4. Energy Testing for Appliances

Guidebook Prescriptions for Energy Testing

1. Begin adopting or establishing test procedures and facilities before standards and label regulations are enacted. Include a significant budget for meetings, testing, and foreign travel.
2. Don't even think about developing a labels or standards program without an independent test facility for ensuring compliance.
3. Ensure that test facilities are certified and will provide credible results.
4. Adopt internationally recognized test and capacity-measurement procedures whenever possible. If this is not possible, consider simplified versions of internationally recognized tests to lower the costs and technological obstacles to testing.
5. Make the procedures for reporting test results, preparing forms, and establishing a database of compliant units as simple and easy to access as possible.
6. Make the mechanism to request waivers, exceptions, or deviations from the test procedure when the test is not appropriate as simple and easy to access as possible.
7. Implement self-certification by manufacturers, if possible, to minimize the cost of a compliance program.

4.1 Energy Testing Infrastructure

The process of creating an energy testing capability must begin long before a labeling or standards-setting program is launched. The major steps in this process are shown in Figure 4-1.

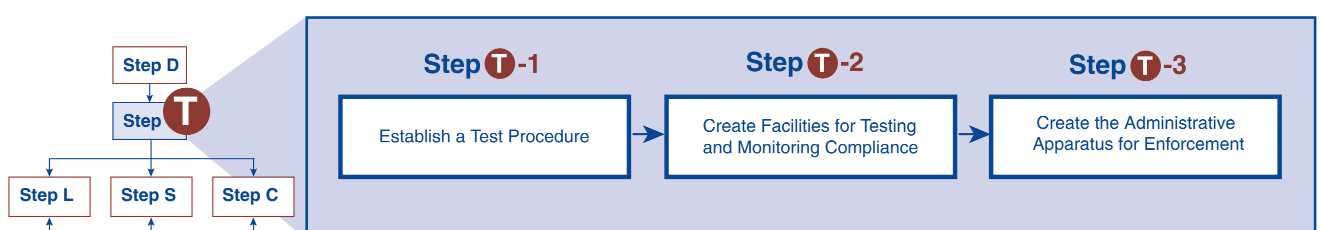

Figure 4-1 Major steps in developing a testing capability for a labeling or standards-setting program

This chapter explains what energy testing is and then describes the infrastructure needed to establish test procedures, test facilities, and testing compliance to support an energy-efficiency labeling or standards-setting program.

4.1.1 Definition of an Energy Test Procedure

An energy test procedure is an agreed-upon method of measuring the energy performance of an appliance. The results of an energy test procedure may be expressed as an efficiency, efficacy (for lighting products), annual energy use, or energy consumption for a specified cycle, depending on the appliance being tested. Worldwide, there are energy test procedures for all major energy-consuming household appliances.

The test procedure and the regulatory standard for an appliance are often lumped together, but they are very different. A regulatory standard establishes a level of minimum energy efficiency; the test procedure describes the method used to measure the energy performance of the product. A regulatory standard typically references the appropriate test procedures.

4.1.2 Importance of Test Procedures

The test procedure (sometimes referred to as "test standard") is the foundation for energy-efficiency standards, labels, and other related programs (Meier and Hill 1997). It gives manufacturers, regulatory authorities, and consumers a way of consistently comparing energy use and savings among different appliance models. A well-designed test procedure meets the needs of its users economically and with an acceptable level of accuracy and correspondence to typical conditions. By contrast, a poorly designed energy test procedure can undermine the effectiveness of everything built upon it. The adoption of established test procedures, especially those of internationally recognized testing organizations, makes it easy to compare the efficiency of different models.

4.1.3 Elements of a Good Test Procedure

The ideal energy test procedure will:

- reflect typical usage conditions
- yield repeatable, accurate results
- reflect the relative performance of different design options for a given appliance
- cover a wide range of models within a category
- produce results that can be easily compared with results from other test procedures
- be inexpensive to perform

Unfortunately, these goals usually conflict with each other. A test that tries to accurately duplicate actual usage will probably be expensive and not easily replicated. For example, most energy test procedures for room air conditioners measure efficiency while a unit is operating at steady state with a specified outdoor temperature. This is a relatively easy mode to test after the test chamber has been created; efficiencies can be measured quickly and reliably. In practice, however, air conditioners operate mostly at part load or at outdoor temperatures higher than specified by the test procedure (efficiency will typically be lower at higher temperatures). Part-load performance is much more complicated to measure, and results are more difficult to reliably duplicate. Likewise, most energy test procedures measure efficiency at a single specified ambient air temperature. Testing at different ambient temperatures requires costly reiterations and still fails to capture all differences in ambient conditions. Testing to country-specific ambient temperatures makes it difficult to compare product performance across borders.

