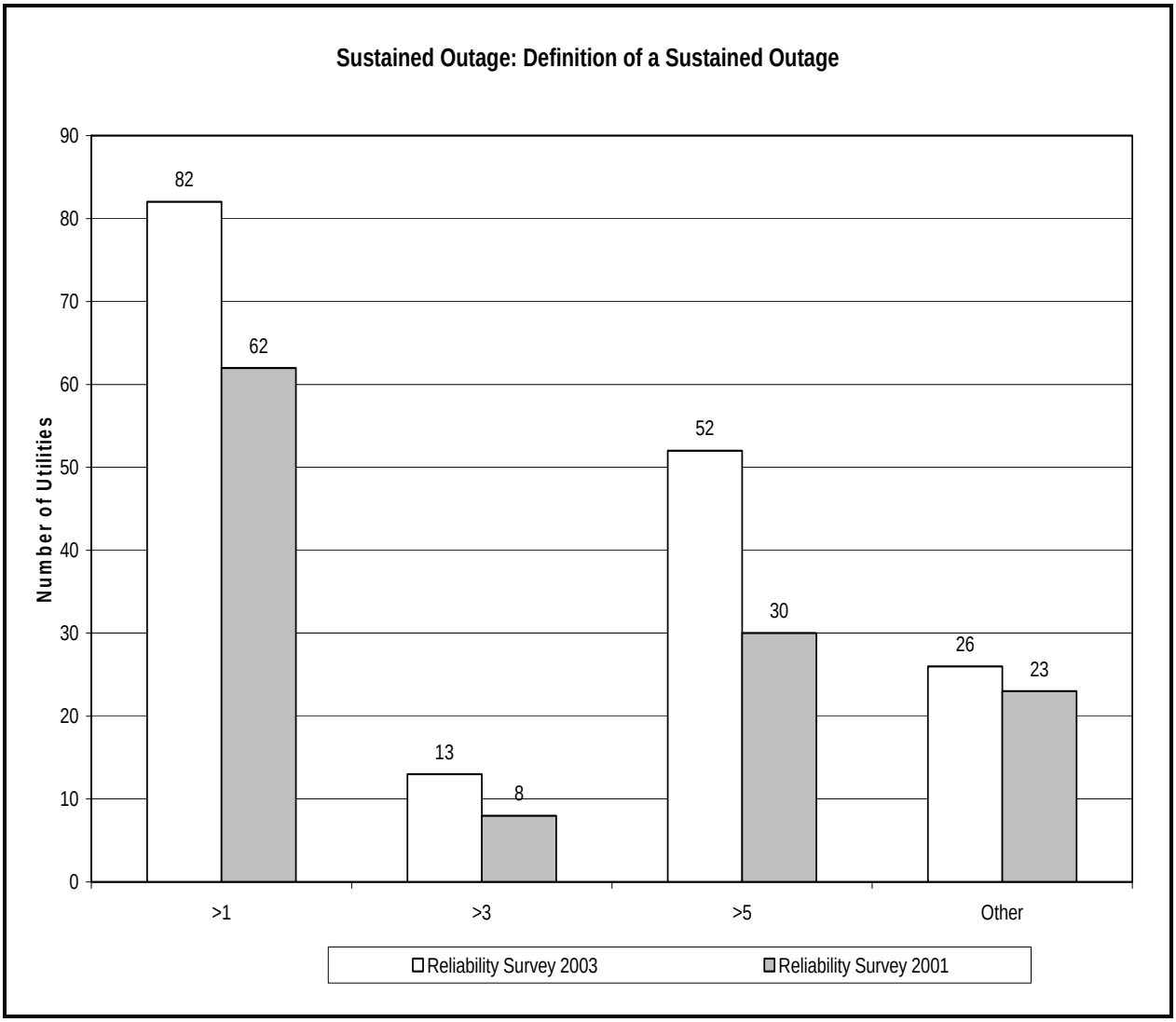
Sustained Outages

In the survey respondents were asked to define outages from the perspective of time and events. Sustained outages were categorized in periods: greater than one (1); three (3); five (5) and other minutes.

The trend in defining sustained outages from the 2001 survey to the 2003 survey remained consistent. A majority of the utilities identified either "greater than 1 minute" or "greater than 5 minutes" as how they define a sustained outage. In the category of "Other" the number of respondents between 2001 and 2003 were very similar. Some of the "Other" definitions of sustained outages were: greater than two (2) minutes, lockout of protective devices, and customer call-ins.

See **Figure 6** on the next page.

Figure 6

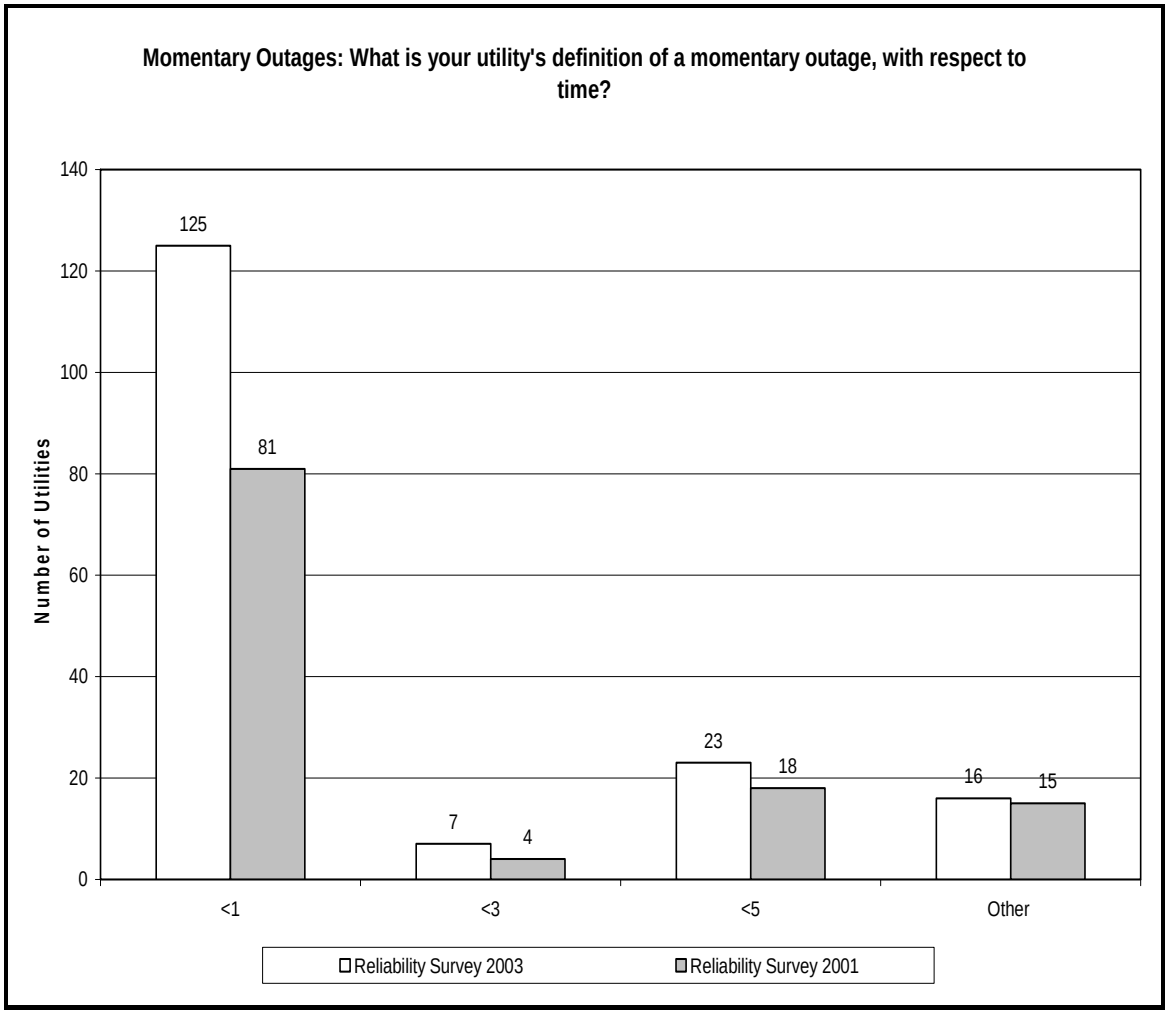


Momentary Outages

Momentary outages were categorized in periods: less than one (1), three (3), five (5) and other minutes. Ninety-five (95) percent of the total respondents, 171, in the 2003 survey answered this question. This represents a two (2) percent increase from 2001. The majority of the respondents, 125, indicated that they define momentary outages as less than one minute, much like the 2001 survey.

