Quality Assurance in ENERGY STAR® Residential Lighting Programmes

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Abstract
The global ENERGY STAR programme relies in large part on manufacturer testing of products and their self-certification that these products meet the programme's performance specifications. Although this has been sufficient for many ENERGY STAR product categories, there have been persistent concerns about the performance of ENERGY STAR labeled products in a few categories, in particular residential light fixtures (RLFs) and compact fluorescent lamps (CFLs). As a result of these concerns, the US Environmental Protection Agency (US EPA), US Department of Energy (US DOE) and other efficiency programme sponsors commissioned independent testing of ENERGY STAR labeled RLFs and CFLs and found an unacceptably high rate of non-compliance with the ENERGY STAR performance specification.
This paper describes the probable causes of non-compliance, and goes on to describe the remedial actions taken to address the problem. Specifically, in October 2004, US EPA revised the performance specification for RLFs to eliminate lifetime certification, and added a manufacturer-paid quality assurance (QA) programme to detect and deter the use of the ENERGY STAR label on non-qualifying ENERGY STAR RLFs. The QA programme is funded by RLF manufacturers, but is implemented by manufacturer-independent testing laboratories that have been accredited by the National Voluntary Laboratory Accreditation Program. A similar programme is being designed for CFLs by US DOE.
The paper describes the design and establishment of the QA programmes and the procedures adopted to ensure their integrity. It continues by discussing the implications of the QA programme for the RLF manufacturers, efficiency programme sponsors, and end-users.

The ENERGY STAR Lighting Programme

In 1992 the US Environmental Protection Agency (EPA) introduced ENERGY STAR as a voluntary labeling programme designed to identify and promote the use of energy-efficient products to reduce greenhouse gas emissions. Computers and monitors were the first labeled products. Through 1995, EPA expanded the label to additional office equipment products and residential heating and cooling equipment. In 1996, EPA partnered with the US Department of Energy to increase the number of product categories covered by ENERGY STAR. The ENERGY STAR label can be found today on more than 40 categories of products, including major appliances, office equipment, lighting, home electronics, and more. EPA has also extended the label to cover new homes and commercial and industrial buildings.
Initially, the ENERGY STAR label was awarded based on manufacturer self-certification of a product's compliance with the relevant ENERGY STAR specification. However, as ENERGY STAR labeled products began to be used more widely, it became clear that many labeled products – particularly in the lighting category – were not compliant with their performance specification.
EPA estimates that the Energy Star RLF and CFL programmes saved 5.3 billion kWh and prevented the emission of 1.1 Million Metric Tonnes of Carbon Equivalent in 2004.[1]

Residential Light Fixtures
The Energy Star label was first applied to residential light fixtures (RLFs) in 1997 by US EPA.[2] The original specification covered system efficacy, total harmonic distortion, power factor, current crest factor, electromagnetic interference/radio frequency interference color rendering index, operating noise, and a variety of other safety and durability factors.[3] As RLF technology advanced, more fixture types and technologies were covered by the specification, and the qualifying criteria were made progressively more stringent. For example, in 2001[4], a specification revision eliminated the use of

magnetic ballasts in linear fluorescent fixtures. This prohibition was extended to all indoor fixtures in a specification revision in 2004.[5] The 2001 revision also required that several performance attributes be tested at a laboratory accredited by the National Voluntary Laboratory Accreditation Program (NVLAP), operated by the US National Institute for Standards and Technology. Revisions in 2001 also addressed lamp life for the first time: an ENERGY STAR fixture's lamps are now required to have an average rated life of at least 10,000 hours.
As of March 1, 2006, there were over 6000 residential light fixture models qualified under the ENERGY STAR programme. These include decorative chandeliers, pendant-mounted fixtures, bath bars, ceiling-mounted fixtures, recessed downlights, under-cabinet fixtures, architectural lights, and outdoor wall-mounted fixtures and post tops.[6]