We can clearly see from the qualifications noted above that an energy test procedure is a compromise; it does not fully meet any of the criteria for an ideal test, but it satisfies enough of them to discourage excessive complaints. At a minimum, a ranking of different models by their tested energy performance should correspond reasonably closely to a ranking by the models' field energy performance. Even this modest criterion has not been widely confirmed owing to a general lack of comparisons between laboratory and field measurements (Meier 1995).

Tested energy performance reflects an appliance's performance only as the appliance leaves the factory and therefore does not account for anything that may happen to the product during transport, installation, or operation. Central air conditioners, for example, require matching and connection of indoor and outdoor components. Mismatched components or improper installation can seriously reduce efficiency. Policies such as training for installers must be used to address these issues.

4.2 Step T-1: Establish a Test Procedure

The first step in developing an energy-efficiency standard or label is to establish energy test procedures for the products that are to have labels or be covered by standards. This step can and should begin even before the standards legislation has been approved. Establishing test procedures requires a significant investment in technical analysis, including participation in meetings and foreign travel to observe test facilities and international standards committees in action. In most cases, test procedures already exist although they may not be formally recognized as established. Manufacturers frequently test their units for quality control and comparison with competing products.

The fundamental choice for a government that is building an energy-efficiency labeling or standards program is whether to develop and achieve consensus on a unique domestic procedure or adopt an established international procedure. In considering this choice, governments will want to review international test procedures, decide which existing test procedures are best suited to modify/use in their country for measuring product energy efficiency or which new procedures to develop, assess the capacity for in-country and neighboring-country laboratories to test energy performance of priority products, and decide whether to expand existing test laboratories, construct new test laboratories, rely on laboratories in neighboring countries, or rely on private-sector laboratories.

4.2.1 Key Institutions Responsible for Making Test Procedures

Test procedures are typically created by manufacturers' associations, government agencies, non-government organizations (NGOs), and professional societies. A partial list of the major institutions responsible for energy test procedures covering appliances is presented in Table 4-1. The two international entities responsible for appliance energy test procedures are the International Organization for Standardization (ISO) and its sister organization, the International Electrotechnical Commission (IEC). ISO mainly focuses on mechanical performance, and IEC mainly focuses on electrical performance. These organizations rely on an international network of regional and national standards organizations. In Europe, the European Committee for Standardization (CEN) and its sister organization the European Committee for Electrotechnical Standardization (CENELEC) are the respective regional equivalents of the ISO and IEC. They have assumed responsibility for European-Union (E.U.)-wide test procedures. In Japan, the Japan Industrial Standards Association (JIS) is responsible for all appliance test procedures. In Korea, the Korea Standards Association (KSA) is responsible for all appliance test procedures, and some other test procedures are in the Korean Ministry of Commerce, Industry, and Energy announcements. In the U.S., the U.S. Department of Energy (U.S. DOE) is primarily responsible for appliance test procedures, with assistance from several organizations. International test procedures are not limited

Table 4-1 **Key Institutions Involved in Creating Energy Test Procedures for Appliances**

A variety of institutions around the world are engaged in creating and harmonizing energy-efficiency test procedures.

Institution	Acronym	URL
International Standards Organization	ISO	www.iso.org/iso/en/ISPPOOnline.frontpage
International Electrotechnical Commission	IEC	ww.iec.ch
European Committee for Electrotechnical Standardization	CENELEC	www.cenelec.be
European Committee for Standardization	CEN	www.cenorm.be
Korean Standards Association	KSA	www.ksa.or.kr
Japan Industrial Standards Committee	JIS	www.jisc.go.jp/eng
American National Standards Institute	ANSI	www.ansi.org
Air-Conditioning and Refrigeration Institute	ARI	www.ari.org
American Society of Heating, Refrigerating, and Air-Conditioning Engineers	ASHRAE	www.ashrae.org
United States Department of Energy	U.S. DOE	www.eere.energy.gov/buildings/appliance_standards www.gpoaccess.gov/cfr/index.html
World Standards Services Network	WSSN	www.wssn.net

to IEC and ISO standards. For example, U.S. DOE test procedures for several appliances are used as a basis for standards throughout North America.

4.2.2 Existing Test Procedures

All major appliances have at least one established energy test procedure, and most appliances have several. Refrigerators alone have at least five international or national energy test procedures (although this number is slowly declining as a result of harmonization). The general approach for each appliance is described in Table 4-2.

Each product requires its own test facility and general approach to testing.

