Title

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Abstract

China is the largest exporter of fluorescent lamps, accounting for 33% of world exports in 2003 and supplying significant quantities to final markets in the United States, Indonesia, Brazil, Korea, and Mexico. China, the United States, and Brazil all have national energy-efficiency labeling programs in place for compact fluorescent lamps (CFLs). As dependence on Chinese imports grow, inconsistencies in testing procedures, laboratory conditions, technical specifications, and classification place additional costs on labeling programs in importing countries and increase the difficulty of identifying, labeling, and promoting energy-efficient CFLs to consumers. We examine critical differences among energy-efficiency labeling programs for CFLs in Brazil, China, United States, and the seven members of the international Efficient Lighting Initiative (ELI) in terms of technical specifications and test procedures, and review issues related to international harmonization of these standards.

1. Background

Energy efficiency labeling of consumer products is increasing internationally as consumers demand better performance and national governments implement market strategies to reduce overall energy demand (Nadel 2002). These labels typically do not carry much information about the product aside from indicating reduced energy consumption over comparable non-labeled products. As such, the credibility of the label is dependent on assurance that specifications and testing procedures used in certifying the product conform to the standards of the labeling program – and that the program is able to maintain a high level of product quality while sourcing from several different regions.

Currently, twenty countries have implemented energy-efficient labeling programs for compact fluorescent lamps, of which only two are mandatory (CLASP 2004). Among the 18 voluntary programs are those of the US (Energy Star), China (CECP), Brazil (Procel/SEAL and Inmetro/ECL) and the Efficient Lighting Initiative (ELI), which initially covered the 7 countries of Argentina, the Czech Republic, Hungary, Latvia, Peru, the Philippines, and South Africa. These 10 countries – with a combined population of nearly 2 billion people – include major producers of CFLs (China and Hungary) and major consumers (China, US and Brazil).

Energy Star

The Energy Star program was established by the US Environmental Protection Agency in 1992, and expanded in partnership with the Department of Energy in 1996. The Energy Star CFL program was first launched in August 1999 under DOE sponsorship. These voluntary specifications were revised in October 2001, and the current specifications went into effect in October 2003. Unlike many other Energy Star qualified products, CFLs are not subject to Federal minimum efficiency or performance requirements

CECP

The Center for the Certification of Energy Conservation Products, or CECP, was established in 1998 to develop and implement China's first voluntary energy efficiency label. Working in coordination with the on-going Global Environmental Facility

(GEF)-supported China Green Lights Program, CECP implemented efficiency and performance specifications for CFLs in December 2002.

Procel

Brazil's National Program for Electrical Energy Conservation, or Procel, was established by the Brazilian government in 1985. Funded in part by a levy on utilities net profits, Procel is a key funder or co-funder of a range of energy conservation projects, including the promotion of CFL use. In 1994, it introduced its voluntary 'seal of approval' or SEAL, to indicate the top rated models in terms of energy efficiency. The current regulations on the use of the SEAL mark on CFLs were issued in November 2002. For CFLs, the SEAL is used in conjunction with the Energy Conservation Label (ECL), a categorical information label. In the following tables, the requirements for both programs are indicated.

Efficient Lighting Initiative

The Efficient Lighting Initiative, or ELI, was established through the funding support of the GEF and implemented through the International Finance Corporation (IFC). It operated from 2000 to 2003 through country programs in Argentina, the Czech Republic, Hungary, Latvia, Peru, the Philippines, and South Africa. The program includes a range of market transformation activities, including the issuance of a ELI label for CFLs meeting the program's voluntary technical specifications. The current specifications were revised in July 2002. In 2004, ELI announced the Next Generation of ELI, to be sponsored by China's CECP. In 2005, the logo and specifications will be turned over to CECP for management and development.

The expansion of independent national standards and labeling programs may pose a barrier to international trade in CFLs. Manufacturers producing for the international market currently face several export specifications due to different national programs and requirements in importing nations. As the number of national labeling programs increases, their costs of manufacturing and testing for each unique set of requirements rises as well. Harmonization of these standards involves the adoption of the same test procedures, mutual recognition of test results, and/or alignment of performance standard levels and labeling criteria. Such an approach allows countries, companies, and consumers to avoid the costs of duplicative testing and non-comparable performance information, while benefiting from a reduction in non-tariff trade barriers and access to a wider market of goods through harmonization of labeling requirements (Fridley & Wiel 2004). In the case of the four programs examined here, harmonizing standards for energy-efficient CFL labeling could help lower costs and expand market share relative to lower-efficiency CFLs and incandescents.

In the following sections, we will highlight the importance of CFLs in international trade, compare performance specifications of the four programs, compare the testing procedures underpinning the performance specifications, and discuss issues of mutual recognition in a harmonized labeling regime.

2. International Trade in CFLs and Fluorescent Lighting

Currently available trade data do not provide sufficient detail to distinguish CFLs from the larger category of fluorescent lighting. However, the aggregate trade volume in fluorescent lighting is likely to be indicative of the relative magnitude of CFL trade flows and its importance to these countries (Table 1).

Table 1 International Trade Flows of Fluorescent Lamps[1]

US$1000s

EXPORT	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Brazil	$5,800	$3,697	$2,891	$5,896	$7,302	$6,396	$9,014
China	$77,641	$106,518	$176,916	$280,290	$536,942	$390,647	$549,161
ELI Countries	$102,401	$128,785	$139,899	$145,098	$157,104	$125,233	$145,143
USA	$124,339	$107,311	$100,763	$98,648	$73,222	$80,070	$76,461
Subtotal	$310,182	$346,311	$420,469	$529,932	$774,570	$602,346	$779,780
World	$1,246,838	$1,355,609	$1,647,467	$1,502,734	$1,545,910	$1,279,633	$1,667,038
% of World Total	25%	26%	26%	35%	50%	47%	47%
IMPORT	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Brazil	$36,533	$45,994	$28,488	$33,878	$113,257	$42,211	$30,912
China	$18,021	$16,200	$24,515	$28,330	$33,852	$34,725	$30,847
ELI Countries	$33,189	$55,902	$54,731	$65,960	$59,450	$49,051	$54,486
USA	$202,607	$269,489	$324,934	$326,419	$577,370	$408,773	$408,087
Subtotal	$290,349	$387,586	$432,668	$454,587	$783,930	$534,760	$524,331
World	$1,606,487	$1,638,976	$1,397,450	$1,671,992	$1,958,637	$1,791,975	$2,109,683
% of World Total	18%	24%	31%	27%	40%	30%	25%

Source: United Commodity Trade Statistics, 2004. HS1996 data for commodity 853931 -- Fluorescent lamps, hot cathode (Discharge lamps, other than ultra-violet lamps)

China alone accounts for about one-third of world exports in fluorescents of nearly US$1.7 billion (export basis), three times the volume of its nearest competitor, France, and seven times that of the US. China's emergence as the leading producer and exporter has been rapid; exports grew at an average annual rate of 40% between 1996 and 2003. In total, the 10 countries under examination here account for nearly half of world exports of fluorescents, though their share of total world imports has varied between 18% and 40%.

The trading relationship among the 10 countries reveals a strong singular dependency on China (Table 2).

Table 2 World Trade in Fluorescent Lamps, 2003

2a: Imports of Fluorescent Lamps in Major Markets

(US$1000s)	EXPORTER					
IMPORTER	Brazil	China	ELI Countries	USA	Subtotal	World
Brasil		$21,063	$1,407	$2,941	$25,411	$30,912
China	$0		$520	$634	$1,155	$30,847
ELI Countries	$385	$14,361	$1,908	$2,409	$17,026	$54,486
USA	$81	$172,265	$27,329		$199,675	$408,087
Subtotal	$466	$207,690	$31,164	$5,984	$243,267	$524,331
World	$9,014	$549,161	$145,143	$76,461	$779,780	$1,667,038

[1] The discrepancy between the total export and import value stems from the calculation of exports on an FOB basis and imports on a CIF basis; incomplete reporting; and possible revaluations at time of import.