Compact Fluorescent Lamps
Compact fluorescent lamps (CFLs) were first covered by an Energy Star specification in 1999 under the leadership of US DOE. The original specification addressed luminous efficacy, lumen maintenance at 40% of rated life, and average rated life. Subsequent versions of the specification addressed lumen maintenance at 1000 hours, rapid cycle stress testing, and interim lifetime testing. A new version of the specification, in development at the time of this writing, may include more stringent criteria regarding efficacy, run-up time, and sample-to-sample performance consistency.[7]
As of February 27, 2006, over 2000 CFL models were qualified under the ENERGY STAR specification. These included bare lamps; globes and other covered lamps; lamps with double, triple, quad, spiral and circline configurations; as well as reflectorised lamps.[8]

ENERGY STAR Quality Assurance Testing

Background
The ENERGY STAR lighting programs for both RLFs and CFLs have data submission requirements for initial product qualification. When manufacturers qualify products, they are required to submit supporting test data from NVLAP-accredited laboratories for tests covering a wide range of performance metrics. However, given the rapidly changing designs of both luminaires and fixtures it became apparent that initial product testing was insufficient to ensure ongoing product quality. EPA, DOE and other efficiency programme sponsors heard a rising number of complaints, particularly concerning premature failure and insufficient light output. While no comprehensive investigation has been undertaken, it is believed that the failure of ENERGY STAR labeled lighting products to perform in accordance with the relevant performance specification is traceable to one or more of the following causes:

- After a product is initially awarded the ENERGY STAR, manufacturers substitute different and potentially non-qualified lamp or ballast components.[9]
- In some instances, manufacturers may be selecting (or modifying) product samples from the production line that do not represent the typical product quality. This may involve, for example, a preliminary internal check by the manufacturer to confirm that the selected sample(s) will comply with the ENERGY STAR specification, prior to the samples being "officially" tested for compliance.
- Where a manufacturer uses an external testing laboratory, there may be instances of "laboratory shopping." Under this scenario, the manufacturer hires Laboratory A to evaluate their product for conformance to the ENERGY STAR specification. If Laboratory A finds that the product does not meet the ENERGY STAR specification, the manufacturer then retains Laboratory B to perform the same tests in the hope that inter-laboratory testing variances will permit the product to be certified. Only the passing results are reported to EPA or DOE.

In 2000, a group of concerned utilities, programme administrators, regional market transformation groups, and energy efficiency advocates formed a new residential lighting testing programme called PEARL (Program for the Evaluation and Analysis of Residential Lighting).
The PEARL Sponsors felt it was critical for consumers to have a positive experience with energy efficient lighting products because:

- These products use roughly one-fourth of the energy used by incandescent lighting products, with comparable light output.
- Lighting represents roughly 15% of residential electricity use and remains a largely untapped opportunity for cost-effective energy savings.

- Unlike their purchase behavior with respect to ENERGY STAR labeled products that last 10 years or more (e.g., refrigerators and air conditioners), consumers buy light bulbs several times each year. This presents an excellent opportunity to familiarise consumers with the benefits of ENERGY STAR and induce them to seek out ENERGY STAR models when they purchase other products that consume much greater amounts of energy.
- If consumers have a bad experience with ENERGY STAR labeled lighting products, it may discourage future purchases of efficient lighting products, and have a negative impact on their opinion of ENERGY STAR overall.[10]

PEARL Programme Description/Structure

Process
The testing process begins when the PEARL Board chooses ENERGY STAR CFLs and RLFs to test (See Figure 1). Their selection is usually based on sales volumes, consumer complaints and the results of prior PEARL testing cycles. Rather than allowing the manufacturers to select samples, the samples are purchased by programme sponsors, and are sent to the Lighting Research Center at Rensselaer Polytechnic Institute where the testing is conducted. In order to develop a representative and diverse selection of products, PEARL sponsors attempt to gather samples from three distinct geographic regions of the country. When possible, different retailers are selected in order to ensure that the products purchased are truly representative of what is on the market for consumers at any given time.

Board Chair
Responsible for developing consensus on policies for data handling, testing protocols, and product lists for testing.

Testing Laboratory
Responsible for performing tests in accordance with NAVLAP test procedures, producing reports, and administering testing funds.