See **Figure 7** on the following page.

Figure 7



Which Types of Outages Are Tracked?

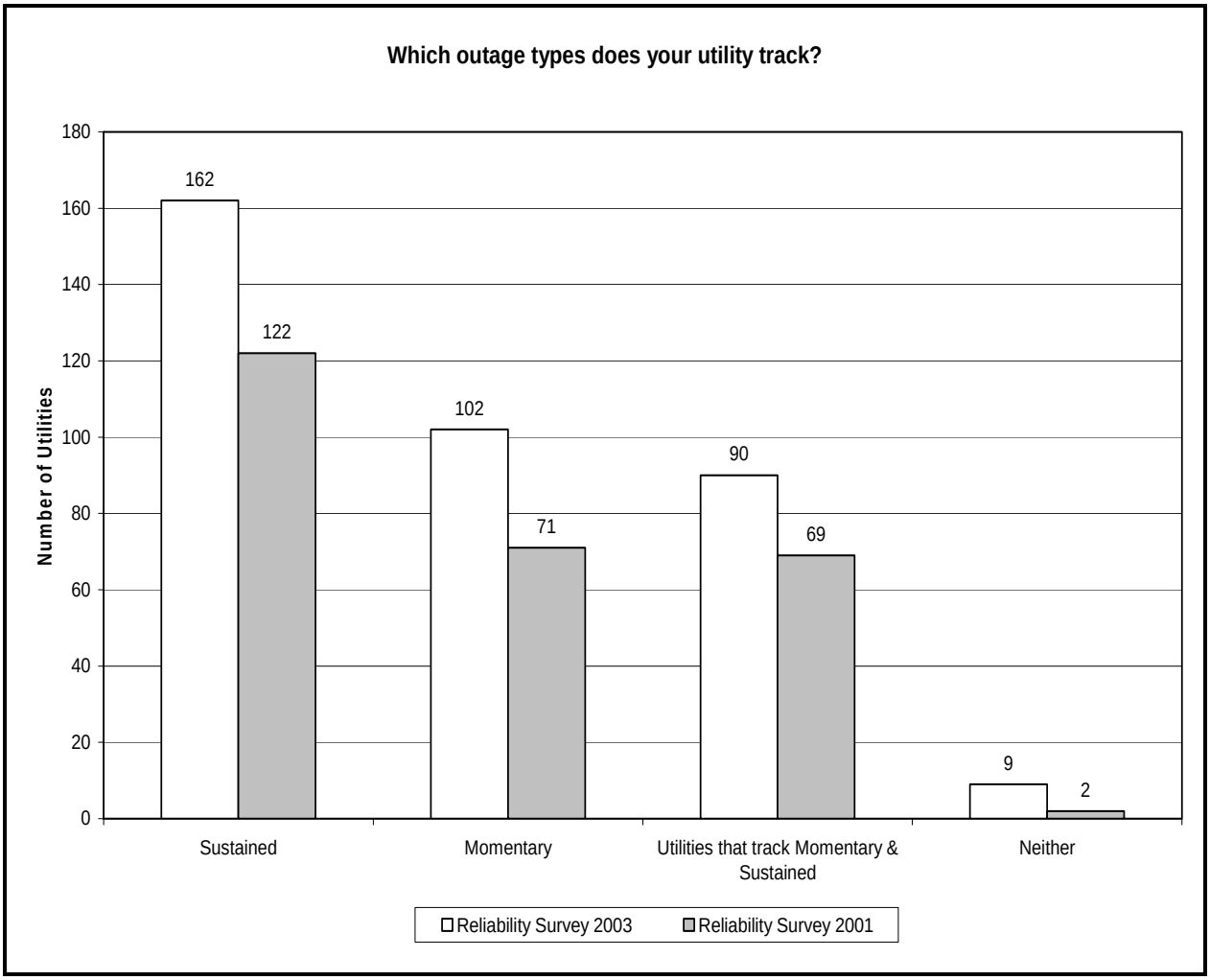
National

The 2003 survey shows a significant increase in the number of utilities tracking types of outages when compared to the 2001 survey statistics. However, comparison according to percentage of response yields different answers:

- Sustained outages—The 2001 survey had 96 percent while in 2003 it was only 90 percent.
- Momentary outages remained relatively the same, 56.3 percent in 2001 and 56.9 percent in 2003.

- Both momentary and sustained outages decreased by four percent from 2001 (54 percent) to 2003 (50 percent).
- Neither increased by 3.5 percent from 2001 (1.5 percent) to 2003 (5 percent).