2b: Percentage of Total Fluorescent Imports in Key Markets by Export Country

	EXPORTER					
IMPORTER	Brazil	China	ELI Countries	USA	Subtotal	World
Brazil		68%	5%	10%	82%	100%
China	0%		2%	2%	4%	100%
ELI Countries	1%	26%	4%	4%	31%	100%
USA	0%	42%	7%		49%	100%
Subtotal	0%	40%	6%	1%	46%	100%
World	1%	33%	9%	5%	47%	100%

Source: UN Commodity Trade Statistics, 2004

In 2003, China accounted for 68% of Brazil's imports of fluorescent lamps, and 42% for the US. The seven ELI countries rely on China less for their imports, importing instead from other European producers, and, in the case of the Philippines, from Indonesia. Nonetheless, China still accounts for a quarter of their imports.

3. Comparison of Technical Specifications

For the purpose of this analysis, we divide product specifications into four key areas: General Testing Requirements and Procedures, Key Technical Specifications, Secondary Technical Specifications, and Labeling and Consumer Requirements. General Testing Requirements and Procedures cover the basic product scope, sample size, laboratory requirements, and other items of program operation. The Key Technical Specifications include those involving energy efficiency, lumen maintenance, and durability and lifetime. Secondary Technical Specifications include items related to acceptable operation of CFLs, including Color Rendering Index and start-up time. The Labeling and Consumer Requirements involve mainly information for the consumer, such as the equivalency to incandescent output and color temperature.

a. General Testing Requirements and Procedures

Product Type Coverage			
CECP	ELI	ENERGY STAR	ECL/SEAL
Unitary CFLs, screw or bayonet base, with electronic or magnetic ballasts, with covers or reflectors	Unitary or modular CFLs, screw or bayonet base, with electronic or magnetic ballasts, with covers or reflectors.	Unitary CFLs and circulars up to 9" diameter, with electronic ballasts, medium screwbase only , with covers or reflectors.	Unitary or modular CFLs and circular fluorescents, with electronic or magnetic ballasts, with covers or reflectors.
Designed to operate at 220 V and 50 Hz with a rated power of ≤60W.	Designed to operate at 220V	Designed to operate at 110V	Designed to operate at 127V and 220V

Product coverage in all 4 programs is similar, and all incorporate screw-based unitary CFLs. The CECP additionally specifies bayonet-based CFLs, while ELI covers both types through reference to "a socket originally intended for standard incandescent use." The Procel program does not specify connection type. All programs but Energy Star include both electronic- and magnetic-ballasted CFLs. The CECP and Energy Star program are limited to unitary CFLs only, but all programs incorporate bare-bulb, covered, or reflector CFLs.

Sample Composition and Test Data Sources			
CECP	ELI	ENERGY STAR	ECL/SEAL
Tests performed at CECP-certified third-party laboratories, paid by manufacturers	Tests performed at ILAC-accredited laboratories, paid by manufacturers	Tests performed at NVLAP or A2LA-accredited laboratories, paid by manufacturers	Tests performed at authorized reference laboratories, paid by manufacturers
Samples selected by manufacturers	Samples selected by manufacturers	Samples selected by manufacturers	Samples selected by manufacturers
Sample size: 12 (for most tests)	Sample size: 10	Sample size: 10 (for most tests)	Sample size: 11; 10 for testing, 1 for control

All programs require the testing of products at accredited laboratories. Owing to the multinational scope of ELI, its program relies on the International Laboratory Accreditation Cooperation (ILAC) body; the other three programs rely on national accreditation bodies. All samples for testing are selected by manufacturers, with the sample size ranging from 10 in the ELI program and Energy Star, to 12 for CECP. Most tests require the tests of the same selection sample, although the Energy Star Rapid Cycle Stress Test requires a separate unique sample of six lamps.

Additional Requirements			
CECP	ELI	ENERGY STAR	ECL/SEAL
Mandatory on-site audit of manufacturing facility for ISO 9000 compliance, followed by annual audits. Random testing of 10 samples once a year.	Optional participation in ELI-operated independent product testing and quality assurance program.	Mandatory participation in an independent product testing and quality assurance program, not linked to CFL qualification for labeling.	

Manufacturers participating in the CECP labeling program must also submit to an on-site audit, conducted by CECP auditors, of manufacturing facilities for compliance to ISO 9000. Manufacturers are requalified annually for the program. Energy Star also requires manufacturers to participate in a third-party quality control verification and testing program using accredited facilities. This requirement, new in the 2003 revision, grew out of earlier complaints of labeled CFLs not performing to Energy Star specifications. ELI has a similar, but optional, program for its manufacturers.

b. *Key Technical Specifications*

Energy Efficiency (Initial Efficacy)							
CECP		ELI		ENERGY STAR		ECL/SEAL	
Bare-tube CFLs							
Rated Input Power 5 to 8 W		Measured Input Power < 15 W		Measured Input Power < 15 W		Rated Input Power < 15 W	
						ECL	*SEAL*
CCT > 4040K:	≥ 46 lm/W	All CCT:	≥ 45 lm/W	≥ 45 lm/W		≥ 40 lm/W	≥ 45 lm/W
CCT ≤ 4040K:	≥ 50 lm/W						
Rated Input Power 9 to 14 W							
CCT > 4040K:	≥ 54 lm/W						
CCT ≤ 4040K:	≥ 58 lm/W						
Rated Input Power 15 to 24 W		Measured Input Power ≥ 15 W		Measured Input Power ≥ 15 W		Rated Input Power ≥ 15 W	
CCT > 4040K:	≥ 61 lm/W	CCT > 4000K	≥ 55 lm/W	≥ 60 lm/W		≥ 40 lm/W	≥ 60 lm/W
CCT ≤ 4040K:	≥ 65 lm/W	CCT ≤ 4000K	≥ 60 lm/W				
Rated Input Power 25 to 60 W							
CCT > 4040K:	≥ 67 lm/W						

Energy Efficiency (Initial Efficacy)					
CECP		ELI	ENERGY STAR	ECL/SEAL	
CCT ≤ 4040K:	≥ 70 lm/W				
CFL with translucent cover					
"For lamps with glass or plastic enclosures the light fluxes can be 10% and 20% respectively lower than lamps without enclosures"		Actual Input Power < 14 W	Actual Input Power < 15 W	Input Power < 15 W	
		≥ 40 lm/W	≥ 40 lm/W	≥ 40 lm/W	≥ 40 lm/W
		Actual Input Power 14 to 19 W	Actual Input Power 15 to 18 W	Actual Input Power 15 to 18 W	
		≥ 48 lm/W	≥ 48 lm/W	≥ 40 lm/W	≥ 48 lm/W
		Actual Input Power 20 to 24 W	Actual Input Power 19 to 24 W	Actual Input Power 19 to 24 W	
		≥ 50 lm/W	≥ 50 lm/W	≥ 40 lm/W	≥ 50 lm/W
		Actual Input Power ≥ 25 W	Actual Input Power ≥ 25 W	Actual Input Power ≥ 25 W	
		≥ 55 lm/W	≥ 55 lm/W	≥ 40 lm/W	≥ 55 lm/W
CFL with reflector					
		Actual Input Power < 19 W	Actual Input Power < 20 W	"Lamps with reflectors should be tested without the same for the purposes of this table"	
		≥ 33 lm/W	≥ 33 lm/W		
		Actual Input Power ≥ 19 W:	Actual Input Power ≥ 20 W:		
		≥ 40 lm/W	≥ 40 lm/W		
Test Procedures					
GB/T 17263-2002 (neq IEC 60969-2000)		*IEC 60969*	*ANSI C78.5-1997 (referencing 40 lm/W)*	*IEC 60901-1/97, NBR 14539-6/00*	

For bare-tube CFLs under 15W in power, the CECP program has the most stringent requirements, with a minimum of 46 lm/W for lamps of 5 to 8 W and a Correlated Color Temperature (CCT) of more than 4040K, and 50 lm/W for lamps of 4040K or less. In contrast, the Energy Star specification is based on a core CCT range of 2700-3000K, with a minimum of 45 lm/W. At 14 W, the requirement of the CECP program rises to 58 lm/W for lamps with a CCT of less than 4040K. ELI and Procel/SEAL both match the Energy Star specifications in this category.