Programme Sponsors
Responsible for nominating products for testing, programme financial support and “off the shelf” lighting product procurement within various geographic regions of the country.

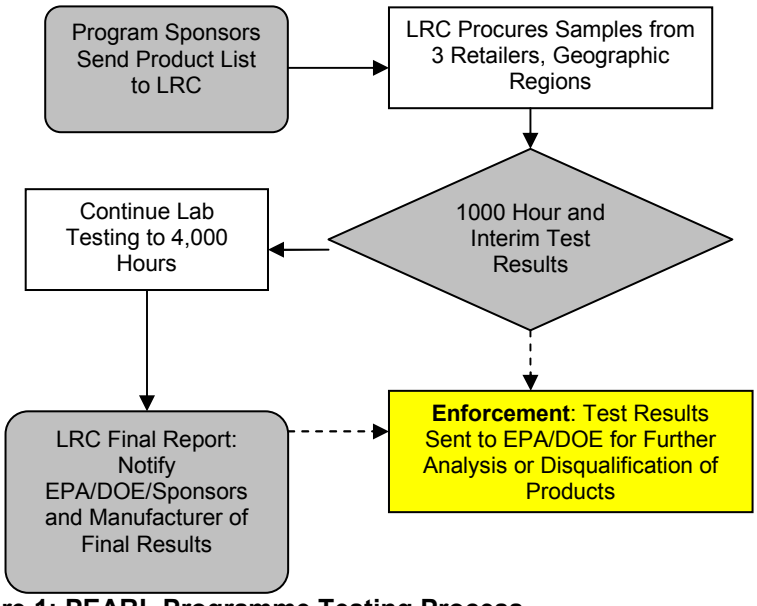

Figure 1: PEARL Programme Testing Process

Analysis of Results
Over the past 5 years, PEARL has been responsible for performing off-the-shelf testing of over 1350 ENERGY STAR labeled CFLs from 23 manufacturers and 43 ENERGY STAR labeled RLFs from 20

manufacturers.[11] The PEARL sponsors have contributed nearly $1 million to establish the programme and perform seven rounds of testing. PEARL has played a critical watchdog role and helped pressure manufacturers to maintain and in many cases improve the quality of their energy-efficient residential lighting products. Figure 2 shows the results of 6 rounds of PEARL testing, indicating that, generally, programme compliance is improving. In particular, one of the key parameters of consumer satisfaction, lumen maintenance, has increased dramatically as manufacturers improved their products and reacted to the news that their products were being tested.