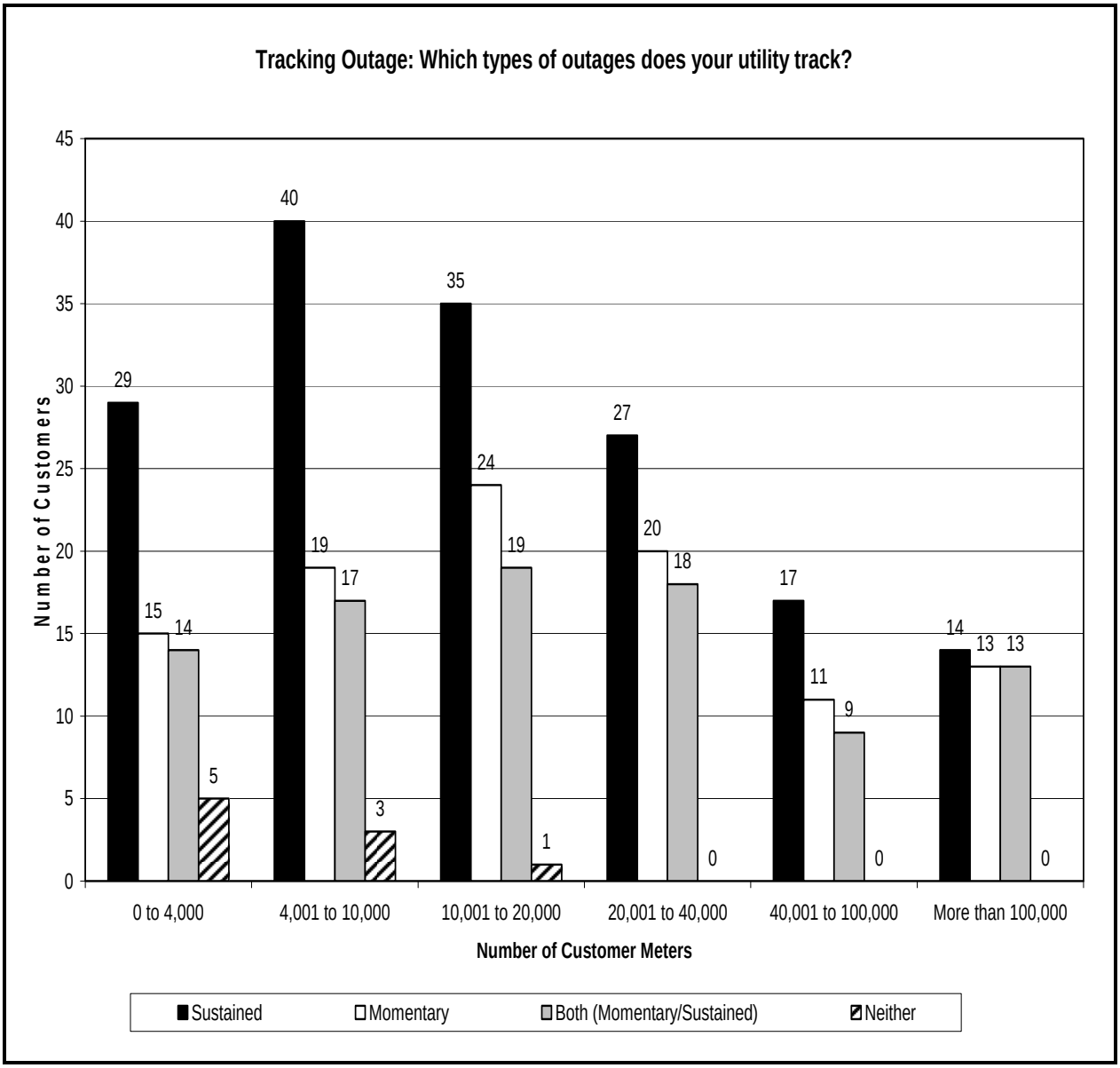
Figure 8



Utility Size

Figure 9 on the next page displays the types of outages tracked according to utility size. This graph emulates the 2003 national perspective as seen in the previous graph.

Figure 9

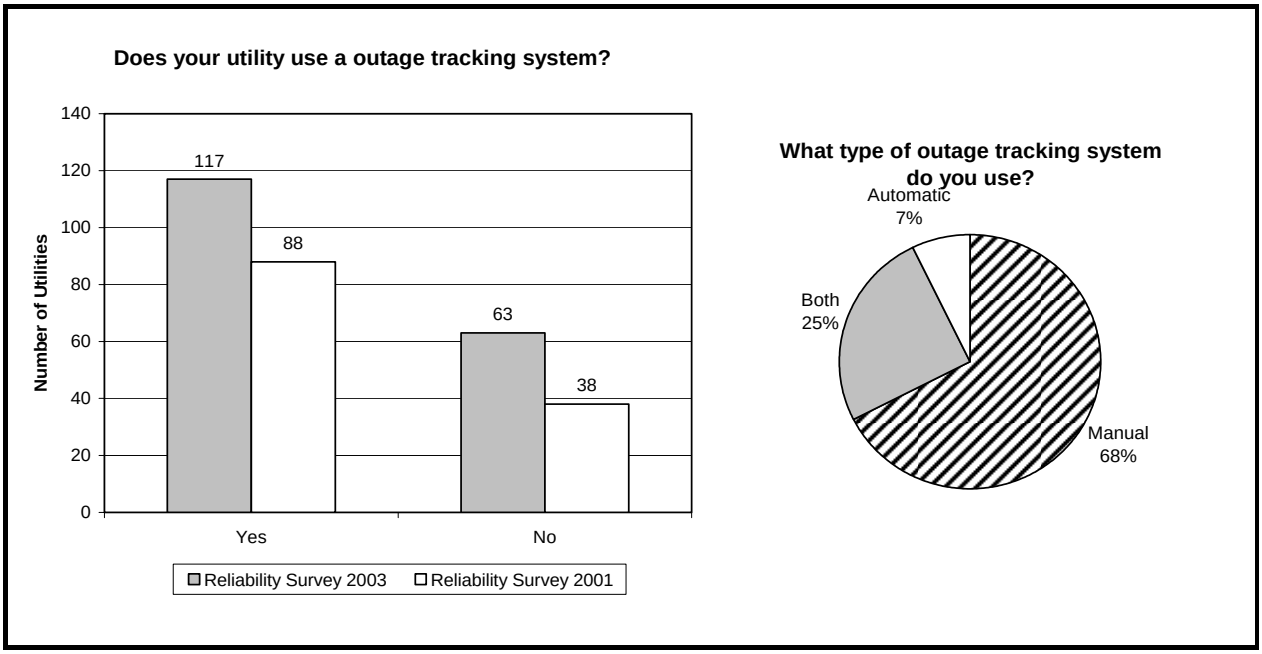


Outage Tracking Systems

We first determined how many utilities use outage-tracking systems. Of the 179 utilities that responded to this question, 117 utilities have an outage tracking system. This is a 32 percent increase from the 2001 survey. Sixty-three (63) utilities do not have an outage tracking system, which is a 65 percent increase from 2001. Almost 61 percent of utilities that do not have outage tracking systems are in the 0 to 4,000 customer-meter category.

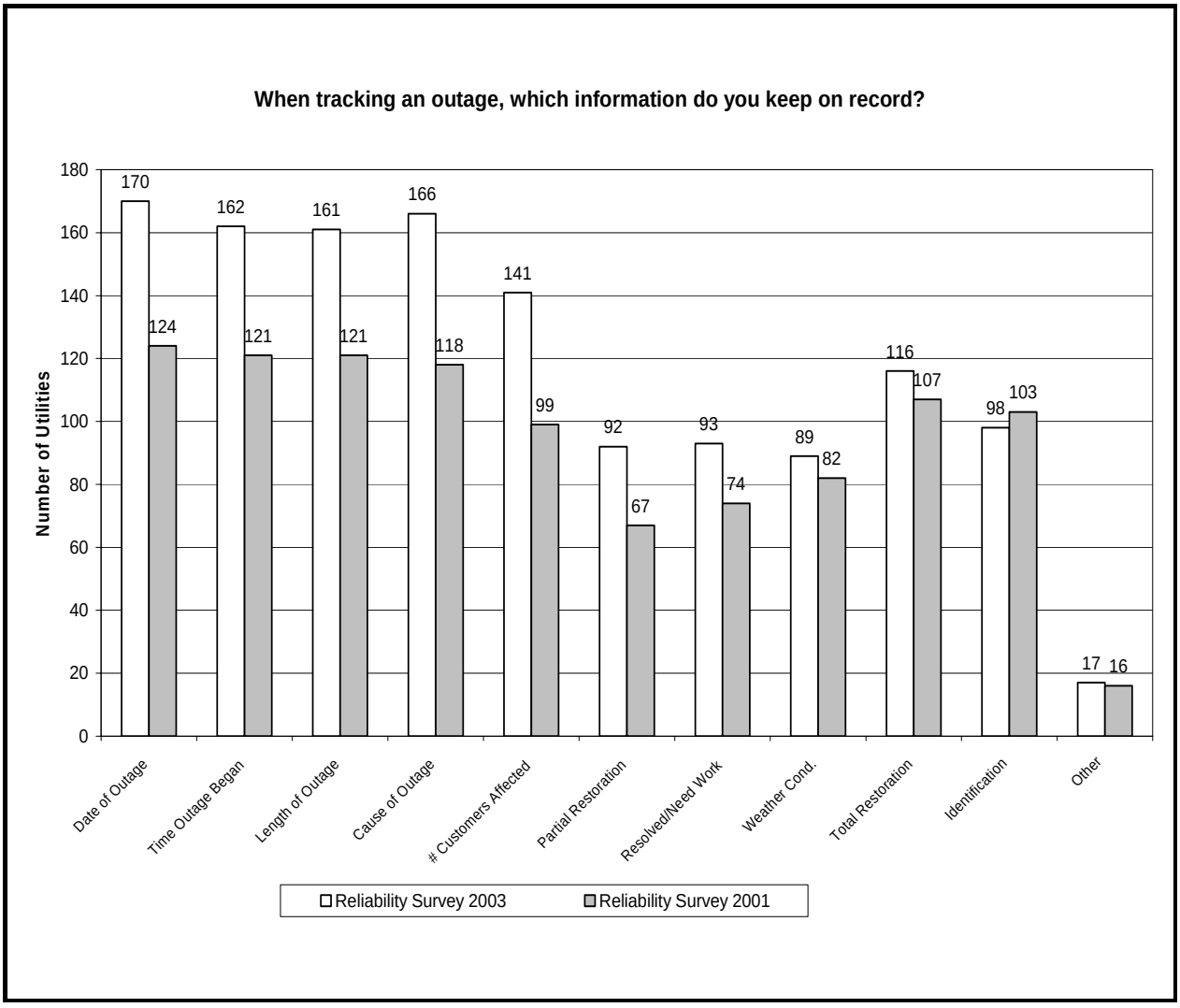
The utilities that do have an outage tracking system were asked to indicate the type of outage tracking system used. Sixty-eight (68) percent used a manual system to track outages while only seven (7) percent were using automatic systems. The 40,000 to 100,000 customer-meter range had the largest number of respondents to indicate using automatic outage tracking systems. (See **Figure 10** below.)