Table 4-2 General Approach for Testing Energy Performance in Major Appliances

Appliance	Description of Energy Test Procedure
Annual Energy Use	
Domestic Refrigerator	Refrigerator is placed in environmental chamber with doors closed. Ambient temperature is slightly higher than room temperature to account for door openings and food loading (IEC and U.S.). In Japan, doors are opened at specified intervals.
Domestic Water Heater	Storage losses are measured under specified conditions. The energy required to service specified hot water draw cycle is sometimes added to this (U.S.).
Efficiency or Efficacy	
Room Air Conditioner	Air conditioner is placed in calorimeter chamber. Heat removal rate is measured under steady-state conditions and at only one level of humidity.
Central Air Conditioner	Heat removal rate is measured using a combined air enthalpy approach at one or more load conditions.
Heat Pump	Heat removal rate is measured using a combined air enthalpy approach at one or more load conditions.
Motor	Motor is placed on a dynamometer test stand and operated at full load and normal temperatures (U.S.). Alternatively, input power and losses are measured, and the difference is assumed to be the output (Japan and IEC).
Furnace/Boiler	Furnace or boiler is operated under steady-state conditions. Heat output is determined indirectly by measuring temperature and concentrations of combustion products. Fan and pump energy is sometimes added to input energy.
Light	Light output is measured in an integrating sphere. Light input is measured differently for each component, depending on type of light, ballast, and other features. Combination yields an efficacy.
Energy Use per Cycle	
Dishwasher	Energy consumption is measured for a standard cleaning cycle. Cleaning performance may also be included (IEC).
Clothes Washer	Energy consumption is measured for a standard cleaning cycle. Cleaning performance may also be included (IEC).

Table 4-3 is a partial list of test procedures that have international significance or recognition for major appliances. The same test procedure often has several different names because it is may be adopted by several different standards organizations. For example, an IEC test standard may reference an identical CENELEC test standard. In addition, many test procedures refer to other test procedures for certain details of the testing process; thus, it is often necessary to obtain several documents to understand the full scope of a test. The exact citation often changes when a test procedure is updated or harmonized, so it is important to determine the most current document before proceeding. A detailed and comprehensive description of current energy test procedures for appliances in the Asia-Pacific region is available in a recent Asia-Pacific Economic Cooperation (APEC) report (Energy Efficient Strategies 1999).

Each product requires its own test procedures.

Table 4-3 **Energy Test Procedures for Common Appliances**

Appliance	International	Japan	United States
Refrigerator/Freezer	Freezer ISO 5155 (freezers), ISO 7371 (refrigerators without freezers), ISO 8187 (refrigerator-freezers), and ISO 8561	JIS C 9607	Code of Federal Regulations (10 CFR Part 430 Subpart B Appendices A1 and B1)
Room Air Conditioner	ISO 5151-94(E)	JIS C9612-94	Code of Federal Regulations (10 CFR Part 430 Subpart B Appendix F)
Central Air Conditioner	ISO 13253	JIS B 8616-93	Code of Federal Regulations (10 CFR Part 430 Subpart B Appendix M)
Heat Pump	Treated as an air conditioner	Treated as an air conditioner	Treated as an air conditioner
Motor	IEC60034-2A	JIS C4210	National Electrical Manufacturers' Association (NEMA), MG 1-1987 (equivalent to Institute of Electrical and Electronics Engineers, (IEEE) 112)
Furnace/Boiler	Depends on fuel used	Depends on fuel used	Code of Federal Regulations (10 CFR Part 430 Subpart B Appendix N))
Water Heater	IEC60379		Code of Federal Regulations (10 CFR Part 430 Subpart B Appendix E)
Light	There is no explicit energy-efficiency test procedure.	There is no explicit energy-efficiency test procedure.	NEMA LE-5
Dishwasher	IEC60436-81		Code of Federal Regulations (10 CFR Part 430 Subpart B Appendix C)
Clothes Washer	IEC60456-98	JIS C9606-93	Code of Federal Regulations (10 CFR Part 430 Subpart B Appendix J)

Energy test procedures for consumer home electronics, such as televisions, VCRs, and audio equipment, have only recently been developed. These are summarized in Table 4-4. A large portion of the total electricity consumed by these appliances is used in standby mode, so the focus of energy test procedures has largely been on standby electricity consumption rather than consumption in the "on" mode.

Information is available in the E.U., the U.S., and Japan regarding newly emerging test procedures for consumer home electronics.

Table 4-4 Energy Test Procedures for Consumer Home Electronics

Appliance	Europe	Japan	United States
Television	www.gealabel.org	www.eccj.or.jp	www.energystar.gov/
Videocassette Recorder	www.gealabel.org	www.eccj.or.jp	www.energystar.gov/
Audio Equipment	www.gealabel.org		www.energystar.gov/
Standby Power	www.gealabel.org		www.energystar.gov/

4.2.3 The Difficulty of Modifying Existing Test Procedures

Modifying an energy test procedure is typically cumbersome and time consuming. Most standards organizations are inherently conservative, so there must be strong pressure before a modification is considered and approved. Thus, standards-setting organizations are typically slow to modify test procedures in response to new technologies in appliances. When regulatory labeling and standards-setting programs are linked to test procedures, modifications become even more difficult. Nevertheless, in cases where there is a consensus that rapid change is needed, such change is possible. For example, the Japanese government was able to significantly modify the test procedures for refrigerators in approximately one year so that these procedures would be in force in time for a new Japanese efficiency standard. This unusually rapid change was accomplished only because of close cooperation among the Japanese government, the manufacturers, and the standards association.