At 15W and above, there is additional divergence in the programs. The CECP program includes two size categories (15-24W, and 25-60W, distinguished further by CCT), while ELI maintains one category but subdivides it according to CCT. Energy Star and Procel both establish one category with a minimum efficacy of 60 lm/W. Again, CECP, in the 4040K and lower class, exceeds Energy Star and Procel with a minimum efficiency of 65 and 70 lm/W.

For covered CFLs, ELI, Energy Star and Procel are virtually the same, with only minor difference in wattage categories. CECP, however, provides for a percentage allowance off the bare bulb values depending on the material used in the cover. In the case of plastic covers (20% allowance), the efficacy requirements remain more stringent than the other three programs.

The CECP program does not address the issue of reflector CFLs specifically, while the Procel program equivalates them to lamps without reflectors and requires testing as such. Energy Star and ELI have nearly identical requirements.

Lumen Maintenance				
CECP	ELI	ENERGY STAR	ECL/SEAL	
1000-Hour Rating				
		≥ 90% of initial output (100 hrs)		
2000-Hour Rating				
			ECL	*SEAL*
≥ 80% of initial output (100 hrs)	≥ 80% of initial output (100 hrs)		≥ 80% of initial output (100 hrs)	≥ 85% of initial output (100 hrs)
40% Rated Lifetime Rating				
		≥ 80% of initial output (100 hrs)		
Test Procedures				
GB/T 17263-2002 (neq IEC 60969-2000)	*IES LM-66-1991 or IEC 60969 (unitary); IEC 60901 (modular)*	*ANSI C78.5-1997 (40% rating)*	*IEC 60901-1/97, NBR 14539-6/00*	

The Energy Star program sets a high (90% or above) initial requirement for CFL lumen maintenance at 1000 hours of testing, while the other 3 programs measure at 2000 hours. The Procel label requires the highest value (85%) in this measurement. Energy Star's 40% rated lifetime requirement—equivalent to a 2400-hour test for its minimum 6000-hour rated CFLs—matches the lumen maintenance value of CECP and ELI at 2000 hours.

Rated Life			
CECP	ELI	ENERGY STAR	ECL/SEAL
≥ 6,000 hours	≥ 6,000 hours	≥ 6,000 hours	max. 1 failure in 10 bulbs in 2000 hrs
Test Procedures			
GB/T 17263-2002 (neq IEC 60969-2000) (self declaration)	*IEC 60969*	*ANSI C78.5-1997 (IESNA LM-65-2001)*	*NBR IEC 60901-1/97, NBR 14539-6/00*

CECP, ELI, and Energy Star have all established a minimum rated life of 6000 hours for CFLs in their programs, while the Procel program does not specify a rated life for bulbs in their program document.

Accelerated Life, or "Stress" Test			
CECP	ELI	ENERGY STAR	ECL/SEAL
	(abolished)	max. 1 failure of 6 units cycled 5 minutes on, 5 minutes off; 1 cycle for every 2 hours of rated life.	
Test Procedures			
		ANSI C78.5-1997 (IESNA LM-65-2001, clauses 2,3,5,6)	

CECP, ELI, and Procel allow manufacturer self-declaration of the rated life of bulbs submitted to their program. Energy Star, however, has established two rounds of testing related to durability and lifetime. The Rapid Cycle Stress Test requires the testing of 6 lamps, in a separate sample selection than those used in the following life tests. For a CFL rated at 6000 hours, this test would require 500 hours to complete and is required to achieve initial qualification for the Energy Star label.

Normal Life Test			
CECP	ELI	ENERGY STAR	ECL/SEAL
Interim Life Test (40% Rated Life)			
		1 failure acceptable; 2 failures require detailed report on specific reasons of failure; 3 failures and product does not qualify. Required for initial qualification.	
100% Life Test			
		Same samples as in interim life test for full rated life. Required for full qualification.	
Test Procedures			
		ANSI C78.5-1997 (IESNA LM-65-2001)	

Only the Energy Star program requires a full life test of CFLs. Full qualification for use of the label requires that lamps be tested to their full rated lifetime, using the same sample set used for the Interim Life Test.

c. *Secondary Technical Specifications*

Color Rendering Index				
CECP		ELI	ENERGY STAR	ECL/SEAL
CCT > 4040K:	CRI ≥ 76	≥ 80 (tube diameter less than 2.0 cm.)	> 80 (average of 10 lamps)	
3500>CCT≤4040:	CRI ≥ 78			
CCT ≤ 3500:	CRI ≥ 80			
Test Procedures				
GB/T 17263-20022002 (neq IEC 60969-2000), GB/T 17262-2002 (neq IEC 60901-2000)		*IEC 60969 and CIE 29/2*	*ANSI C78.5-1997 (CIE Publication 13.3-1995)*	

The three programs that have explicit requirements for Color Rendering Index are roughly similar, requiring a measure of 80 or more. The CECP program distinguishes CRI with relation to color temperature, but in the common color category of 3500K or less also requires a minimum of 80.

Start time						
CECP		ELI		ENERGY STAR		ECL/SEAL
Time from ignition to full start						
Magnetic ballast:	10 seconds	1.5 seconds (max. power, min. start temperature)		< 1 second.		
Electronic ballast:	4 seconds					
Time to stabilized light output						
80% rated output:	≤ 3 minutes	75% rated output:	≤ 100 seconds			
Full run-up	≤ 40 minutes			Full run-up (sample average)	≤ 3 minutes	
Test Procedures						
GB/T 17263-2002 (neq IEC 60969-2000)		*ANSI C78.5-1997*		*ANSI C78.5-1997, clauses 3.11, 4.8*		

The CECP program has the laxest requirements for start time, allowing up to 4 seconds for an electronically ballasted CFL. In contrast, Energy Star requires CFLs to start up in less than one second. No explicit start time appears in the ECL/SEAL program document. Requirements on time to stabilized light output vary even more widely, with CECP allowing up to 40 minutes to reach full run-up, compared to the 3 minutes allowed by Energy Star. Both CECP and ELI provide intermediate requirements for partial run-up. ECL/SEAL does not provide explicit requirements in the program document for run-up time.

Power Factor and Harmonic Distortion					
CECP		ELI	ENERGY STAR	ECL/SEAL	
Power Factor					
		PF ≥ 0.5	PF ≥ 0.5	PF ≥ 0.5	
				CFL < 30 W (voluntary)	
				High power factor	≥ 0.92
				CFL ≥ 30 W (mandatory)	
				High power factor	≥ 0.92
Harmonic Distortion					
CFL≤ 25 W				CFL < 30 W (voluntary)	
Harmonic Order	Max Harmonic Current			Total harmonic dist.	≤ 33%
(n)	*(mA/W)*			CFL ≥ 30 W (mandatory)	
3	3.4			Total harmonic dist.	≤ 33%
5	1.9				
7	1				
9	0.5				
11	0.35				
13 ≤ n ≤ 39	3.85/n				
CFL > 25 W					
Harmonic Order	Max Harmonic Current as % Line Frequency Input Current				
(n)	*(%)*				
2	2				
3	30λ				
5	10				
7	7				
9	5				
11 ≤ n ≤ 39	3				
where λ is line power factor					
Test Procedures					
IEC 61000-3-2		*IEC 61000. IEC 61000-3-2 (Latvia, Hungary, Czech)*	*ANSI C78.5 4.13, ref ANSI C82.77 (recommends THD ≤ 32% for commercial electronic ballasts)*	*NBR 14539-2000; CISPR 15/96*	

The ELI, Energy Star, and the basic Procel requirement limit the power factor to a minimum of 0.5. Procel also includes a voluntary requirement for CFLs less than 30W to include a ”high power factor” of no less than 0.92; this becomes mandatory in CFLs of 30W or higher power.