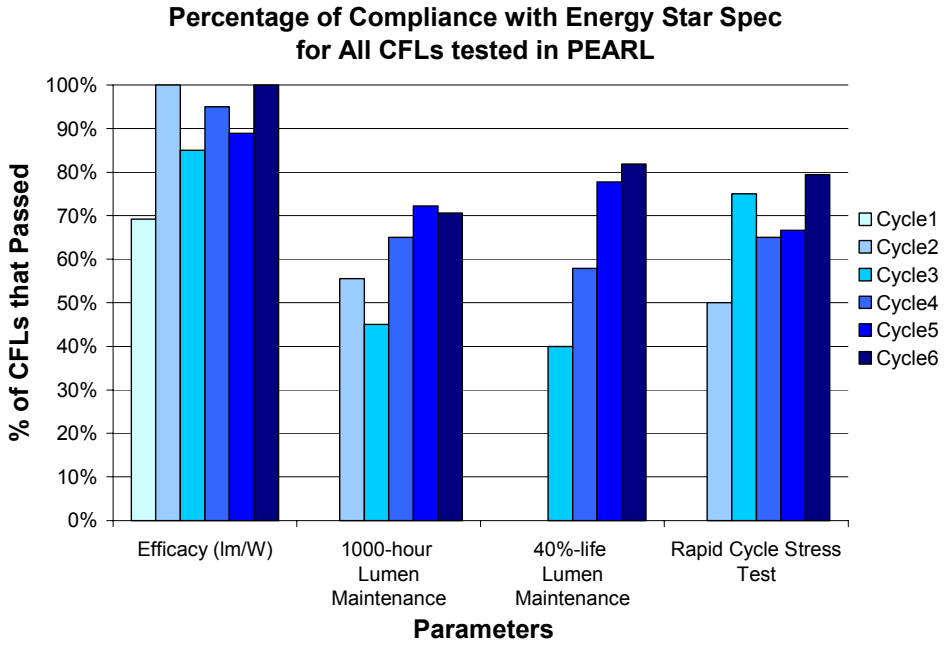

Figure 2: PEARL Results by Test Type Through Time

Figure 3 shows PEARL results by lamp type, including bare lamp (including helix type), covered lamp, and reflector lamps.[12] The results are rather alarming in that they reveal widespread non-compliance for certain product categories. For example, only 32% of the reflector lamps met the 1,000 hour lumen maintenance test, and worse yet, fewer than 25% of reflector lamps met the 40% rated life lumen maintenance requirement. Among the lamp categories, bare lamps performed the best with covered lamp performance falling between the bare lamps and the reflectors. These results indicate a startling disconnect between initial product qualification and ongoing product performance. Products that initially met ENERGY STAR performance levels with manufacturer-supplied test data were found to be non-compliant at a later date when samples were purchased off the shelf and tested by a third party lab.

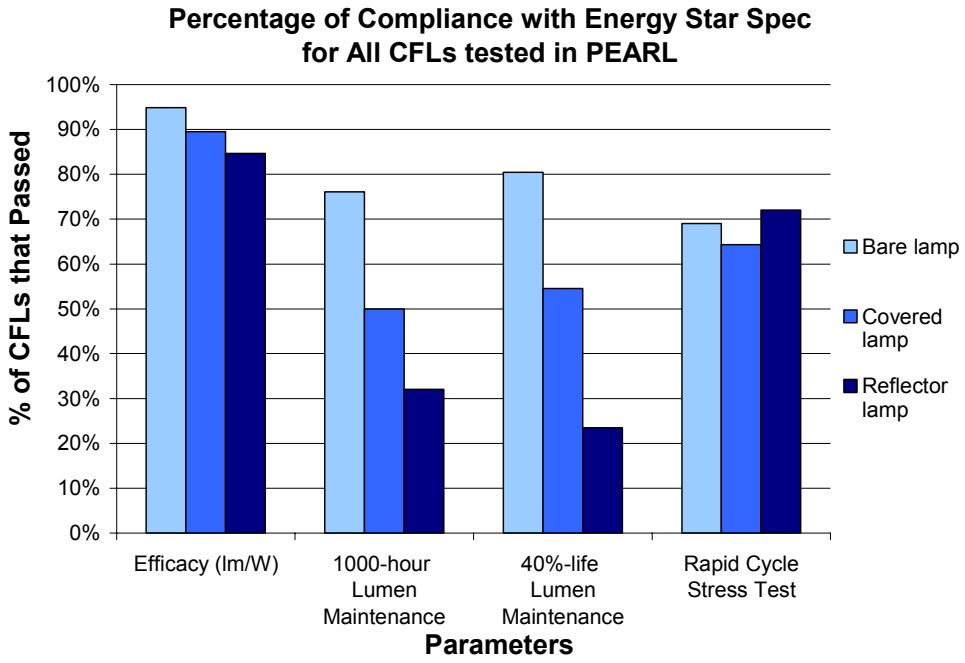

Figure 3: PEARL Test Results, by Lamp Type, All Test Cycles

In addition to the numerous CFLs tested through the PEARL programme, RLFs were also included in the tests. These tests revealed that compliance was generally good. (It should be noted that lumen maintenance was not tested since it was not part of the ENERGY STAR specification for RLFs at the time. The most recent RLF specification includes requirements for lumen maintenance, thus future testing schemes will test for this parameter.)[13]