4.2.4 The Difficulty of Translating Results from One Test to Another

Energy tests, whether for labels or standards, are expensive. The efficiency test for a gas-fired water heater costs about US$1,000 per unit. One internationally recognized testing laboratory charges roughly US$2,000 to perform the U.S. DOE test procedure on a single refrigerator and US$6,000 for a central air-conditioning unit. The laboratory tests and administrative work needed to create an E.U. energy label for a clothes-washing machine cost about US$3,800 (Sommer 1996). Because of the cost of testing, it is tempting to try to compare results from one test to those from another. This should generally be avoided, however, because test procedures often differ in important aspects, which leads to widely different energy values. For example, furnace and boiler efficiency tests in the E.U. are based on the fuel's "low heating value," that is, excluding the latent heat of condensation of the combustion gases. Tests in the U.S. typically use the "high heating value." This difference alone will cause at least a 5% difference in reported efficiency. Formulas for converting values from one test to another have been attempted but with little success (Meier 1987; Bansal and Krüger 1995). One exception is motors. An algorithm has been prepared for translating motor test results from one protocol to another within specified margins of error (de Almeida and Busch 2000).

Tests sometimes differ in underlying philosophy as well as in method. European tests for washing machines seek to measure the energy required to achieve a standard level of cleaning performance. U.S. test procedures simply measure energy consumption for a standard cycle and allow the manufacturer to determine the level of cleaning performance. Performance tests, like those used in Europe, are generally more complicated and expensive; combining cleaning performance with energy measurement tends to make the test procedure less repeatable and reproducible than is possible when only energy is measured. These differences lead to significantly different test procedures.

4.2.5 Selecting a Test Procedure; Considering Alignment

Creating an energy test procedure requires investments in a physical setup, including test facilities and trained technicians, as well as the resulting institutional investments in the administrative apparatus and representation at technical meetings. Stakeholders, such as manufacturers, trade organizations, and government agencies, are involved in supporting these investments. The infrastructure will be different for each appliance depending on the level of sophistication and advancement of the industry, the extent of imports, and the choice of test procedure. Small or poor countries may be unable to support these costs and therefore may be obliged to accept internationally sanctioned test procedures from ISO and IEC. Countries with close economic ties to Japan, the E.U., or the U.S. may find it convenient to align with their strongest trade partner. If the U.S. is the strongest partner, it may be simpler to align with the Canadian Standards Association (CSA) test procedures because CSA tests, while nearly identical to U.S. tests, are specified in Système Internationale (SI) units. Alignment has the advantage of allowing a country to draw upon an existing test and an international network of testing facilities to reduce barriers against import and export of appliances. Local manufacturers planning for eventual foreign trade or multinational firms seeking to standardize production facilities will likely support this approach.

By contrast, a country may be saddled with a test procedure that is unnecessarily complex or simply inappropriate for local conditions. Japan decided that the ISO test for refrigerators was not appropriate because it ignores the impact of humidity and door openings, so Japan replaced the ISO test with its own procedure. Particular costs imposed by certain tests should also be considered. For example, some clothes washer and dishwasher tests require a standardized detergent. Special test materials are typically available from only one or two suppliers at high prices. For example, the ISO refrigerator test requires the use of thermal mass with specific properties (to simulate food), which is available from only a few suppliers.

Modification of recognized international test protocols should be approached with caution. In addition to eliminating the potential for aligning or harmonizing test protocols with other regions, alterations introduce the need to verify repeatability and reproducibility of the test. These changes increase the cost of developing the test protocol.

In deciding whether to develop a unique domestic test procedure, adopt an established international procedure, or adopt a simplified version of an international test procedure, policy makers should consider the criteria discussed in Section 4.1.3. Because a new domestic procedure will take more time to develop and maintain than an existing test procedure, there must be strong reasons for not selecting an existing test procedure. Small countries or those with a very small local appliance manufacturing base should have extraordinary reasons not to adopt an internationally recognized standard before proceeding to develop their own. Countries with a large appliance manufacturing industry have more flexibility regarding local test procedures. One example is the case of Japan and washing machines. The IEC test procedure is strongly oriented toward hot water washing. Japanese clothes washing practices rely almost exclusively on ambient water temperatures (thanks to the presence of soft water throughout Japan). Because the efficiency of hot water use is not relevant to Japan, Japan's tests emphasize motor efficiency over hot water use. It is sometimes possible to align some aspects of an appliance's test procedures with international procedures while establishing local procedures for others. As conditions in the country change, the mix of local and international test procedures can also change.