Figure 10



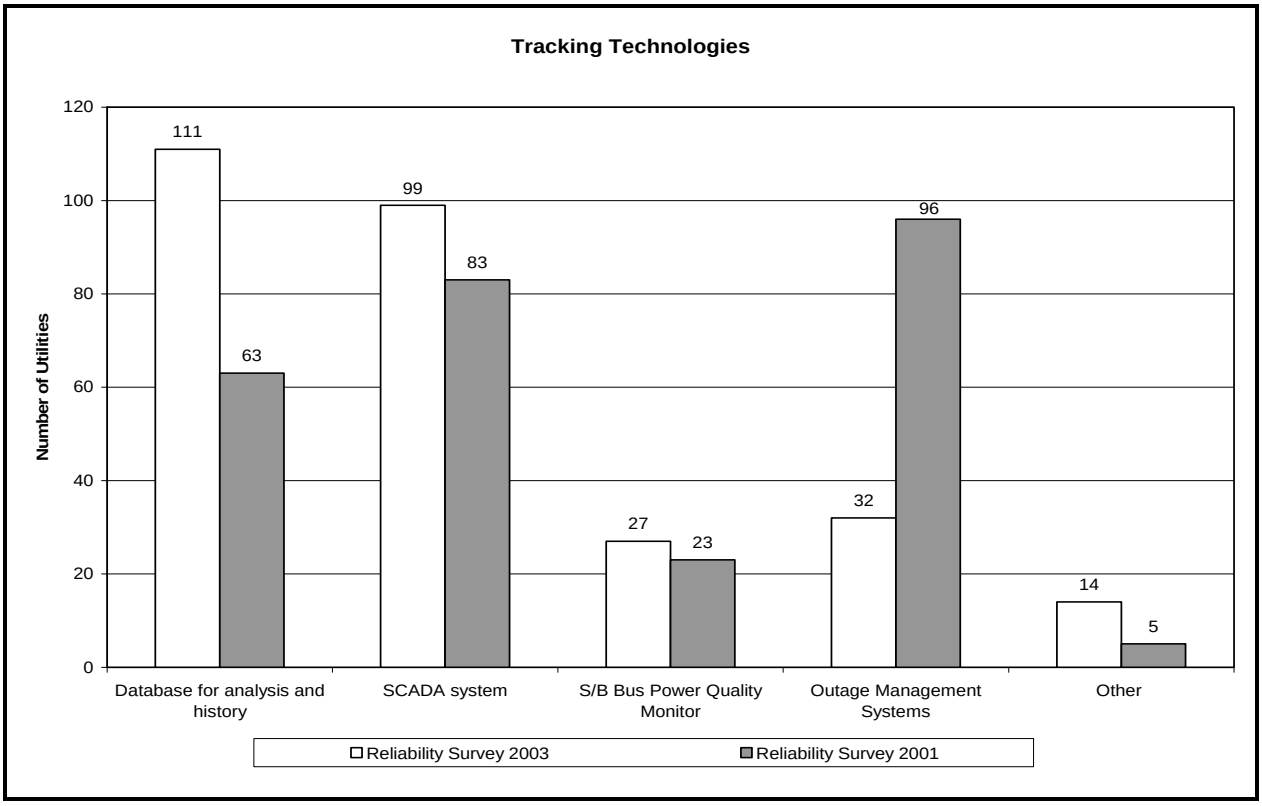
For tracking, utilities keep records of various things related to the outage such as time, date, weather conditions, etc. This survey asked respondents what types of information they keep record of during an outage. Ninety-four (94) percent keep track of the date, which was the largest category in the 2001 survey. However, the number of utilities that are keeping a record of line identification, poles, etc., has decreased by one (1) percent. Some of the "Other" information that utilities are keeping track of during outages are key accounts, crew members working, and repair actions. See **Figure 11** on the next page for more information.

Figure 11


When tracking an outage, which information do you keep on record?
Number of Utilities
180
160
140
120
100
80
60
40
20
0
170
124
162
121
161
121
166
118
141
99
92
67
93
74
89
82
116
107
98
103
17
16
Date of Outage
Time Outage Began
Length of Outage
Cause of Outage
Customers Affected
Partial Restoration
Resolved/Need Work
Weather Cond.
Total Restoration
Identification
Other
Reliability Survey 2003
Reliability Survey 2001

To keep track of the outages and associated information, such as equipment failure, date, weather conditions, etc; many utilities use various pieces of equipment to record this vital information. The majority of the responding utilities identified using databases (111) and /or SCADA systems (99). Thirty-two (32) utilities responded to using outage management systems, a 66 percent decrease from the 2001 survey. The large difference in the numbers between the 2001 and 2003 survey could be attributed to the expanded survey, which resulted in a change of placement for this question on the survey. See **Figure 12** below.