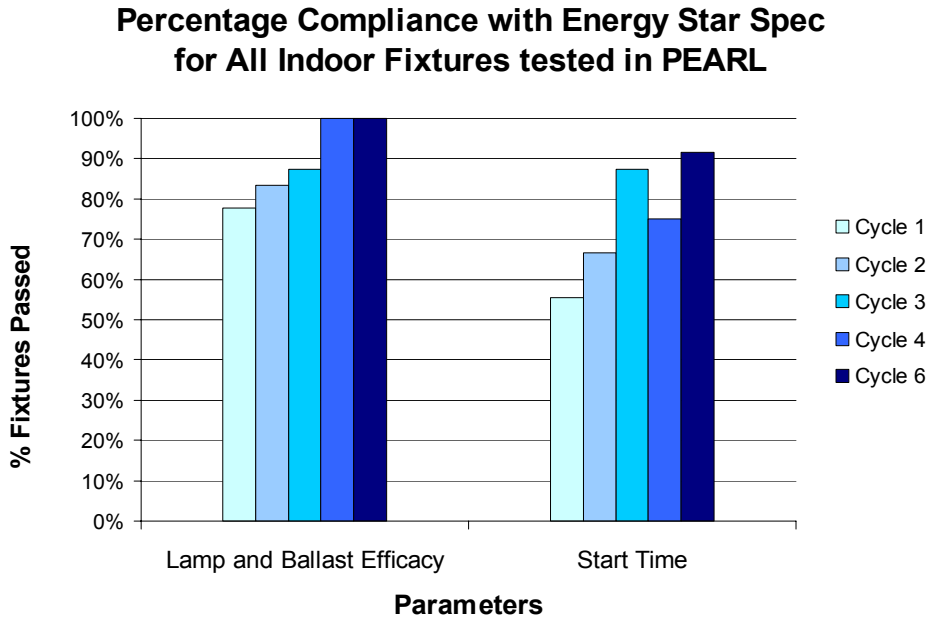

Figure 4: PEARL Results for Residential Light Fixtures

Figure 4 shows that compliance improved with each PEARL round, eventually reaching 90% compliance in the 6th round of testing. These results further support the observation that ongoing compliance testing induces improved performance.

Comparison of Results with Previous Research
These results are consistent with observations from previous studies of lighting testing programmes. Specifically, Granda and Conway studied the impacts of both the PEARL and the IFC/GEF Efficient Lighting Initiative (ELI) testing programmes. The researchers concluded that the PEARL and ELI programs were having a positive impact on lighting quality, shown by increasing compliance and improved product performance with each successive PEARL cycle.[14]

The Shift to Manufacturer-Funded Testing

In 2005 the energy efficiency community announced that they would no longer be able to support testing of CFL and RLFs indefinitely. At that time they mustered support for one final round of PEARL testing (Round 7), which is underway as of the writing of this paper.[15] Having largely achieved their goals of raising performance levels, and showing how essential testing was to ensure product performance and programme compliance, the energy efficiency community requested that ongoing third-party testing be integrated with future versions of ENERGY STAR specifications.[16] EPA and DOE responded to this charge by creating manufacturer-funded quality assurance (QA) programmes as part of their periodic revision of the ENERGY STAR specifications for RLFs and CFLs.

Compact Fluorescent Lamps
In December of 2005, DOE released a draft CFL specification revision for comment. There were a number of performance issues addressed in the proposed revision, including a requirement that CFL manufacturers participate in a "third party testing and verification program."[17]
The goals of the Third-Party Testing and Verification Programme are to:

- Develop a CFL testing programme that will aid DOE in maintaining quality control of its ENERGY STAR CFL program.
- Develop a mechanism to assure CFL programme sponsors and manufacturers alike that qualified products do meet programme requirements.
- Provide a basis upon which DOE can reasonably disqualify a product that does not exhibit the performance necessary to keep its ENERGY STAR status.
- Maintain the precepts of the ENERGY STAR program, the highest of which is that the consumer receives superior products that perform as advertised.

The programme structure includes:

- A product selection committee, responsible for overseeing the final product selection process for each testing cycle. The committee is to consist of 5 representatives: two members from industry; two members from a lighting stakeholder group or utility; and, DOE.
- Technical and Research Committee: This committee will monitor technical and scientific developments involving lighting industry specifications, regulations, and testing processes.
- A Third Party Programme Administrator will provide overall programme management.