Choosing a test procedure for a product may be especially difficult if several different tests are used by manufacturers in a country (perhaps because the manufacturers are local subsidiaries of companies from different countries that use different procedures). A trade association of manufacturers and the domestic standards association (the local counterpart to ISO) typically work together to establish a test procedure, but the government can also assemble its own advisory group and select a test procedure on its own. In the long run, however, some sort of technical review group will be required to enhance and/or legitimize in-house government expertise.

The process will generally be faster if an existing test procedure is simply adopted than if a unique domestic procedure is established. The speed of adoption will also depend on the extent to which the government decides to involve local manufacturers; the greater the involvement, the slower but more effective the process. The speed will also depend on the government's approach to certification and enforcement (discussed in Chapter 8). If a completely new test procedure is created, then it must be publicly announced and field tested, and staff must be trained to perform it. This process can easily take longer than one year. Staff training is particularly important because most of the tests will be conducted by manufacturers in their own facilities.

4.2.6 Considering Regional Harmonization

There is an increasing trend for neighboring countries within a formal or even loosely defined trade region to go beyond unilateral alignment and to harmonize their energy-efficiency test procedures by mutual agreement. Harmonization involves the adoption of the same test procedures, mutual recognition of test results, and/or alignment of performance standards levels and energy-labeling criteria for particular appliances. Like alignment, this approach allows countries, companies, and consumers to avoid the costs of duplicative testing and non-comparable performance information and to access a wider market of goods.

Recognizing this, many countries are participating in regional activities directed at harmonizing energy-efficiency standards and labels and the testing that underlies both of these measures. As mentioned in Chapter 3, such activities are being undertaken by APEC, the South Asia Regional Initiative for Energy Cooperation and Development (SARI/E), the Pan American Standards Commission (COPANT), the Association of Southeast Asian Nations (ASEAN), and the North American Energy Working Group (NAEWG).

Harmonization discussions are complex and slow because standards, harmonization, and regulations can create non-tariff trade barriers. Reduction of trade barriers is not necessarily "beneficial" to all concerned.

Regional Efforts to Harmonize Test Procedures and Enhance Mutual Recognition of Test Results in South Asia

In July, 2003, a SARI/E energy project sponsored by the United States Agency for International Development (U.S. AID) had the goal of assessing the capabilities of testing facilities in South Asia and determining the improvements needed in order to support a regional standards and labeling program. Test facilities in India, Bangladesh, Sri Lanka, and Nepal were assessed for their capabilities to test refrigerators, ceiling fans, lighting, and motors. The end goal was for the region to use common test procedures and to allow for the test results in one country to be valid in another. To achieve this goal, test laboratories must have adequate facilities, trained personnel, and calibrated instrumentation to provide test results that are both repeatable within the same laboratory and reproducible at other test facilities.

Not all of the countries had adequate facilities to test all of the four products. The assessment uncovered a need to upgrade some test facilities and to provide training in conducting tests. Differences and similarities in the test standards and facilities were listed.

To create confidence in the repeatability of test results from the same laboratory and reproducibility of test results between laboratories, it was recommended that the laboratories be accredited by an internationally recognized body. As part of the accreditation, a round-robin, inter-laboratrycomparison testing program would be implemented. This approach is especially important in cases where ambiguity in the test procedures could result in different laboratories interpreting the test procedure differently.

Although some countries had the ultimate goal of establishing their own internationally recognized accreditation bodies, a cost-effective alternative was to use the services of the National Accreditation Board for Testing & Calibration Laboratories (NABL), an International LaboratoryAccreditation Cooperation (ILAC)-recognized accreditation body in India. Mutual recognition agreements between standards-setting and labeling agencies would also be necessary to insure that the results from a laboratory in one country are accepted in another country.

Results of this project were made publicly available in a report available on the internet: www.sari-energy.org/projectreports.asp?ReportCatID=energy%20efficiency. In addition, a workshop entitled "Designing and Managing Energy Test Facilities & Protocols" was attended by all of the SARI/E countries. India, Bangladesh, Sri Lanka, Nepal, Bhutan, and Maldives participated in the workshop. The purpose of the workshop was to bring together both technical and policy experts involved in standards and labeling efforts in each country to discuss energy test protocols, capabilities of test facilities, and possibiities for harmonizing the test protocols and accreditation procedures. Continuing dialog among the SARI/E countries is needed to complete the goal of harmonized test procedures and standards-setting and labeling programs.

Countries and world bodies promoting regional endeavors must understand and account for the trading patterns of the manufacturers they are trying to influence. The following inserts provide a glimpse of such deliberations in the SARI/E and NAEWG regions, respectively. (See inserts: *Regional Efforts to Harmonize Test Procedures and Enhance Mutal Recognition of Test Results in South Asia* and *Regional Efforts to Harmonize Test Procedures and Enhance Mutal Recognition of Test Results in North Americ*a.)