Figure 12



II. OPERATIONS

These sections will discuss some of the operational questions that were posed on the 2003 survey. Just like in the previous section, there will be comparisons to the 2001 survey, national, region, and the customer-meter categories. The following are the topics that will be evaluated:

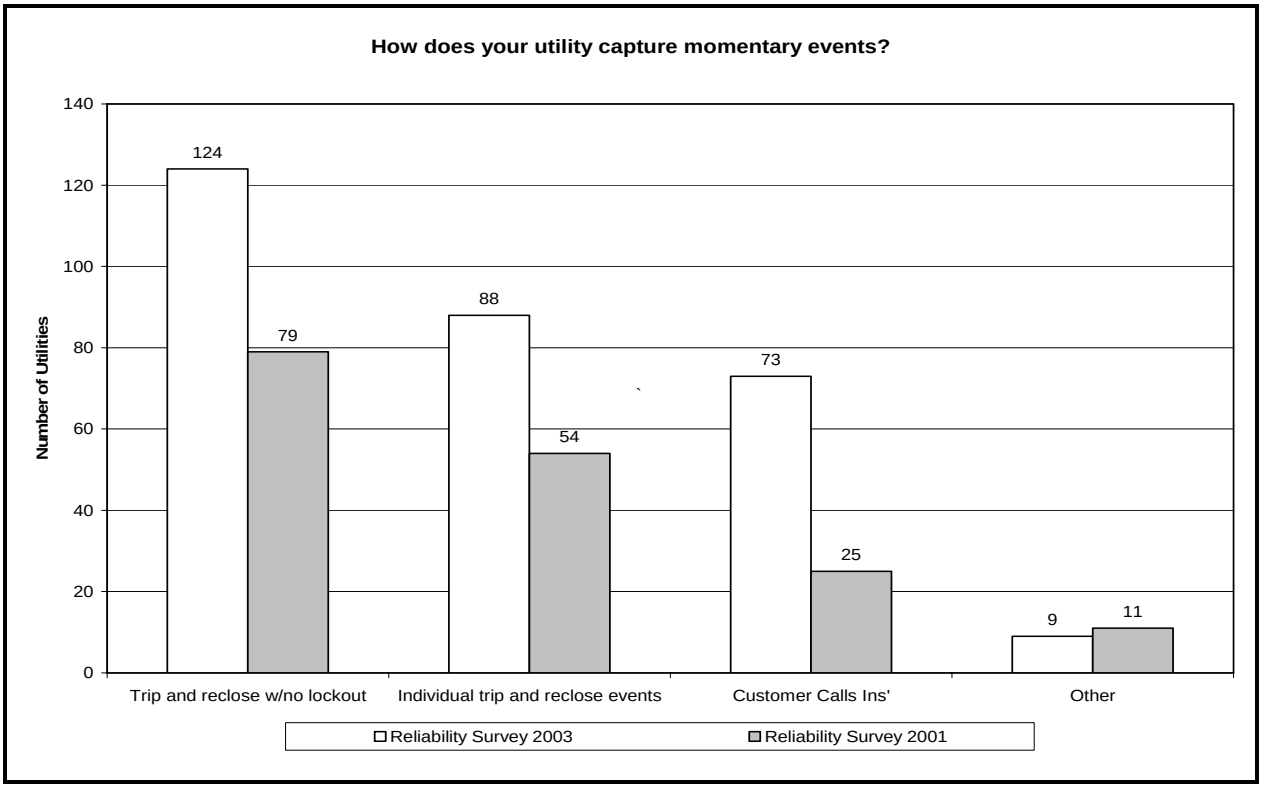
- **Power Quality—**Capturing momentary outages, recording voltage deviation and total harmonic distortion and power quality (PQ) indexing methods;
- **Outage Restoration—**Catastrophe plan and mutual assistance agreements and SCADA;
- **Work Force Issues—**Line crew coverage (24x7 and storms), average number of crews, and utility vehicle usage policies;
- **System Operation—**Substation, distribution, and relaying practice.

Power Quality

In the section titled "How do utilities define outages?" over seventy-three (73) percent of the 2003 respondents have identified momentary as less than one minute. To delve deeper, the next logical question would be: How does your utility capture momentary events? This same question was posed in the 2001 survey, and a majority of the respondents indicated "trips and reclose without lockout" as the way they captured momentary outages. In the 2003 survey 124 respondents indicated this same method of capturing momentary events.

See **Figure 13** on the following page.

Figure 13



Some utilities use more than one of the identified indicators to capture momentary events. "Other"' methods utilities use for capturing momentary events are SCADA and Substation Bus Monitoring.

An element of power quality that was addressed in this survey was the recording of voltage deviation at the substation bus. Fifty-four (54) percent of the responding utilities answered "Yes" to recording voltage deviation at the substation bus. This is down by three (3) percent when compared to the 2001 survey.

Table 15

Do you record voltage deviation at the substation bus?	
Yes	**96**
No	**67**

One hundred sixty-one (161) utilities responded to the question on recording the total harmonic distortion (THD) within the distribution system. The utilities that responded "Yes" represent 24 percent of the responding utilities. This is a six (6) percent decrease in comparison to the 2001 survey, where 30 percent of the responding utilities replied "Yes" to measuring THD.

Table 16

Do you record Total Harmonic Distortion (THD) levels anywhere on your system?	
Yes	**43**
No	**131**

For the utilities that responded positively to recording THDs, an additional question was posed as to where within the distribution system the THD is measured.

Table 17

Where within the distribution system do you measure THD? *			
Customer Meter	**Customer Transformer**	**Substation**	**Other**
17	**6**	**29**	**10**
**** Some utilities measure at more than one location.***			

The "Other" points of measurement are: customer's equipment, recloser, and portable equipment.

Outage Restoration

The survey investigated outage restoration measures such as catastrophe plans, mutual aid agreements, SCADA, and crew coverage.

Hurricanes, snow/ice storms, wildfires, and tornados are some of the reasons to have an effective catastrophe plan. In such cases where an extreme event happens some utilities have taken the proactive steps to enter into mutual aid agreements with other local utilities. Eighty-three (83) percent of the responding utilities in this survey have a catastrophe plan, which is an increase of 22 percent from the 2001 survey. See **Figures 14 and 15** below and on the next page.