The CECP program requirement is in terms of harmonics alone. Harmonics and (true) power factor are closely related (Grady & Gilleskie 1993), and one term can be such expressed in terms of the other. Calculation of CECP’s harmonics requirements for CFLs of 25W power or less to an equivalent power factor is not easy, but the CECP requirements for limits on harmonics in CFLs greater than 25 W can be calculated in power factor terms for purpose of this comparison. [2] In this case, the equivalent (true) power factor would have an upper limit of 0.95, significantly higher than the ELI and Energy Star requirements, and basically equivalent to the high power factor on Procel-labeled CFLs (voluntary under 30W). Similarly, the 33% total harmonics distortion maximum in the Procel program results in the same upper-bound true power factor of 0.95. Though the Energy Star program specifies only power factor limits, its referent testing document recommends a maximum total harmonics distortion of 32%.

d. Labeling and Consumer Requirements

CFL vs. GLS Life Equivalency				
CECP	ELI	ENERGY STAR		ECL/SEAL
		Rated Lifetime	Years of Residential Use Claimed (3hrs/day)	
		6,000 hours	5 years	
		8,000 hours	7 years	
		10,000 hours	9 years	
		12,000 hours	11 years	
		15,000 hours	13 years	

Only Energy Star provides guidance for the consumer on equating the rated lifetime of CFLs to the number of years the packaging can claim as the CFL lifetime. The assumption used in the guidance is 3 hours per day of usage.

CFL vs. GLS Illuminance Equivalency							
CECP	ELI		ENERGY STAR		ECL/SEAL		
	CFL Initial Lumens	Rated Wattage of Filament Lamp Equivalent	CFL Initial Lumens	Rated Wattage of Filament Lamp Equivalent	Rated Wattage of Filament Lamp Equivalent	Luminous Flow	Luminous Flow
	lumens	W	Lumens	W	W	127V (lm)	220V (lm)
					15	104	110
	≥ 214	≤ 25			25	214	220
	≥ 386	≤ 40	≥ 450	≤ 40	40	480	415
	≥ 660	≤ 60	≥ 800	≤ 60	60	804	715
	≥ 874	≤ 75	≥ 1,100	≤ 75	75	1018	890
	≥ 1246	≤ 100	≥ 1,600	≤ 100	100	1507	1350
	≥ 2009	≤ 150	≥ 2,600	≤ 150	150	2330	2180
					200	3274	3090

ELI, Energy Star, and the Procel program all provide guidance for the consumer on the wattage equivalency of CFLs to incandescent lamps based on the lumen output of the CFLs. Because of the differing nature of light dispersion from CFLs compared to incandescents and their perceived brightness by the user, there is not a standard approach to this equivalency across the programs. In the Energy Star program, incandescent categories are limited to those most popular in the market, from 40W to 150W, while Procel extends the range from 15W to 200W. In general, Energy Star has more stringent requirements on lumen output at higher incandescent wattages, while the Procel program is higher (for 127V lamps) at lower wattages. The ELI equivalencies are lower across all categories.

[2] $pf_{true} \le pf_{dist} = \frac{1}{\sqrt{1 + (THD_I/100)^2}}$

Color Temperature Reporting and Labeling				
CECP	ELI	ENERGY STAR	ECL/SEAL	
		If not 2700-3000K CCT, temperature and color (cool/warm) must be stated.	< 3300K	Warm
			≥ 3300 to 5000K	Neutral
			> 5000K	Cold

The ECL/SEAL program requires the labeling of CFL packages with adjectival color temperatures mapped to three ranges of CCTs. Energy Star, in contrast, assumes a color temperature of 2700-3000K, and requires labeling of the color and temperature of any CFL outside of that range. Neither CECP nor ELI has corresponding requirements.

4. Comparison of Test Procedures

As shown at the bottom of each table in the previous section, each performance specification is measured by a standardized test procedure to ensure replicability and comparability of results. Each program has selected a range of test procedures to reference, but most are drawn from the IEC (International Electrotechnical Commission) (or localized national versions based on the IEC), ANSI (American National Standards Institute) and IESNA (Illuminating Engineering Society of North America). China's CECP relies on national GB (*Guo Biao*) test procedures based on the IEC series, while the ELI program references both IEC and ANSI test procedures. Energy Star specifications are based on ANSI and IESNA, while the Procel program in Brazil references localized NBR (*Norma Brasiliera Registrata*) test procedures derived from the IEC. (Table 3)

Table 3. Labeling Programs and Test Methods

Program	CECP	ELI	Energy Star	SEAL/Procel
Source of primary test method	IEC	IEC ANSI	ANSI IESNA	IEC

Whether IEC, ANSI, or IESNA, no single test standard document encompasses the entire range of test procedures used in each program. "Top level" standards such as IEC 60969 in turn reference further IEC test standards such as IEC 60968, which elaborate specifically on safety requirements. As such, analyzing all the test procedures used to support a labelling program requires the review of many test standards documents, some of which provide only a single requirement or test condition as part of the entire testing process.

In this analysis, we will look only at the "top level" standards of the IEC, ANSI, and IESNA series that describe the basic electrical and photometric measurements required for the key performance specifications of CFLs. These test standards include:

IEC 60969. *Self-ballasted lamps for general lighting services—Performance requirements*. Edition 1.2, 2001-03.

IEC 60901-1/97. *Single-capped fluorescent lamps—Performance specifications*. Edition 2.2, 2001-11.

ANSI C78.375-1997. *Fluorescent Lamps—Guide for Electrical Measurements*. First Edition, 1997.

IESNA LM-66-00. *IESNA Approved Method for the Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps*. 2000.

IESNA LM-65-01. *IESNA Approved Method for Life Testing of Compact Fluorescent Lamps*. 2001.

The analysis divides the test procedures into five major subsections for sake of comparison. These five subsections include Initial and Ambient Conditions, Lamp Preparation, Electrical Characteristics, Photometric Testing, and Life Test.

Most of the test conditions and procedures to be followed for each of these subsections are contained in the major top-level test standards. In some cases, test method details, such as lamp selection, are referenced to other standards, with only general statements presented in the top-level standards.

All programs refer to the Commission Internationale de l'Eclairage (CIE) test standard for color rendering testing. Because this procedure is already in use among all programs, it will not be further reviewed.

a. *Initial and Ambient Conditions*

The test standards are all virtually in accord on the initial conditions required before testing. All that specify air flow require a draft-free location (IESNA specifies air movement of no more than 4 meters/minute, or 0.15 mph), and ambient temperatures of 25ºC +/- 1^{o}C. The ANSI and IESNA standards further specify the distance from the lamp for measurement of the ambient temperature; this is not indicated in the IEC test standards.

IEC and IESNA both require avoidance of excessive vibration to the lamp, and indicate that test orientation should generally be base-up, except in situations where the manufacturer or distributor has indicated otherwise, such as those designed to be operated horizontally or base-down.

IESNA is the only test standard that describes a method for handling a CFL if it is to be moved. Both IEC and IESNA have marking requirements, although the IESNA marking contents are not specified except for tracking purposes.

IEC and ANSI differ in the initial requirements for starting time and run-up testing: IEC requires a 24 hr switched-off period in a 7^{o}C temperature range that differs from that required for electrical, photometric or cathode characteristics testing. ANSI allows a 12 hr switched-off period, but with no difference in ambient temperature requirements.

Item	Condition	IEC 60969	IEC 60901-1/97	ANSI C78.375	IESNA LM-66-00	IESNA LM-65-01
1	**Air flow**	Draft free	Draft free	Draft free	Not to exceed 4 m/min (0.15 mph)	
2.	**Ambient temperature**	25^{o} C, ±1^{o} C and maximum relative humidity of 65%	25^{o} C, ±1^{o} C (electrical, photometric, cathode characteristics)	25^{o} C, ±1^{o} C, measured at least 1 ft and no more than 3 ft from the lamp at the same height of the lamp	Must be maintained at 25^{o}C ±1^{o}C and measured no more than 1 m from the lamp at same height as lamp. Lamps with amalgam may be tested at a higher temperature which should be	

Item	Condition	IEC 60969	IEC 60901-1/97	ANSI C78.375	IESNA LM-66-00	IESNA LM-65-01
					noted.	
3.	**Vibration**	Lamps should not be subjected to excessive vibration and shock.				Lamps should not be subjected to excessive vibration and shock.
4.	**Orientation**	Base up (vertical) unless otherwise indicated by manufacturer	As specified on lamp data sheet	As specified in appropriate lamp standard; generally, single-based lamps are operated base-up		
5.	**Lamp Handling**					Prior to operation, lamps shall be cleaned . If lamps are to be moved, maintain same lamp orientation during move. CFLs should cool for at least 1 hour prior to being disturbed.
6.	**Lamp Marking**		Nominal wattage & further information that defines electrical & photometric characteristics shall be marked on lamp.			Mark and track each individual lamp during testing
7.	**Starting time and run-up**	Tests shall be made before ageing, except Vapor Pressure Control lamps, which are to be switched off for at least 24 hrs before the test	Lamps shall be off and in 20^{o} to 27^{o} C temp & 65% relative humidity for the test and for 24 hrs prior to test.	Lamps shall be off and stored at specified ambient temperature for minimum 12 hours before test (ANSI C78.5-2003)		

b. Lamp Preparation

Lamp preparation includes the procedures required before testing of the lamp takes place. Here, the two major test standard series differ primarily in the details of the steps required after "seasoning" of the lamp and prior to the stabilization of light output before testing begins. ("Seasoning" refers to an initial period in which a new lamp is aged by leaving it on for 100 hours, as both IESNA and IEC require.) Both test procedures emphasize the need to allow excess mercury to collect in the coldest part of the lamp prior to testing through a process of "preburning". In the IEC standard, this process may take "up to 15 hrs". In the IESNA test standard, however, the preburning period is up to 5 hours, although it is noted that this can be achieved during the seasoning period of a new lamp provided that the mercury in the lamp is not disturbed prior to taking the test.