Regional Efforts to Harmonize Test Procedures and Enhance Mutual Recognition of Test Results in North America

Recognizing that differences among national test procedures and the failure to accept each other's test results are barriers to regional trade in energy-efficient products, Canada, Mexico, and the U.S. have been exploring the harmonization of test procedures and the mutual recognition of test results.

In 1992, The Energy Efficiency Expert Group of NAEWG analyzed the commonalities and differences among the three countries' test procedures to identify areas for potential harmonization. By meeting on a regular basis and frequently exchanging information, the dozen individuals participating in the Expert Group determined that there were 46 energy-using products for which at least one of the three countries had energy efficiency regulations. Three products—refrigerators/freezers, room air conditioners, and integral horsepower electric motors—appeared to have nearly identical test procedures in the three countries; 10 other products had different test procedures but showed near-term potential for harmonization. Through line-by-line comparisons of the three most similar test procedures, the NAEWG Expert Group verified that, apart from minor wording differences, they were identical. The next three products for comparison will likely be dry-type distribution transformers, residential central air conditioners, and linear fluorescent lamps.

The Expert Group has also been exploring mechanisms for facilitating mutual recognition of testing laboratory results among the three countries to minimize duplicative testing requirements. One possibility is to enhance mutual accreditation of the three countries' test laboratories, e.g., by having Mexican entities join international agreements in which U.S. and Canadian accreditation bodies already participate (such as ILAC). In addition, the Expert Group is compiling guidance on requirements for manufacturing and selling different products in the three countries and exploring ways to facilitate the process at each stage.

After three years, the Experts Group is still meeting regularly with a full agenda. Each country has solicited the input of its domestic stakeholders on both the harmonization of test procedures and the mutual recognition of test results. In addition to consulting with domestic manufacturers and trade associations, the Expert Group has consulted with the international Council for Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), which has agreed to review its test procedure comparison results.

By collaborating, the three countries hope to reduce the costs of compliance with standards and mandatory labeling programs in the region, accelerate the replacement of less efficient products, and facilitate the transformation of the regional market for energy-efficient products (NAEWG 2002).

4.2.7 Announcing the Test Procedure

The final test procedure needs to be decided and announced well in advance of the start date for efficiency labels or standards. Manufacturers need time to equip and certify their own test facilities and then more time to determine which models comply.

4.2.8 Normalizing Energy Values for Volume, Capacity, and Performance

Most energy measurements are normalized by volume or capacity or categorized by some other feature. These numbers typically become the "denominators" used in stating energy performance test results. Usually, separate test prescriptions define the way volume, capacity, illumination, performance, or other characteristics are to be uniformly measured. These details are as important as the energy measurements themselves. For example, inappropriate measurement of an appliance's capacity can result in an inaccurate declaration of efficiency. Therefore, along with establishing the test procedure, it is beneficial to establish a procedure for measuring capacity.

4.2.9 Reconciling Test Values and Declared Energy Consumption

There is a natural variation in the energy efficiency of appliances as they come off the assembly line. For example, two air conditioners leaving the assembly line one week apart may differ in efficiency by as much as 5% depending on the degree of quality control in the manufacturing facility. This variation arises from minute differences in components, materials, and assembly. There must, therefore, be a separate procedure for converting measurements of individual appliances' energy performance into a value representing the entire production run (the "declared" energy consumption). The choice of procedure is important because it has a major impact on the cost of testing (that is, on the number of units that need to be tested), the ability to provide accurate declared values, and the ease of enforcing energy standards.

Most tests include a procedure to establish a declared energy consumption for an appliance. This typically involves randomly selecting two or more appliances after they leave the assembly line. The declared value is usually the mean of the measurements of these two units. However, if their test values differ by more than a certain amount (determined by a statistical formula), then additional units must be tested. Here is the current ISO (1999) procedure for refrigerators:

> If the energy consumption is stated by the manufacturer, the value measured in the energy-consumption test shall not be greater by more than 15% of the stated energy consumption.
>
> If the result of the test carried out on the first appliance is greater than the declared value plus 15%, the test shall be carried out on a further three appliances.
>
> If the three additional tests are required, the arithmetical mean of the energy-consumption values of these three appliances shall be equal to or less than the declared value plus 10%.

In practice, some manufacturers measure the energy performance of one unit and then declare the energy consumption to be 15% less than the measured value. This yields a declared energy consumption that, while clearly avoiding the intent of the procedure, remains legitimate. The U.S. has established more stringent criteria for establishing declared values in an effort to reduce misleading ratings.

4.2.10 Emerging Issues in Energy Testing

It is important to recognize some of the emerging issues that will affect all energy test procedures, especially issues related to regulatory standards and energy labels. These issues will be discussed in future meetings of technical committees of the standards-making bodies.

Appliances increasingly contain microprocessors linked to an array of sensors and controls. Microprocessor control offers many opportunities for energy savings, such as variable-speed drive in air conditioners, the ability to adjust a wash cycle based on how soiled the clothes are, or the ability to vary combustion conditions in a boiler based on demand. Savings of more than 30% are often easy to achieve with microprocessor controls, and test procedures should be changed to credit these savings.