Figure 14

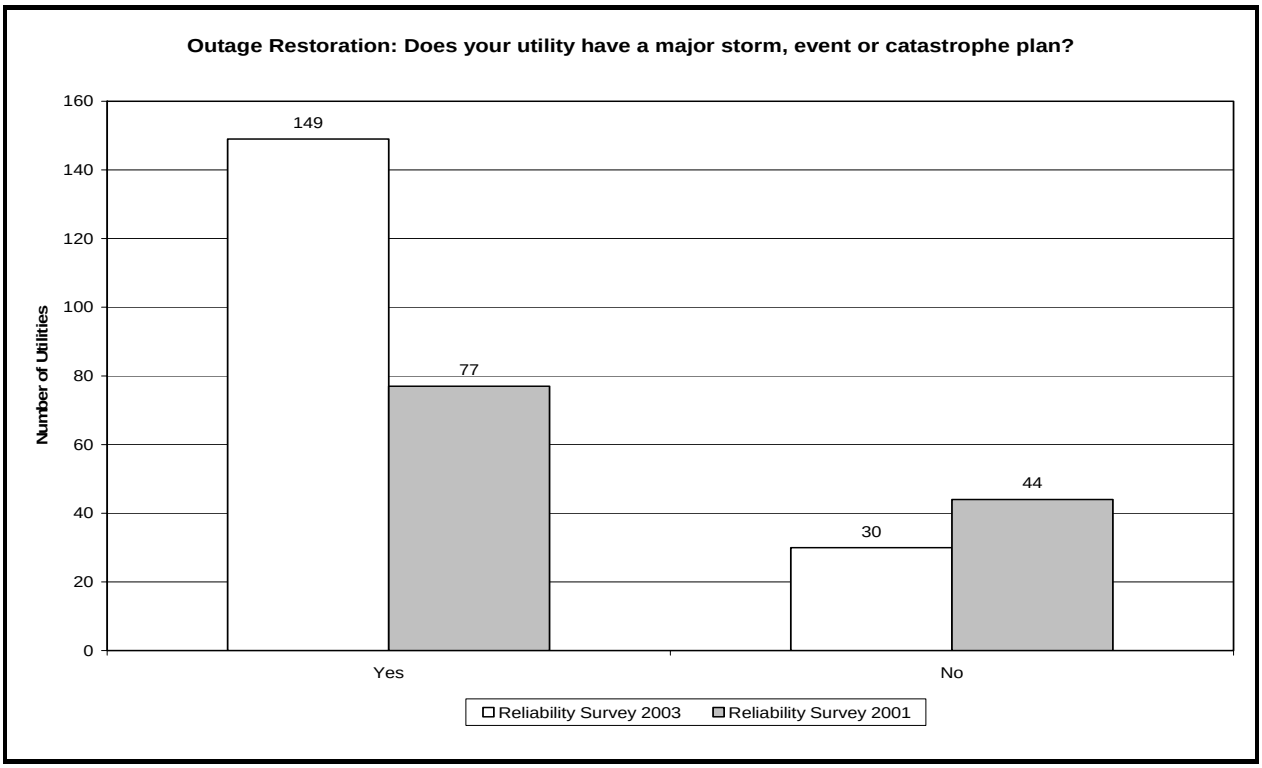
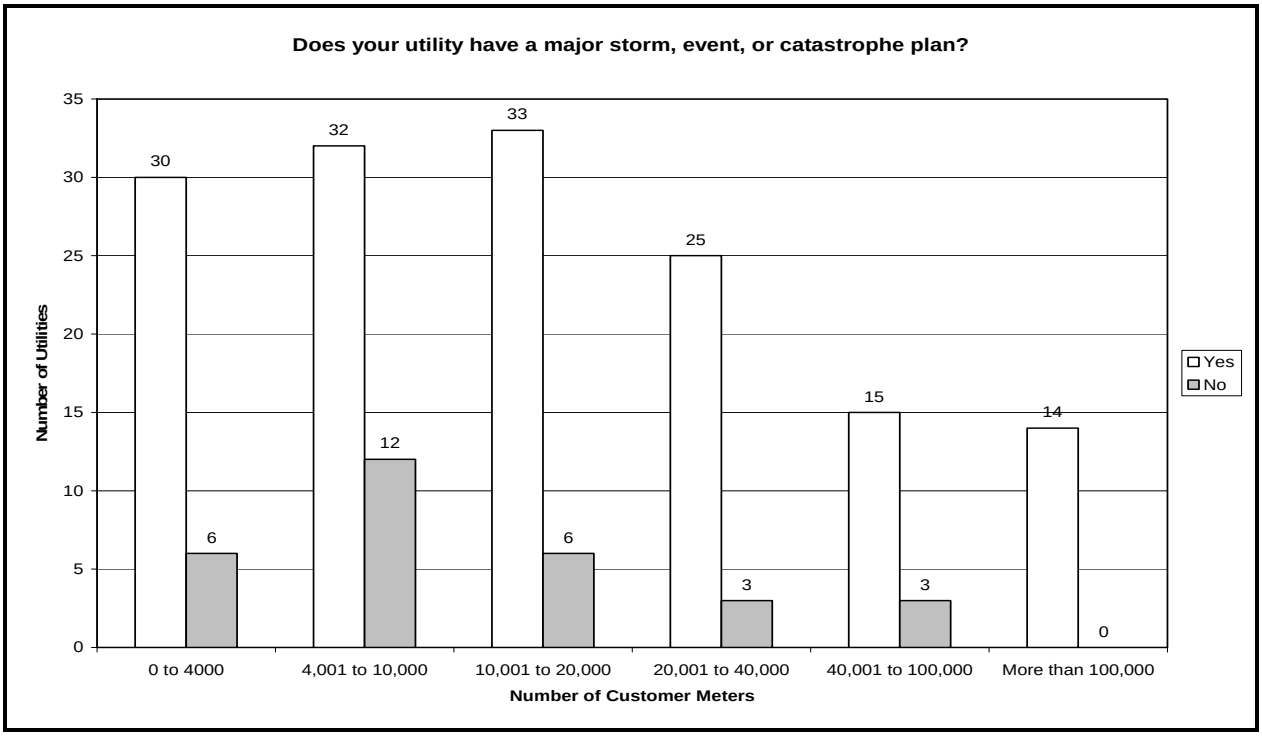


Figure 15



Eighty-nine (89) percent of the responding utilities are active participants in mutual assistance agreements. See **Figures 16–18** on the following pages for more information.

