Fitted Target Efficacy (FTE) Algorithm

DOE's proposed ENERGY STAR requirement for outdoor pole-mounted area and roadway luminaires is based on fitted target efficacy (FTE). DOE has developed a software tool that uses standard absolute luminaire photometry (test procedure LM-79-08, formatted per LM-63 as a .ies file) to perform the necessary calculations. The calculation procedure (or algorithm) for Fitted Target Efficacy (FTE) can also be performed as outlined below using commercially available lighting software like AGI32, Lumen Designer, AutoLux, and Visual.

The algorithm is detailed below, explaining how FTE is calculated. Luminaire manufacturers would not be required to use this procedure as part of the ENERGY STAR qualification process. The FTE software tool provided by DOE ENERGY STAR performs these calculations quickly and easily. The procedure is provided below for information and reference purposes for all stakeholders.

Steps to calculate FTE using lighting design software:

1. Load IES file into the lighting software. Do not apply a light loss factor.
2. Draw a rectangle at (x,y) coordinates of (-8,-6) for the bottom-left corner and (8,6) for the top-right corner. Any units may be used (inches or feet or meters) since calculated distance is ultimately relative to mounting height (MH).
3. Create a calculation grid covering this rectangle, with 0.1 by 0.1 grid spacing, centered such that points are not placed at (0,0) or along the edges of the rectangle. This should yield 19,200 calculation points of horizontal illuminance at grade.
4. Locate a luminaire at (0,0,1) such that it is centered in the rectangle and mounted 1.0-MH above the calculation plane.
5. Orient the luminaire in the positive-y direction (twelve o'clock) such that backlight falls in the negative-y quadrants. Use zero arm length, zero tilt, zero roll, and zero spin. Do not model the pole as an obstructive (shadow casting) object.
6. If the lighting software offers a choice of calculation modes, choose the simple version that does not include radiative transfer for interreflected light. (For example, the "direct" mode in AGI32.) Illuminance calculations are most accurate and consistent when only the inverse-square cosine method is used.
7. Run the calculation. Calculated units of illuminance are lumens per MH^2. Use precision of two decimal places.
8. Delete/remove calculation points that are less than 1/30 the maximum point.
9. If the resulting average is more than 6 times the remaining minimum point, iteratively remove the minimum point until the average-to-minimum ratio is less than 6. (Such iteration would be necessary for approximately half of available HID luminaires.)
10. Multiply the number of remaining points times 0.01 to calculate the area of uniform coverage (or uniform pool), in units of MH^2.
11. Multiply the uniform pool area by the average illuminance to calculate the **total luminous flux** falling in the area of uniform coverage (or uniform pool), in lumens.
12. Draw a rectangle containing all remaining calculation points.

13. If the rectangle exhibits asymmetry about the y-axis, redraw the rectangle using the x-coordinate of greatest magnitude. For example, if the left side of the rectangle has an x-coordinate of -4.0 and the right side has an x-coordinate of 3.5, extend the right side to an x-coordinate of 4.0.
14. If both y-coordinates of the rectangle are positive, change the lower y-coordinate to zero.
15. If the negative y-coordinate of the rectangle is greater in magnitude than the positive y-coordinate, change the positive y-coordinate to the absolute value of the negative y-coordinate for symmetry about the x-axis.
16. Calculate the area of the rectangle.
17. Calculate the **percent coverage** as the area of the uniform pool divided by the area of the rectangular target.
18. Multiply the total luminous flux landing in the uniform pool (from step 11) by the percent coverage of rectangular target (from step 17) to score highest those distributions approximatingrectangles. This calculation yields an adjusted total luminous flux.
19. Divide the adjusted total luminous flux (from step 18) by the **total input power** to the luminaire to calculate FTE, in lm/W.
20. The luminaire is considered Shielded if the magnitude of the negative y-coordinate of the rectangular target is less than 1.5-MH. Otherwise, the luminaire is considered Unshielded.
21. Determine whether the luminaire is considered Low Output or High Output by finding the total luminaire output (in lumens) from the laboratory report.
22. Determine whether the luminaire meets the draft ENERGY STAR requirement for FTE based on its shielding-output category. (See **Table 1** below.)

Table 1. ENERGY STAR Draft – July 01, 2009
Minimum Fitted Target Efficacy (FTE) for
Outdoor Pole-Mounted Area and Roadway Luminaires

Shielded (< 1.5 MH house-side)		Unshielded (≥ 1.5 MH house-side)	
Low Output < 9,500 lumens	High Output ≥ 9,500 lumens	Low Output < 13,300 lumens	High Output ≥ 13,300 lumens
37 lm/W	48 lm/W	53 lm/W	70 lm/W

FTE Example

Below is a sample calculation using commercially-available lighting software, for a simple cosine distribution that could be expected from a perfectly diffuse source. The luminaire defined in **Figure 1** below has a total output of 1,009 lumens (Low Output) and total input power of 15W. Luminaire efficacy is thus 67 lm/W.

```
IESNA:LM-63-1995
[TEST]      sample
[ISSUEDATE] sample
[MANUFAC] sample
[LUMCAT] sample
[LUMINAIRE] COSINE UP/DOWN
[LAMP] sample
TILT=NONE
1 -1 1 21 1 1 1 0.5 0.5 0
1 1 15
0 5 15 25 35 45 55 65 75 85 90 95 105 115 125 135 145 155 165 175 180
0
292 292 283 265 240 207 167 123 76 25 0 2 7 13 16 20 24 25 27 29 29
```

Figure 1. IES file used for sample calculation.