However, the same technology also can be used to circumvent or defeat a test procedure (Meier 1998). The authors are aware of two cases where a microprocessor was designed to sense when an appliance was being tested, and, in response, switch to a special low-energy mode. Several manufacturers of automobiles and diesel engines were caught using this strategy and were fined nearly US$1 billion. Although such deception is highly unusual, it is useful for practitioners of appliance testing to be aware of the possibility.

Eventually, all appliance energy test procedures will need to be revised to reflect the increasing use of microprocessor controls because the tests will need to assess both the behavior of the mechanical components (the "hardware") and the programming (the "software") installed to operate the device.

Standards-setting organizations are beginning to address this dilemma, especially in office equipment, in which power-management logic is already widely used (and required for endorsement by ENERGY STAR).

The World is Starting to Adapt Test Procedures to More Fairly Characterize "Smart" Devices

The original U.S. DOE test for dishwasher energy performance required that clean dishes be inserted in the racks during the test. Units with soil sensors appeared to be very efficient because they used the minimum amount of water to clean the already-clean dishes. During the late 1990s, a U.S. consumer organization observed that in real-world situations many dishwashers with soil sensors actually used more hot water and energy than traditional, mechanical designs. The organization advised its members to ignore the energy labels because they were misleading. As a result, U.S. DOE developed a new test involving soiled dishes. This is the first and only time that the authors are aware of an energy-performance test for a white goods appliance being modified for such a reason. The revision also included a measurement of standby power consumption (which was also a first).

The approach involves developing a typical operating cycle that captures all of the major operating modes. There has been less progress with respect to white goods and microprocessors. The recent modification of the U.S. DOE test for dishwashers to reflect microprocessors appears to be the first (see insert: *The World is Starting to Adapt Test Procedures to More Fairly Characterize "Smart" Devices* on the previous page).

The separation of energy test procedures and mandatory regulations is becoming less clear. One example of this situation arises in the relation of testing tolerances to energy labels. The European A-G energy-efficiency labeling scheme assigns a range for each letter category roughly equal to 10% of the efficiency range. Because the ISO test procedure for refrigerators establishes a 15% tolerance in measurements, manufacturers exploited the tolerance limit in the early years of the labeling scheme and sometimes claimed a C refrigerator to be an A (Winward 1998). Although round-robin testing, industry testing guidelines, and increased check testing since then appear to have reduced the magnitude of routine exploitation of tolerances, the European labeling system is putting pressure on ISO and IEC to require narrower tolerances.

4.3 Step T-2: Create a Facility for Testing and Monitoring Compliance

Test facilities are needed to perform energy tests. Almost every appliance requires a unique energy test setup. For example, a refrigerator requires an environmental chamber, and an air conditioner requires a calorimeter chamber. A list of some firms capable of performing internationally recognized energy tests along with an accompanying certification of results is shown in Table 4-5. The websites listed in the table describe the kinds of facilities and special features available. Most modern facilities can test several units at one time and collect all data on a data logger system. A country may decide to avoid developing

Many firms around the world are available to perform internationally recognized energy tests and certify the results.

Table 4-5 **Some Firms that Can Perform Internationally Recognized Energy Tests along with Accompanying Certification of Results**

Name	Country	URL
Intertek Testing Service	U.S.	www.itsglobal.com
Underwriters Laboratories, Inc.	U.S.	www.ul.com
CSA	Canada	www.csa.ca/
Korea Testing Laboratory	Korea	www.ktl.re.kr/eng
Le Laboratoire Central des Industries Electriques (LCIE)	France	www.lcie.fr
Laboratoire National d'Essais (LNE)	France	www.lne.fr

its own test facility and use commercial facilities for occasional compliance testing (such as random tests) because test facilities are expensive to construct and maintain. A fully operational (i.e. turnkey) motor testing facility, for example, costs up to US$100,000. A turnkey room air-conditioning test facility (a balanced calorimeter room) costs about $500,000 and requires at least two staff members to operate efficiently. A new turnkey facility capable of testing all major appliances (including motors and lights) costs many millions of dollars and requires at least 15 full-time staff members.

Most large, international appliance manufacturers maintain their own in-house test facilities to ensure that their units comply with energy regulations. These firms use energy tests not only to verify compliance but also as an element of quality control, prototype testing, and checking competitors' models. For these reasons, appliance testing most often takes place on the manufacturers' premises. Smaller manufacturers may rely on cruder test facilities with less precise results and contract with private, independent test laboratories when more precise measurements are needed.