Programme Scope and Timing:

- Number of products tested -The programme is designed to test a substantial number of qualified products, with the target goal of testing 20% of the products on the ENERGY STAR product list every year.
- Timeline - The program, as proposed, would test two cycles of products per year, starting on September 1, 2006, with the initial product nominations.
- Product procurement – Must be done "off the shelf" (at retail) without manufacturer involvement; samples should be taken from a wide geographic area to ensure that a broad sample is procured.
- Manufacturer nominations of competitors' products – will be accepted with either test data or other rationale indicating that testing is warranted.
- Programme costs – costs will be set by the Programme Administrator for each set of tests. Fees will be paid by manufacturers to the Third-Party Programme Administrator, and the Administrator in turn will select a qualified laboratory and forward payment, less a 20% administrative fee, to the laboratory for product procurement and testing.[18]

Programme Status and Remaining Issues
As of the release of the latest programme draft, several issues remained before programme implementation could begin by the proposed September 1, 2006 start date:

1) The testing committees need to be formed.
2) The technical committees need to be formed.
3) There are questions from the efficiency community regarding the transparency of the process, and they are seeking access to more data than DOE is currently proposing to offer.
4) Programme costs and overall administration needs to be finalised.

Residential Light Fixtures
EPA introduced a systematic, manufacturer-paid quality assurance programme in October 2004 with the release of Version 4 of the RLF specification. The principal elements of the programme include:

- Product selection: EPA will select RLFs for testing from the list of ENERGY STAR qualified fixtures. It is expected that attention will focus on fixtures with high sales volume and/or a high frequency of complaints. Nominations will also be accepted from other efficiency programme sponsors, such as electric utilities, as well as from retailers of RLFs and fixture manufacturers. To limit the financial burden of the QA process, no manufacturer will be asked to pay for QA testing of more than two of their fixtures in a given year. EPA will notify manufacturers that one or two of their RLFs have been selected for QA testing; the manufacturer will then be responsible for retaining a testing laboratory (see below) to perform the QA testing.
- Parameters tested: The QA testing process will focus on the ENERGY STAR parameters of greatest importance to consumer acceptance and those that have shown the highest frequency of failure in the PEARL testing process: efficacy; lamp start time; correlated color temperature; color rendering index; lamp base type; lumen maintenance; and maximum ballast operating case temperature. In addition, the RLFs will be examined for conformance with the ENERGY STAR consumer education requirements.
- Testing laboratories: All QA testing must be performed by an independent NVLAP-accredited testing laboratory. Manufacturers may not perform QA testing in their own testing laboratories, even if they are NVLAP-accredited.
- Sample acquisition: The testing laboratory will be responsible for sample acquisition. The sampling strategy will be similar to that used in the PEARL program. Samples will be purchased from retailers whenever possible, and the testing laboratory will strive to purchase three samples from geographically diverse locations.
- Testing strategy: In an effort to contain the cost of the QA programme, product testing will begin with only one of the three samples. If this sample meets all of the ENERGY STAR specifications, then the other two samples will not be tested. However, if the first sample fails to meet any performance parameter, the other two samples will be tested as well. If two or three samples fail to meet the same performance parameter of the ENERGY STAR specification, the RLF will have its ENERGY STAR label revoked.
- Information flow: The testing laboratory is required to provide documentation of the test results to EPA as well as the manufacturer paying for the tests. EPA will use those data to maintain or revoke a product's ENERGY STAR qualification. EPA may also choose to release aggregated data on the results of the QA program.