The maximum calculated illuminance is 290 lm/MH^2, so points below 9.67 must be removed (because they exceed the maximum-to-minimum ratio of 30:1), per **Figure 2** below.

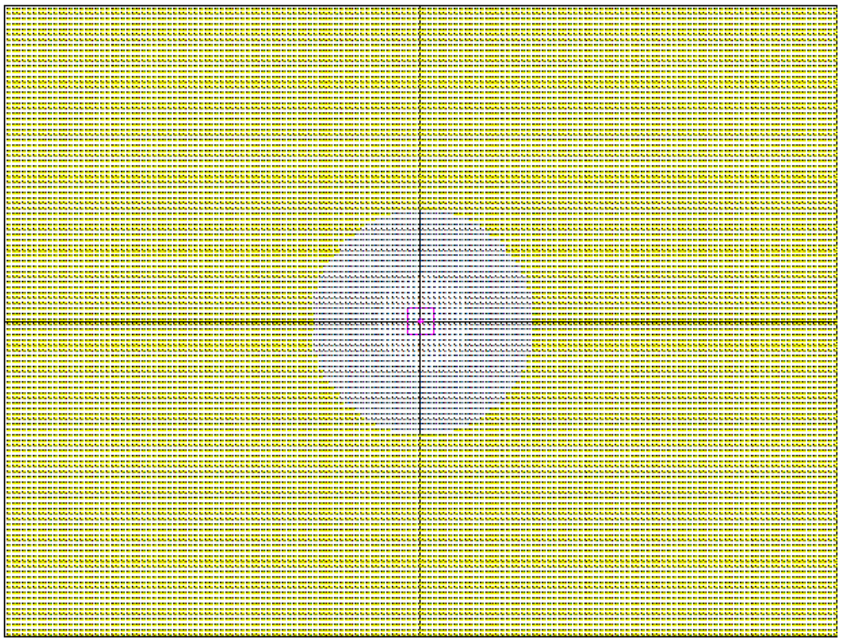

Figure 2. First calculation, with points to be removed in yellow.

With an average illuminance of 53.57 lm/MH^2 and a minimum of 9.96 lm/MH^2, the average-to-minimum ratio is 5.38. Since uniformity is better (less) than 6:1 avg:min , further (iterative) removal of points is not necessary for this distribution. The rectangular target is drawn from coordinates (-2.1,-2.1) to (2.1,2.1) per **Figure 3** below, and the luminaire is thus considered Unshielded, because the uniform area extends more than 1.5 times the mounting height in the back (house-side) direction.

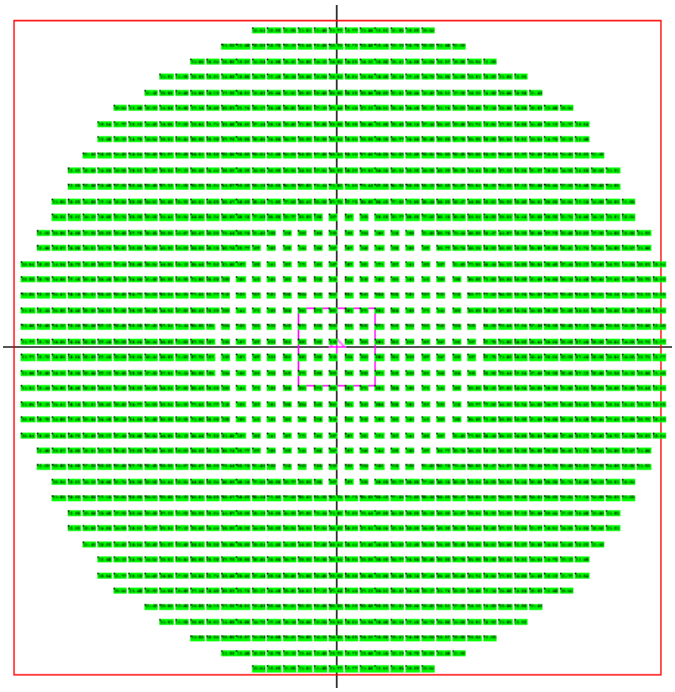

Figure 3. Rectangular Target (in red) drawn around Uniform Pool.

A total of 1396 calculation points remain, yielding 53.57 x 0.1^2 x 1396 = 747.8 lumens in the uniform pool. The percent coverage is calculated as (0.1^2 x 1396) / $(2 \times 2.1)^2$ = 79.1%. FTE is thus 747.8 x 79.1% / 15 = 39 lm/W, falling short of the required 53 lm/W for Unshielded Low-Output luminaires.