Once the lamp is placed on the test circuit, both test procedures require they be switched on for a period of 15 minutes to achieve light stabilization (40 minutes for amalgam lamps in the IESNA test).

Item	Condition	IEC 60969	IEC 60901-1/97	ANSI C78.375	IESNA LM-66-00	IESNA LM-65-01
1	**Lamp Selection**	One or more similar units for purpose of type test (identical in photometric & electrical rating).				Shall represent the purpose of the test. Effects of variables discussed in *IESNA Lighting Handbook*, 9th Edition, Chapter 2, New York, Illuminating Engineering Society of North America, 2000
2	**Seasoning**	Lamps shall have been aged for a period of 100 hrs of normal operation	Lamps shall have been aged for a period of 100 hrs of normal operation	Seasoning for 100 hrs done in specified position	IESNA LM-54-99 Approved Guide to Lamp Seasoning (100 hrs)	
3	**Preburning**		Conditioning period as stated by manufacturer, up to 15 hrs, for relighting within 24 hrs.	Seasoning fluorescent lamps in the specified position will eliminate the need for a separate preburning	Initial preburn should be at ±5% rated voltage typically for 5 hrs in ambient temperature not to exceed 40^{o}C	
4	**Lamp transfer**		Kept in same position and not subjected to vibration and shock		Initial cool-down for 15 minutes. Keep lamp in same orientation as during preburn. Addl operating period on measurement circuit nec. to restore stability before taking photometrics	

Item	Condition	IEC 60969	IEC 60901-1/97	ANSI C78.375	IESNA LM-66-00	IESNA LM-65-01
5	**Stabilization**		15 minutes	15 minutes continuous burning	40 minutes continuous burn for amalgam lamps; 15 minutes for others	
6	**Lamp orientation**				Seasoning, preburning & photometric measurements must be done with lamp in same orientation (usually base up).	

c. Electrical Characteristics

With regard to required electrical characteristics for the testing of CFLs, the various test procedures are fairly congruent. All require a sine waveform for the voltage, and where harmonics are specified, they are limited to 3% of the fundamental. Supply voltage is similarly limited to various of ±0.5% during the stabilization period, and ±0.2% during testing; the IESNA LM 66-00 test alone requires a tighter tolerance of ±0.1%, but it does not specify if it is for stabilization, testing, or both.

All the test standards specify the placement of the voltmeter and wattmeter on the lamp side of the current in the testing circuit, with optional configurations in the case of using a multifunction meter combining voltmeter, wattmeter and ammeter into one. Finally, only IESNA includes specific limitations on measurement uncertainties allowed for voltage and current. All require the same limitation for impedance, either expressed as "high" (no less than 100,000 ohms) for voltage, or "low" or "lowest possible" for current.

Item	Condition	IEC 60969	IEC 60901-1/97	ANSI C78.375-1997	IESNA LM-66-00	IESNA LM-65-01
1	**Power Source**					
	Waveshape	Harmonics are under consideration	Wave shape of supply voltage shall be a sine wave and total harmonic content shall not exceed 3%.	Wave shape of supply voltage shall be a sine wave and rms summation of harmonic components not to exceed 3% of fundamental.	Sinusoidal waveshape and rms summation of harmonic components not to exceed 3.0% of fundamental.	Waveshape such that total harmonic distortion shall not exceed 3% of fundamental.
	Voltage	Stable within ±0.5% during stabilization periods and ±0.2% at moment of measurements. For life testing	Test voltage applied to circuit shall be as specified on relevant lamp data sheet.	Supply voltage equal to rated voltage of reference ballast and stable within ±0.5% during stabilization,	AC power source regulated to within ±0.1%	Shall conform to rated input voltage (rms) & frequency of ballast, regulated to within ±2% of rms value.

Item	Condition	IEC 60969	IEC 60901-1/97	ANSI C78.375-1997	IESNA LM-66-00	IESNA LM-65-01
		tolerance is 2%.		and ±0.2% during measurement		
2	**Circuits**				Variable power source must be capable of providing AC voltages of 120V.	
	Method for connecting test instruments		Voltmeter & wattmeter connected on lamp side of current measuring instruments. Two switches to remove instruments from test.	Voltmeter & potential element of wattmeter connected on lamp side of current-measuring instruments.	Voltmeter & potential element of wattmeter connected on lamp side of current measuring instruments. Must have switches to remove certain instruments from test.	
3	**Electrical instrumentation**					
	Uncertainties		Instruments must be essential free from waveform errors and suitable for the frequency of operation	Instruments must be essential free from waveform errors and suitable for the frequency of operation	Shall be ±0.5% or better for voltage & current and ±0.75% or better for wattage.	
	Impedance limits		Voltage measuring circuit shall have an impedance not less than 100,000 ohms; current measuring circuit shall have lowest possible impedance.	Voltage measuring circuit shall have an impedance not less than 100,000 ohms; current measuring circuit shall have lowest possible impedance.	For voltmeter should be high & for ammeters low. Test instrument connected in parallel shall draw no more than 1.0 % of rated lamp current. For instrument connected in series not to exceed 2.0%.	

d. Photometric Testing

Only two of the test procedures used in the four CFL labelling programs described here reference details of photometric testing. For photometric testing, the electrical and circuit requirements are the same as for electrical testing summarized above, but the actual test conditions for the photometrics (luminous intensity, luminous flux, color) are primarily derived from the CIE in all cases.

IESNA LM-66, however, incorporates many more details of the requirements within the test standard itself, although CIE is the primary reference. Further, IESNA provides several options on the measurement of luminous flux, either through the use of an integrating sphere, or though computation from normal intensity if the flux/intensity ratio of a lamp is known. IESNA also includes a detailed annex of a methodology to correct for deviations in system response from V(λ), drawn mostly from CIE documents but also from other specialized journals.

Item	Condition	IEC 60969	IESNA LM-66-00
1	**Lamp Connections**		Whenever possible use a Kelvin (4-point) measurement socket . Two leads provide voltage to lamp & 2 leads measure the lamp voltage.
2	**Photometer**	Electrical & photometric instruments shall have guaranteed accuracy commensurate with requirements of the test.	Shall have relative spectral responsivity which approximates the V***(λ)*** function (CIE No. 64-1984 *Determination of the Spectral Responsivity of Optical Radiation Detectors*.)
	Luminous intensity		Shall have an approximate cosine response.
3.	**Normal intensity**		Directional light output measurement taken at a distance of at least 5 times longest dimension of lamp.
4.	**Intensity distribution**		Measurement of luminous intensity distribution around a lamp. Similar to normal intensity but set up so angles between detector and lamp axis can be varied. Since CFLs must remain in a fixed orientation (for proper cooling of mercury) a movable mirror goniophotometer can be used.
5	**Integrating Sphere Measurement**	Measure in accordance with relevant recommendations of the CIE	Integrating sphere gives total luminous flux of lamp in one measurement. Ambient temperature inside sphere of 25ºC ±1ºC. Normally sphere is larger than 1.5m in diameter. (CIE 84-1989, The Measurements of Luminous Flux.)
6	**"Peak" (light output) method**		To reduce test time, measurements can be taken at peak light output. Peak measurement must be multiplied by correction factor (stabilized lumens divided by peak lumens). Heated photometric enclosure may be required.

e. Life Test

The final major area of testing involves life testing of CFLs. This process involves much long testing times than the other measurements, and some of the basic conditions vary from the electrical and photometric tests. For life testing, the range of allowable ambient temperatures is much broader, from a low of 15ºC in all three test procedures to a high of 50ºC in the IEC 60901 test procedure. All require minimum air flows around the bulbs and avoidance of shock.