Figure 16

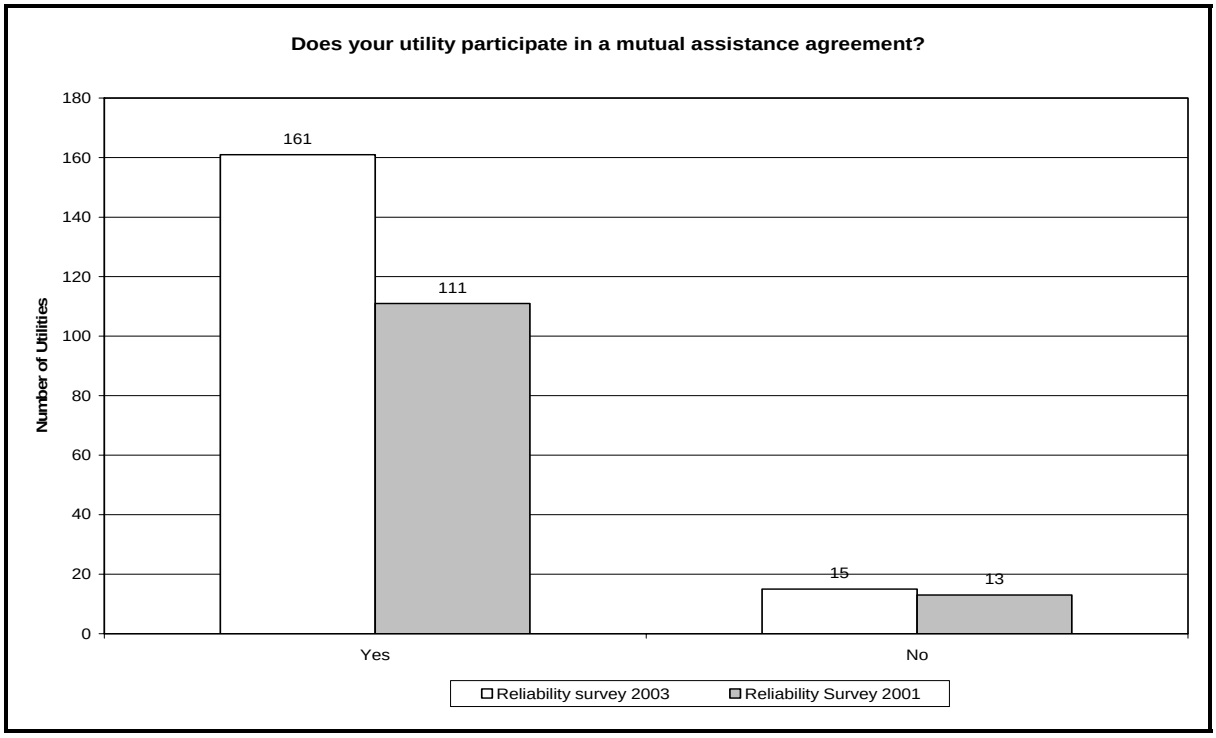


Figure 17

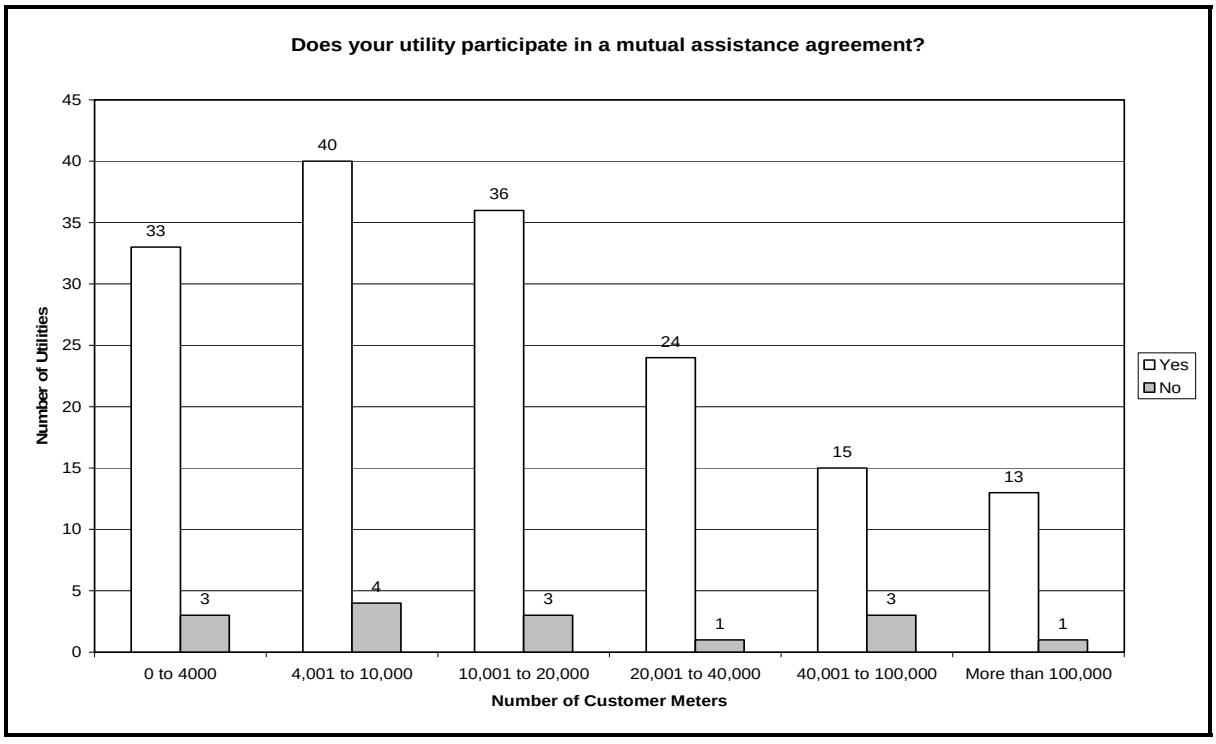
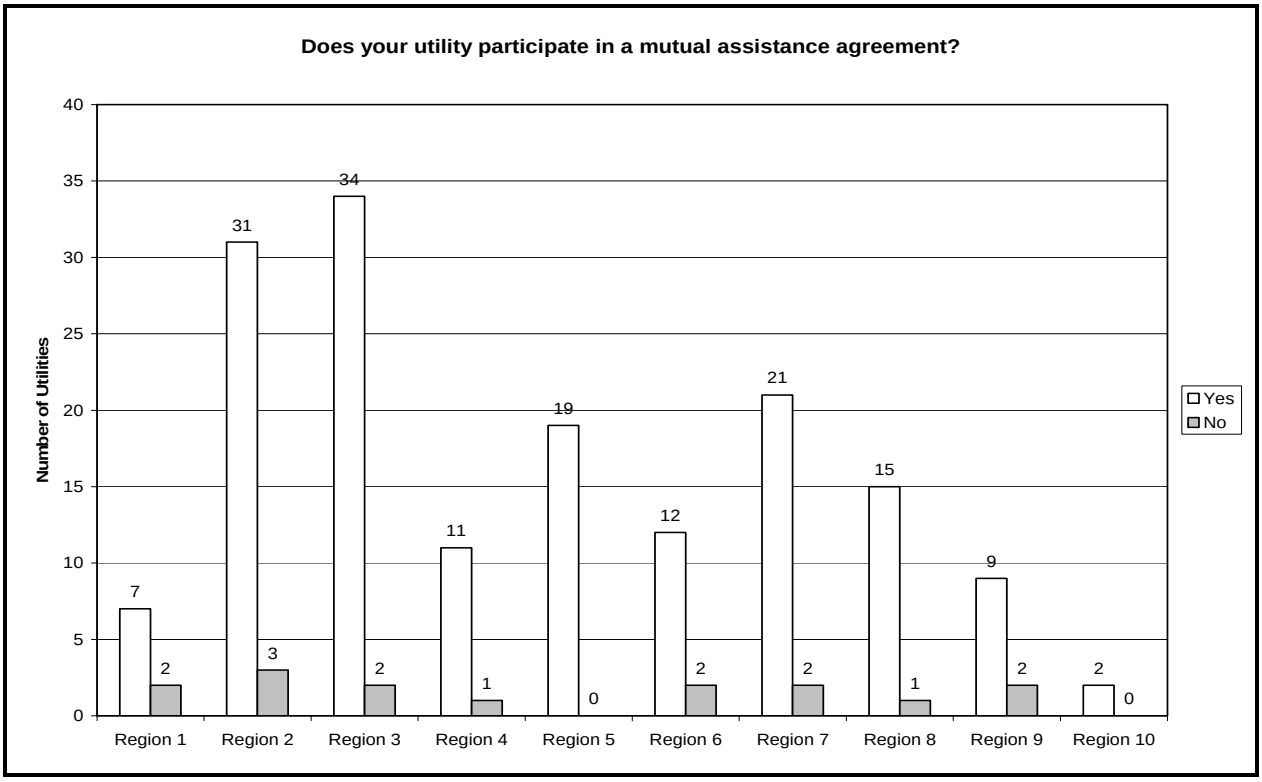


Figure 18



Work Force Issues

Line workers and the coverage they provide are a key human resource for a utility. In the survey a question was posed, "Does your utility provide twenty-four hour crew coverage?" One hundred forty-two (142) utilities replied "Yes," they do offer twenty-four hour crew coverage, while 33 said "No," and five (5) said they implement "Other" methods. The "Other" method being applied by utilities to achieve twenty-four hour crew coverage is lineman on-call.

See **Figure 19** on the next page for a graphical representation of utility responses on twenty-four hour crew coverage and **Table 18** for a breakdown of responses by utility size (customer-meters).