Programme Status and Remaining Issues
The energy efficiency community has high hopes that the RLF QA process will have an even greater impact on product quality than PEARL had. However, it is important to acknowledge the challenges confronting the QA program:

- Cost: Even if only one sample is tested, the cost of purchasing three samples and testing one could exceed $2000. However if a full three sample test were required the cost could be several thousand dollars. While this is expected to be a manageable cost for large, high-volume manufacturers, it could prove unacceptably burdensome to smaller, lower-volume and lower-margin manufacturers. This may result in fewer RLFs being qualified under ENERGY STAR.
- Time: Most of the QA test elements can be completed in a matter of weeks. Lumen maintenance testing, however, will take many months. The first sample will have a first lumen maintenance check at 1000 hours. If the sample fails to meet the lumen maintenance at 40%

of rated life criterion at the 1000-hour mark, then testing will begin immediately on the other 2 samples. A disqualifying failure (i.e., two or three samples failing the same parameter), however, cannot occur for lumen maintenance until the second and third samples are also checked at their 1000-hour mark. Thus, the earliest a lumen-maintenance disqualification can be determined is after 2000 hours of cycling. At the other extreme, the first sample may have an acceptable lumen maintenance level at 1000 hours, but fail at the 40% of rated life mark. Testing on the other two samples would begin at that point, with the potential for several thousand additional hours of cycling for these two samples before any conclusions can be drawn. Thus, more than a year could pass from testing initiation before an RLF would conclusively fail the lumen maintenance test.

- Product turnover: Given the thousands of Energy Star qualified RLFs, and the hundreds of new ones introduced every year, the QA process will face the challenge of relevance and impact. EPA expects to QA test dozens of RLFs each year, and hopes that this will be a credible level of oversight that will be taken seriously by the industry. The PEARL programme, which tested RLFs in similar numbers, clearly had a beneficial impact on product quality.

The procedural guidelines for the RLF QA programme became final in April 2006, at which time the first notification letters were sent to manufacturers directing them to begin quality assurance testing on their ENERGY STAR RLFs. The first negative results may be reported as early as the summer of 2006, while the last result (e.g., 40% of rated life lumen maintenance testing on multiple samples) from this first round of QA testing may not be reported until the second half of 2007.

Implications and Outlook

Full implementation of the QA programs will result in testing a larger number of products than has been done in the past. Going forward, both the ENERGY STAR RLF and CFL QA programmes will have material cost implications for manufacturers. These costs take two forms: first, there are the costs of the tests themselves. Second, the more significant cost may appear as increased component costs, phosphor costs and revised quality control procedures in reaction to the increased level of scrutiny and third-party testing underway.

Quality/number of products

Assuming that RLF and CFL manufacturers will be more careful about which products they submit for ENERGY STAR qualification, we expect the gross number of “qualified products” on the ENERGY STAR website to decrease. Manufacturers are expected to remove products from the list in order to avoid the potential penalties associated with having a product tested and de-listed. At the same time, as the number of marginal products fall, those left on the list will be the ones that manufacturers are more confident in, and will be of higher quality. The net result will be a smaller list of higher quality products, which will benefit ENERGY STAR, its programme partners and allies, and, most importantly, the general public.

Ramifications for other ENERGY STAR qualified products

Viewed among the list of over 40 product categories, lighting products are somewhat unique. The industry in general lacks strict performance guidelines that are present in other product categories such as appliances and heating/cooling systems. There is no expectation that the QA model being implemented for residential lighting products will be applied to other product categories, but it is always a possibility.

However, another consequence of the QA process is the potential to move ENERGY STAR closer to an “external certification” model, which would potentially mean that in the long term EPA and DOE would no longer be required to review test data, but would instead rely on third parties for both initial product qualification and ongoing quality assurance.

Conclusion

Ongoing testing of lighting products is necessary to ensure the integrity of efficient lighting programmes. The results from PEARL indicate that, in the early rounds of testing, compliance was low, and certain product categories (e.g., CFL reflectors) displayed performance problems, some of

which continue to this day. The authors also showed how compliance increased with each successive round of testing, indicating that product quality was increasing in response to ongoing testing. The paper also discussed two programmes in development, one from EPA and one from DOE, which will rely on the manufacturers to fund future QA testing. It is possible that the QA process will result in fewer but higher quality products remaining on the ENERGY STAR list. Finally, based on the experience outlined here with low compliance levels in early rounds of testing, the authors conclude that any sponsor of an energy-efficient lighting programme should establish an ongoing third-party testing process to ensure that the public and the environment truly benefit from the efforts of the programme.

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