Similarly, all require that input voltage be regulated to within 2% of the rated voltage of the ballast and that the lamps be tested in the orientation as directed by the manufacturer for its use.

The IESNA test standard recommends the used of elapsed time meters to provide a temporal record, although video camera or other monitors are allowed if their provide sufficiency time accuracy. IESNA also requires that failures be checked at an interval no more than 0.5% of the rated life of the lamp (e.g. 30-hour intervals in the case of a 6000-hour rated lamp) and notes of causation be made.

The largest difference in the test procedures lies in the operating cycle requirement. IEC 60969 indicates that lamps should be switched off eight times in every 24 hours running, with off periods of 10 to 15 minutes, and on periods of at least 10 minutes. IEC 60901 extends this operating cycle to 15 minutes off after 2 hours 45 minutes of operation. IESNA, in contrast, specifies 20 minutes off after 3 hours of operation. Interestingly, IEC 60901 refers to the IESNA (North America) cycle as a note to its own operating cycle requirement.

Item	Condition	IEC 60969	IEC 60901-1/97	IESNA LM-65-01
1	**Ambient conditions**	Within the range of 15°C to 40°C; excessive drafts avoided. These conditions are under consideration.	Within the range of 15°C to 50°C; excessive drafts avoided.	Must be controlled within limits set by lamp & ballast manufacturers; usually between 15°C and 35°C. Testing must be suspended if temperature range is exceeded. Airflow minimized.
2	**Orientation & Spacing**		As specified on lamp data sheet	Orientation shall be as specified by manufacturer or what will be used in application. Lamps/fixtures shall be spaced to allow airflow around each lamp/fixture.
3	**Power Supply**	Rated voltage with a tolerance of ±2%	Supply voltage and frequency not to vary more than 2% from the rated voltage and frequency of the ballast	Input voltage regulated to within ±2% of rated rms value.
4	**Auxiliary Equipment**		Lamps with internal starter shall not be operated on high-frequency circuits.	CFLs with integrated ballast & starter shall be tested as complete units.
5	**Instrumentation**			Accurate recording of elapsed time is important. Elapsed time meter connected to rack is best. Video, current monitors or other instruments can be used if designed to provide sufficient temporal accuracy.

Item	Condition	IEC 60969	IEC 60901-1/97	IESNA LM-65-01
6	**Lamp connections**		Temperature of end cap, measured at bottom of guide post, should not exceed the maximum value in lamp data sheet.	Lampholders shall be rated for specific test application. Inspection of contacts & tests for cathode heating voltage should be made whenever lamp lamps placed on rack.
7	**Operating cycle**	Lamps shall be switched off 8 times in every 24 hr running time. "Off" period shall be between 10 min. and 15 min. "On" period shall be at least 10 min.	165 min on and 15 min off (N. Amer times are noted)	180 min on and 20 min off
8	**Test quantity**	Minimum of 20 lamps		
9	**Recording failures**			Check at an interval no more than 0.5% of rated life and investigate and note cause

5. Issues of Laboratory Accreditation and Mutual Recognition

In addition to harmonization of performance specifications and harmonization of the testing procedures, the last element crucial to a full harmonization of the four programs involves laboratory accreditation and mutual recognition of testing results. These issues are important because of the need to know that laboratories have run the test accurately, that the test results are reproducible and accurate, and that all parties involved (manufacturers, distributors, labelling authorities) have confidence in the test results.

As noted in section 3"General Testing Requirements and Procedures", each national program requires testing in a nationally accredited laboratory; ELI, being a multinational program, extends that to laboratories accredited through bodies party to the International Laboratory Accreditation Cooperation. Cross-national or mutual recognition of test results, however, is a more challenging issue, since there are additional issues of laboratory certification, a mechanism to challenge results, of dispute resolution, enforcement, and of check-testing, as these also vary from country to country and need to be considered in a larger mutual recognition arrangement.

a. Accreditation

In some countries the test laboratories doing the testing must be accredited. The diagram below shows the different levels of accreditation organizations (Figure 1). Basically, test facilities are accredited by a national accreditation body. National accreditation bodies may belong to a regional accreditation organization which in turn may belong to an international accreditation organization. Accreditation bodies may be independent, non-governmental organizations or they may be associated with a government agency. Figure 1 depicts this hierarchy of accreditation organizations, with the International Laboratory Accreditation Cooperation (ILAC) at the top, the regional accreditation bodies on the second tier (NACLA: North American Cooperation for Laboratory Accreditation; IAAC: InterAmerican Accreditation Cooperation; APLAC: Asia-Pacific Laboratory Cooperation), followed by national or independent accreditation bodies which may also be a direct member or signatory to ILAC. Auditors represent individual accreditation bodies and carry out the actual accreditation assessments. The accreditation may be a team more than one individual with one assessing the general requirements and another with expertise in a specific field of measurement.

Accreditation differs from certification. Accreditation is formally defined in ISO/IEC Guide 2 as a procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks. Certification, on the other hand is defined in ISO/IEC Guide 2 as a procedure by which a third party gives written assurance that a product, process, or service conforms to specified requirements (IAAC 2005)

b. International Accreditation Organization—ILAC

The most wide reaching accreditation organization is the International Laboratory Accreditation Cooperation (ILAC). The goal of ILAC is to develop a global network of accredited testing and calibration laboratories that can be relied on to provide accurate results. In turn, such a network assists in "promoting cross-border stakeholder confidence and acceptance of accredited laboratory data" to enhance international trade. (ILAC 2005) ILAC prefers agreement between accrediting bodies and not governments.

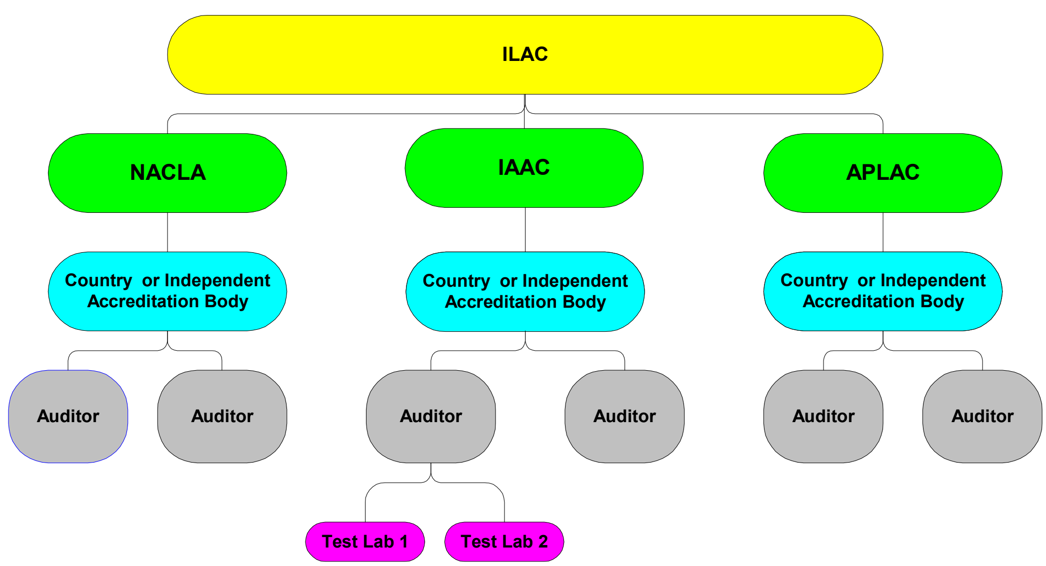

Figure 1 Hierarchy of Accreditation Organizations

ILAC itself does not accredit laboratories. Its purpose is to provide information to other accreditation bodies. It also facilitates and encourages the development of Mutual Recognition Arrangements (MRAs) and Memoranda of Understanding (MOUs) between national accreditation bodies. Regional accreditation cooperations as well as national cooperations can be members or signatories of ILAC.