Figure 19

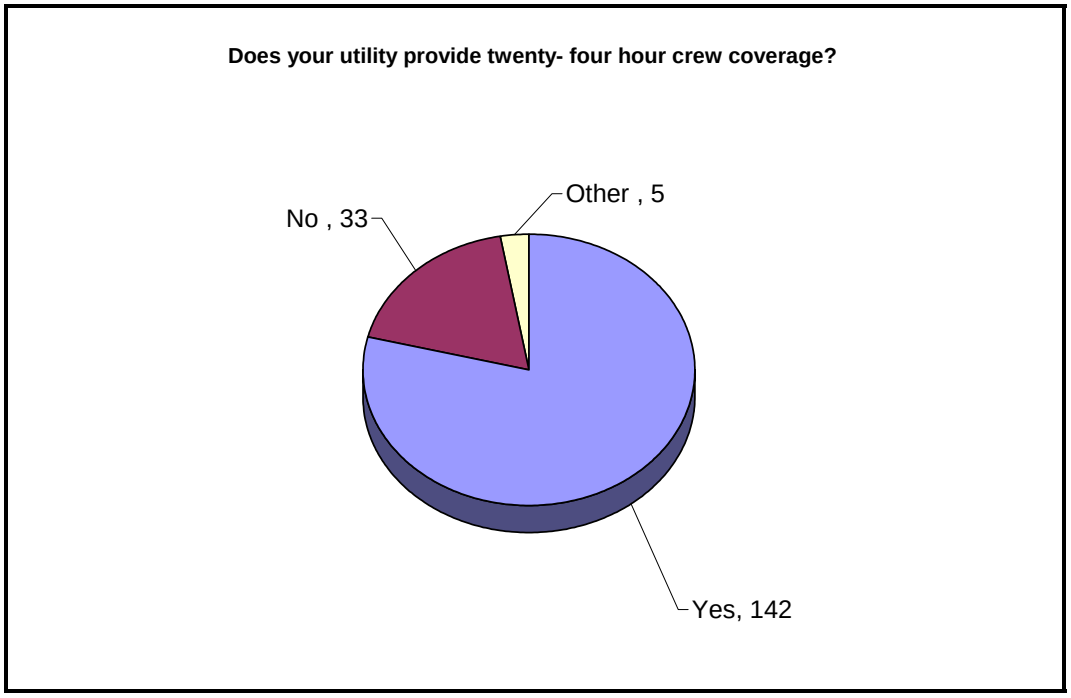
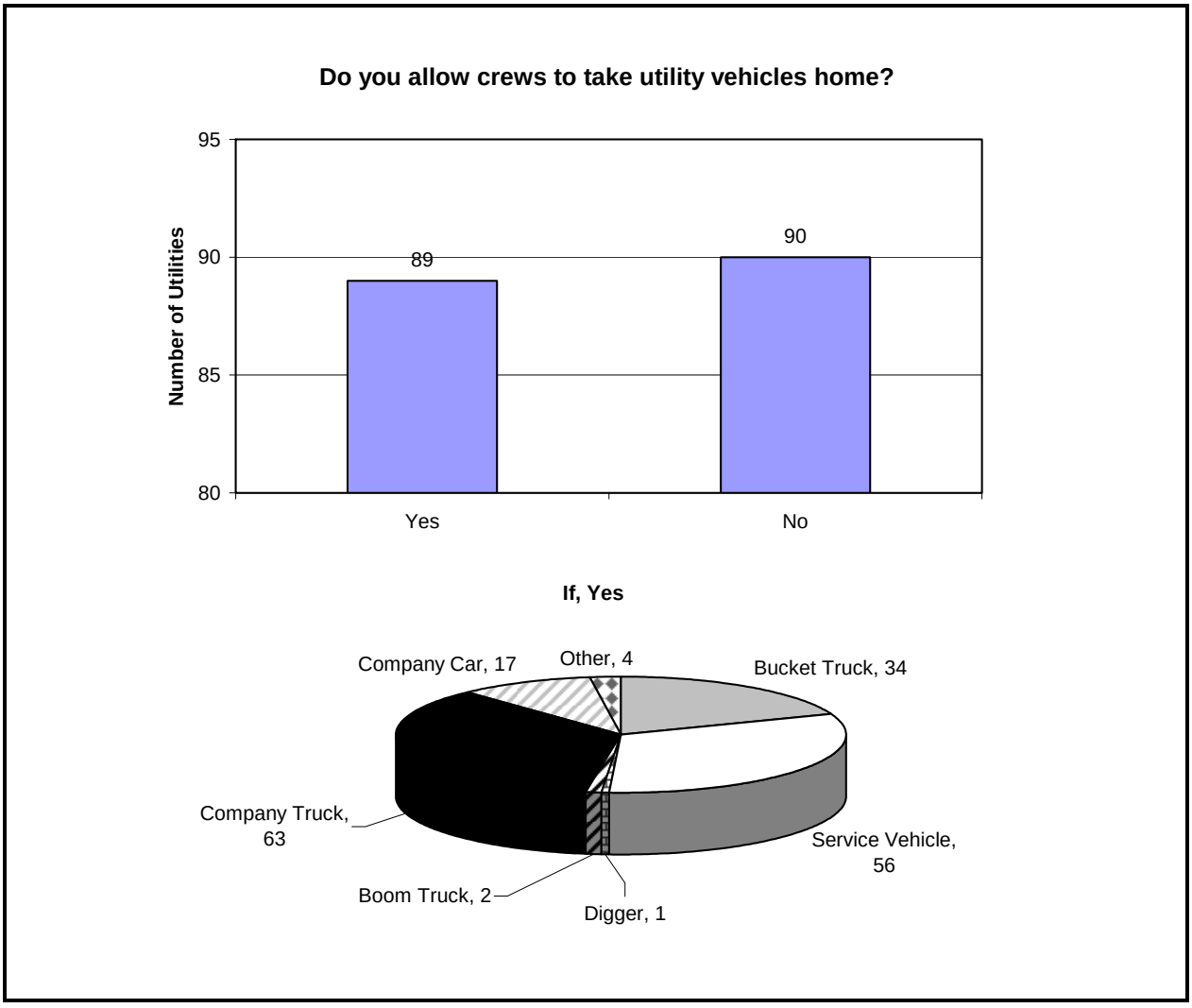


Table 18

Does your utility provide twenty-four hour crew coverage? *(by customer meters)*			
Customer Meters	**Yes**	**No**	**Other**
0 to 4,000	30	6	0
4,001 to 10,000	32	10	3
10,001 to 20,000	33	5	1
20,001 to 40,000	24	3	1
40,001 to 100,000	12	6	0
More than 100,000	11	3	0

The next question posed under the work force issues section was "Do you allow crews to take utility vehicles home?" As shown in **Figure 20** below, survey respondents are almost evenly split on this question with one vote giving the majority to "No." For those utilities that do allow crews to take vehicles home the majority said the company truck (70 percent), followed by the service vehicle (62 percent).

Figure 20



Also in the work force issues section all the respondents were polled as to the number of line crews that they employed. From that data, averages were calculated and are displayed in **Table 19**. Many utilities commented on this question that they used both journeymen and apprentices to make line crews, and therefore the question could not be answered accurately.

Table 19

Customer-Meter Categories	Average # of Journeyman Crews	Average # of Apprentice Crews	Average # of Contract Crews
0 to 4,000	2	1	0
4,001 to 10,000	3	0	0
10,001 to 20,000	4	0	1
20,001 to 40,000	5	1	1
40,001 to 100,000	11	5	7
More than 100,000	51	2	19

System Operation

To evaluate additional elements of how utilities operate their distribution systems, questions were posed about operating procedures at substations, within the distribution system, and relaying practices. See **Tables 20–22** below.

Table 20. Substations

Do you have transformer overload guidelines?	
Yes	126
No	52
Do you have an established maintenance program?	
Yes	158
No	21

Table 21. Distribution

Do you utilize flicker standards for residential designs?	
Yes	63
No	109
Do you have regular inspection and maintenance plan?	
Yes	141
No	33

Table 22. Relaying Practice

Relaying Practice: Philosophy	
Fuse Save (instantaneous trip first, then blow fuse)	76
Fuse Force (fuse blown prior to breaker operation)	103

Conclusion

The number of survey respondents has increased. However, this survey still has some growing pains. For example, in the reliability indices data area there is a need for accurate calculations of reliability statistics, thereby allowing us to calculate accurate averages.

Additionally, some of the questions do not properly reflect utility operation. For example, Question 3 under Work Force Issues (Section VII of the Survey) only addresses journeyman and apprentice crews, not the crews that are mixed with journeymen and apprentices. Along with this question we should have addressed the number of personnel—two, three, four, or five people—on each crew.

These are just a few areas that need to be further developed in order to improve the quality of the data that results from this survey. The next survey is scheduled for distribution during the fourth (4th) quarter of 2005. If you have any suggested topic areas or questions, please email them to James Strange at jstrange@appanet.org.