A government that operates a labeling or standards-setting program must have a facility that can perform reliable, unbiased energy tests. The facility can be operated by the government or a private firm. Few, if any, countries maintain government laboratories for large-scale appliance testing. Even the U. S. lacks a full-fledged, government-operated appliance test facility. Other national testing facilities, such as those in France, Australia, and Canada, perform private testing to defray the cost of maintaining the facilities. By contrast, in the Philippines, testing fees go back into the federal treasury instead of being reinvested in the facility, so it is difficult to maintain the facility's performance and capabilities (Egan et al. 1997). A preferred course of action is to reinvest the fees in the facility to help guarantee its long-term existence and value.

If energy testing is not widely practiced in a country, a government testing facility may be needed to stimulate improvements in the quality of private test facilities. One procedure is the round-robin test in which several facilities test the same appliance and compare results to those obtained in the government facility. This process identifies incorrect procedures or equipment. Round-robin measurements have been conducted occasionally in Europe and the U.S. and have often revealed surprisingly large variations in measurement results. The Philippines has also used this strategy.

Energy tests, including setup and breakdown, take considerable time to perform. Room air conditioners require four to six hours. Refrigerators must be tested for a minimum of 24 hours. Most protocols require at least two tests to bracket the desired temperatures. Many tests, such as those for refrigerators and air conditioners, require that the test facility and the appliance reach steady-state conditions for at least an hour before the test may begin. These requirements severely restrict the ability of a test facility to test many units rapidly.

Regardless of who actually performs energy tests, the government must establish a procedure for monitoring compliance with labels or standards. The process must specify how test appliances are to be selected from the factory inventory or off the floor at appliance stores, how many units must be tested, and who pays for the tests. This procedure can be aggressive, with a schedule of random testing, or activated only in response to complaints. An aggressive policy is advisable in the beginning so that manufacturers take a standard or label procedure seriously. Later, a complaint-triggered compliance check can be substituted. In the U.S., the standards program appears to have operated reasonably honestly with almost no government-initiated compliance monitoring. In Europe, manufacturers began more honestly reporting test results only after a compliance-monitoring scheme was initiated. The role of testing in the compliance regime of any standards-setting or labeling program is described further in Section 8.8.

4.4 Step T-3: Incorporate Testing into Enforcement

Many of the administrative aspects of establishing and administering appliance efficiency labels and standards are discussed elsewhere in this guidebook. However, a brief overview of administrative matters specifically related to test procedures and enforcement is provided below.

4.4.1 Establishing Administrative Mechanisms for Certification, Data Collection, and Appeal

The government or an NGO must prepare forms, organize procedures for reporting test results, and establish a database of compliant units. These mechanisms must be in place before labels or standards become mandatory.

First, the government must establish a procedure to certify test results. The two primary options, government testing and self-certification, are discussed in detail in Chapter 8. A self-certification procedure is generally superior because it is cheaper, faster, and relies on manufacturers' existing test facilities. For short periods, while the industry is in its infancy, it may make sense to have a higher-precision central facility administer tests and charge manufacturers for this service. Manufacturers are often uncomfortable with government certification because they would rather keep results secret until it is necessary to submit them. Over the long run, manufacturers will likely try to replace government certification with self-certification. A compliance-monitoring procedure must accompany any self-certification to ensure that manufacturers submit accurate results to the government. This procedure should include a process for considering complaints from one manufacturer about another and complaints from consumer associations. Japanese consumer organizations, for example, were instrumental in causing Japanese energy test procedures to be modified, and various European consumer organizations have exerted considerable pressure on European manufacturers to more honestly report energy efficiency.

No test procedure can adequately characterize 100% of the products that must conform to a label or standard requirement because new technologies or special features appear faster than tests can be modified to accommodate them. It is therefore essential to develop a flexible, intelligent, and rapid mechanism for administering enforcement and waivers. A process must be available to address the small percentage of products that cannot be tested using the recognized test. A manufacturer may be prevented from offering a product if it is inefficient but should not be prevented from offering a product because the product cannot be tested.

4.4.2 Establishing Procedures to Certify Independent and Manufacturer Test Facilities

The government must also create a procedure to ensure that testing facilities correctly perform tests with properly calibrated equipment. The procedures for conformity certification, often called accreditation, are well documented by international standards organizations (Breitenberg 1997). As mentioned earlier, an important aspect in less-developed countries will be staff training, including regular testing using round-robin measurements.

No matter which aspect of energy testing is being addressed—establishing a test procedure, creating a test facility, or creating the administrative apparatus for enforcement—it is important to remember that all of these elements should be addressed as early as possible in the process of developing labeling and standards-setting programs. An early start ensures time for proper technical analysis, observation of international test facilities, and review of existing international test procedures. After a testing capability is developed, the next step is to design and implement a labeling program, to analyze and set standards, or both, depending on the overall program. The development of a labeling program is described in Chapter 5; standards-setting is described in Chapter 6. A more thorough discussion of how verification and compliance regimes ensure the integrity of energy-efficiency labeling and standards-setting programs appears in Chapter 8.