The ILAC Mutual Recognition Arrangement (MRA)

The ILAC MRA came into effect in 2001 as the first international mutual recognition arrangement among accreditation bodies. The purpose was to reduce the barriers to trade by building confidence in the accuracy of laboratory testing and avoiding multiple testing of a product as it enters international trade. An accreditation body can be just a member of ILAC or it can be signatory to ILAC. Having signatory status means that the accreditation body or organization has signed a MRA with ILAC. The MRA document states principles and procedures for running an accreditation body. These include the rules and procedures contained in the ILAC documents, ILAC P1 and ILAC P2. In addition the accreditation body signatory must conform to the ISO/IEC Standard 17025, "*General requirements for the competence of testing and calibration laboratories*" and to the ISO/IEC Guideline 58, "*Calibration and testing laboratory accreditation system – General requirements for operation and recognition*". (ILAC 2005a) As of July 2004, there were 46 signatories to the ILAC Arrangement, including the US (American Association for Laboratory Accreditation—A2LA, and National Voluntary Laboratory Accreditation program—NVLAP), Brazil (Diretoria de Credenciamento e Qualidade/Instituto Nacional de Metrologia, Normalizacao e Qualidade Industrial—INMETRO), and China (China National Accreditation Board for Laboratories—CNAL)

c. Regional Accreditation Cooperations

The purposes of regional accreditation cooperatives mirror that of ILAC but on a regional level. The regional accreditation bodies of interest for trade between the United States, Brazil and China are shown below.

Asia Pacific Laboratory Accreditation Cooperation -APLAC

Both the US and Chinese accreditation bodies are signatories to APLAC, which was established as a regional cooperation in 1995. The objectives of APLAC include information exchange, publishing of accreditation documents, reducing technical barrier to trade, promoting international acceptance of test data, and establishment and maintenance of multilateral Mutual Recognition Arrangements (MRA) (APLAC 2005).

The APLAC MRA states, "This Arrangement by itself does not provide any recognition or accreditation under any law or regulation in the economy of any signatory body. However, the signatories intend to promote to their governments the use of this Arrangement in support of recognition arrangements in the regulated sector."

North American Cooperation for Laboratory Accreditation (NACLA)

NACLA was established in 1998 and includes both private-sector and public-sector stakeholders. The primary purpose of NACLA is to serve as an evaluator, based on NACLA procedures and international standards, of laboratory accreditation bodies in the US, though expansion to Canada and Mexico may be possible at a future date. NVLAP, a key laboratory accreditation body in the US, is one of the members of NACLA. (NACLA 2005)

Inter-American Accreditation Cooperation- IAAC

The Inter-American Accreditation Cooperation, or IAAC, is an association of accreditation bodies in North, Central, and South America. The focus of the group is conformity assessment, and both Brazil and the US are members of the cooperation. IAAC also hosts a Multilateral Recognition Arrangement (MLA), which was signed on October 24, 2002, first by A2LA of the US, INMETRO of Brazil and SCC of Canada. Accession to the arrangement signifies that the parties agree to formally recognize and promote the equivalency of each other's laboratory accreditations. Since these three bodies already recognize each other under the ILAC Mutual Recognition Agreement (MRA), the signing is largely symbolic but promotes recognition in the Americas. (IAAC 2005a)

d. National Accreditation Bodies

These accreditation bodies accredit individual test laboratories and sometimes accredit certification agencies that certify laboratories for specific tests and procedures. ISO standard 17025 is usually used as the body of criteria that a test laboratory must meet. The standard lists general guidelines and requirements for running a test laboratory. The individual laboratory must typically write two manuals: a policy and a technical manual, in which more detail is provided on exactly how the objectives in ISO 17025 will be met, such as the specific policy and procedure for calibrating instruments. Accreditation then involves the visit of one or more auditors to review these manuals along with a site visit of the test facility, and the on-site audit may also include witnessing a test procedure in process. In addition, the laboratory may be required to run comparison tests with other laboratories as a condition of accreditation. Often, an accreditation agency does not have the personnel or expertise for all kinds of technical audits, although they are capable of performing a general audit. To fill the need of knowledgeable auditors, accreditation bodies often use consultants with specialized knowledge.

Table 4 Accreditation Bodies by Country

Country	Accreditation Bodies
U.S.A.	NVLAP, A2LA
China	CNACL
Brazil	INMETRO

If the certification agencies accept each countries test results or results from test laboratories that are accepted by each countries certifying agencies (CECP, EPA, Procel), then accreditation may not be needed. However, accreditation increases confidence in test laboratory results. In the United States trade associations have also run certification agencies, but contract with a third-party test laboratory to do the actual testing. These certification agencies are commonly accredited based on provisions in ISO Guide 65.

The cost of becoming an accredited laboratory in the United States is approximately US$60,000 to US$100,000.

e. Mutual Recognition Arrangements

Mutual Recognition Arrangements (MRAs) can function at different levels. The APLAC MRA described above is designed to ensure mutual acceptance of the competency of each country's accreditation body to carry about proper laboratory accreditation procedures. MRAs can also be signed among or between governments as the mechanism to formally accept the test results from laboratories certified in specific testing procedures, such as lighting or ballast testing. The Association of Southeast Asian Nations (ASEAN) has, for example, signed an MRA in 2002 on electrical and electronic equipment whereby the test results of any listed certified laboratory is accepted in other ASEAN member nations[3]. MRA may also require that signatories be signatories to ILAC, APLAC, or other accreditation bodies.

6. Summary and Conclusions

All four programs examined here have comprehensive requirements for the voluntary labeling of CFLs. They all play an important role in providing guidance to consumers on the purchase of quality products, and given the potential for energy savings by greater consumer acceptance of CFLs, an expansion of their market impact would be desirable.

The four programs represent a consumer base of about 2 billion people, and there is extensive trade among the country participants. Harmonization of the program requirements, allowing acceptance in one country of the product testing results from another country, may be one way to expand the market share of qualified CFLs, reduce CFL costs, and promote greater market transformation. China, as the world's largest producer and exporter of fluorescent lamps and CFLs, is a key country to the success of such a program.

The challenges to harmonization are multiple, but the technical comparisons here demonstrate that nearly all the basic elements of such a harmonized program are in place, and each country has a well-developed program for implementation and administration. Harmonization requires consideration of both technical specifications and test procedures. In terms of technical specifications, the following areas cover the major items of technical difference among the programs that may require the most effort to achieve harmonization.

Lumen Efficacy

The efficacy requirements of Chinese CFLs exceed those of all other programs and acknowledges the inherent lower efficiency of CFLs of higher color temperatures. In China, the predominant share in the domestic market of CFLs by color temperature is in the 5000-6500K range, while most of the exported CFLs are manufactured in the 2700-3000K range (CECP 2004), so both are widely produced. These specifications and related volumes of production suggest that higher lumen efficacies are possible in all programs. For a program such as Energy Star, in which the test method requires the reporting of the "lesser of the lumens per watt" in the test sample of 10 lamps (Energy Star 2003), high color temperature CFLs are naturally at a disadvantage compared to CFLs in the standard 2700-3000K temperature-range assumed for the program and popular in the US market. This disadvantage could be reduced through the use of an average lumens per watt measurement for the sample, or additional clas-

[3] "Asean Sectoral Mutual Recognition Arrangement For Electrical And Electronic Equipment," 2002, http://www.aseansec.org/6677.htm

sifications and efficacy specifications could be established for higher color temperature CFLs. The ELI program recognizes the efficacy differences by color temperature only at the higher (15W and above), as lower-wattage CFLs are generally not used for primary lighting in the ELI markets (CECP 2004).

Lifetime and Lifetime Testing

Hearing consumer concern that Energy Star-labeled CFLs were not performing to their rated lifetime specifications, and recognizing that poor consumer perception of CFL quality hurt the prospects for increasing labeled CFL market share, the Energy Star program implemented more stringent lifetime testing requirements, include the accelerated life test, interim life (40%) test, and full life test. Given the long life of labeled CFLs, full life testing (lasting nearly 14 months for a 10,000 hour-rated CFL) is often perceived as a burden to manufacturers, who face long delays in bringing new labeled products to market with such a requirement. The Energy Star program, however, provides an acceptable compromise between rigorous testing of CFLs and market access for qualifying lamps by dividing the qualification period into two segments: an initial qualification when the lamp passes all the requirements of interim life testing (40% of rated life), and full qualification when the lamp passes the full-life test, which must be reported within 45 days of the end of the rated life period from when testing began. With this approach, manufacturers are able to market qualifying lamps after 2400 hours/3.3 months (for a 6000 hour lamp) of testing, but have up to an additional 6.5 months to complete the full-life testing and submit the test results. This two-stage approach of initial and full qualification allows a reduction in premarket testing expenses, but it increases the confidence of the quality of the certified product and helps minimize the volume of poorer quality CFLs that reach the market between initial and full qualification times. As an added control for quality, Energy Star requires participation in a third-party testing program that will take marketed samples of qualifying CFLs for testing, requiring manufacturers to explain any failures and face decertification of products when the third-party results vary from those submitted by the manufacturer.

The ELI program has a similar, but voluntary, quality assurance testing program in place. The CECP program, however, incorporates annual audits as part of the certification procedure. Each year after a product qualifies, the manufacturer is subject to a "supervision audit" of the facility, and must submit additional CFL samples for testing at certified laboratories in order to maintain certification. Both programs recognize the consumer concern for quality assurance and could incorporate an expanded process of two-stage certification tied to the existing requirement for 2000 hours of testing for lumen maintenance (as is required also by the Procel program).

Power Factor and Harmonics

The four programs diverge significantly on the importance placed on the power factor and harmonic distortion in CFLs. In typical household situations, CFL loads are far outweighed by those of refrigerators, televisions and computers, in which power factors range from 0.58 (computers) to 0.87 (refrigerators) (Grady & Gilleskie 1993), so controlling power factor has become a secondary issue, particularly for the Energy Star and ELI programs. China and Brazil, however, place higher importance on controlling the power factor and harmonic distortion, given the potential for extensive CFL use in commercial or other establishments. As noted earlier, the ability to control total harmonic distortion (THD) through control of the true power factor allows the possibility of CECP simplifying their current approach and establishing a related power factor of about 0.92, which matches Procel's voluntary level for CFLs under

30W. Similarly, acknowledging the difference in contribution to load, all four programs could consider Procel's two-tiered approach of a recommended power factor level for lower-power CFLs and a mandatory power factor specification on the higher-powered CFLs.

In terms of test procedures, the four programs all use test procedures that for the most part are sourced from the IEC, ANSI, IES, and CIE, or adapted from them. The requirements of the top-level IEC test procedures, commonly used internationally, differ only in minor details from the procedures laid out by the ANSI and IES, primarily in the area of time requirements of preburning and cycling during different tests. Circuitry, electrical requirements, ambient temperatures, power quality, connections, voltage stability and other key elements of the test procedures are essentially equivalent. Tests related to color and color temperature are all based on the CIE series, and present no problems of consistency.

"Essential equivalency", however, is not a sufficient basis on which to establish mutual recognition of test results. Although all the laboratories used in these programs are accredited by national or international accreditation bodies, which in turn all belong to ILAC, not all laboratories in each country are necessarily certified in conducting the various IEC, ANSI, and IES test procedures. Although an MRA or MOU of mutual recognition could be signed among the 4 programs, it would likely need to be preconditioned that the accredited labs also be certified to conduct the specific tests (and this sometimes involves participating in a round-robin testing program to ensure inter-laboratory consistency). Alternatively, programs could adopt a common test procedure based, for example, on the IEC and CIE series, but such a revision of a national program may be more problematic compared to acceptance of test results from non-national labs that are both accredited and certified in the specific test procedures adopted by the national program.

Follow-on

In May 2005, at the occasion of the 6th International Conference on Energy Efficient Lighting in Shanghai, more than 80 delegates participated in a special-session debate about CFLs, covering many of the issues concerning harmonization reviewed in this report. At this session, the delegates agreed in principle to pursue international CFL harmonization, including further research on the issues of creating a uniform testing procedure that could eventually be submitted to the IEC or other international body; and further research on development of a range of performance specifications for self ballasted CFLs to facilitate testing comparisons and possible rationalization of CFL performance requirements (APEC-ESIS 2005).

The process, supported in principle by the CFL certification programs of Australia (AGO), China (CECP), the US (Energy Star), and the European Union (Code of Conduct) may result in the eventual establishment of a unified test procedure and related sets of performance specifications that would enhance international trade, provide national flexibility in the preferred level of stringency adopted, reduce duplicative testing costs, reduce program administrative costs, and enhance consumers' ability to purchase high-quality efficient CFLs. The potential savings from a possible acceleration of CFL penetration in world markets as a result of harmonization are substantial. Even a 0.5% increase in the rate of CFL sales growth worldwide as a result of harmonization would result in nearly 19 million tonnes of CO_2 savings by the 10^{th} year of the program.

7. References

APLAC 2005. Asia-Pacific Laboratory Accreditation Cooperation. http://www.aplac.org/aboutaplac/general_info.htm. Accessed June 2005.

APEC-ESIS 2005. "International Initiative Launched on Compact Fluorescent Lamps", http://www.apec-esis.org/whatsnew.php?id=100084. Accessed June 2005.

CLASP 2004. "S&L Worldwide Summary: CFLs". www.clasponline.org/findworldwideproduct.php3. 2004. Accessed November 2004.

CECP 2002. *Rules on the Implementation of Energy Conservation Product Certification for Self-Ballasted Fluorescent Lamps for General Lighting.* No. CSC/G20-2002. CECP: Beijing, December 2002.

CECP 2004. Zhang Guoqin, CECP, personal communication, 29 November 2004.

Grady & Gilleskie 1993. Grady, W. Mack, Robert J. Gilleskie, "Harmonics and How They Relate to Power Factor", in *Proceedings of the EPRI Power Quality Issues & Opportunities Conference*, San Diego, CA, November 1993.

Energy Star 2003. *ENERGY STAR® Program Requirements for CFLs: ENERGY STAR Eligibility Criteria: Energy-Efficiency Criteria – Version 3.0.* Online at www.energystar.gov/ia/partners/ product_specs/program_reqs/cfls_prog_req.pdf. Accessed November 2004.

Fridley & Wiel 2004. Fridley, David G. and Steven Wiel, "Trade Flow Analysis Helps Define Opportunities For Regional Harmonization of Standards and Labeling", in *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings*, Washington, DC: ACEEE, August 2004.

ELI 2002. *EFC/GEF Efficient Lighting Initiative: Voluntary Technical Specification Compact Fluorescent Lamps*. Online at http://www.efficientlighting.net/prod_tecn_esp.htm. Accessed November 2004

IAAC 2005. Interamerican Accreditation Cooperation, *Accreditation vs. Certification of Laboratories: the Roles Of ISO/IEC 17025 and ISO 9001*, http://iaac-accreditation.org/Documents/Control%E9es/PU/IAAC-17025vs9001paper.pdf. Accessed June 2005.

IAAC 2005a. http://iaac-accreditation.org/. Accessed June 2005.

ILAC 2005. www.ilac.org. Accessed June 2005.

ILAC 2005a. *The ILAC Mutual Recognition Arrangment.* http://www.ilac.org/downloads/Arrangement.pdf Accessed June 2005.

Inmetro 2004. *Regulamento Específico para uso da etiqueta nacional de conservação de energia – ence: Lâmpadas fluorescentes compactas, circulares ou similares (integrados ou não, com reator electromagnéticao ou electrônico)*. Online at http://www.procel.gov.br/procel/site/seloprocel/equipamentoscomselo_1044.asp. Accessed November 2004.

Nadel, Steven 2002. "Appliance and Equipment Efficiency Standards," *Annual Review of Energy and the Environment*, Vol. 27:159-92

NACLA 2005. North America Cooperation for Laboratory Accreditation. www.nacla.net. Accessed June 2005.

UN Commodity Trade Statistics, 2004. United Nations Statistical Division, Commodity Trade Statistics Database. Online at http://unstats.un.org/unsd/comtrade/default.aspx. Accessed October 2004.