ENERGY STAR® Performance Ratings
Technical Methodology for Hotel

This document presents specific details on the EPA's analytical result and rating methodology for Hotel. For background on the technical approach to development of the Energy Performance Ratings, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf).

Model Release Date[1]

Most Recent Update: February 2009
Original Release Date: April 2002

Portfolio Manager Definition

Hotel applies to buildings that rent overnight accommodations on a room/suite basis, typically including a bath/shower and other facilities in guest rooms. The total gross floor area should include all interior space, including guestrooms, halls, lobbies, atria, food preparation and restaurant space, conference and banquet space, health clubs/spas, indoor pool areas, and laundry facilities, as well as all space used for supporting functions such as elevator shafts, stairways, mechanical rooms, storage areas, employee break rooms, back-of-house offices, etc.

Reference Data

The Hotel regression model is based on data from the Department of Energy, Energy Information Administration's 2003 Commercial Building Energy Consumption Survey (CBECS). Detailed information on this survey, including complete data files, is publicly available at: http://www.eia.doe.gov/emeu/cbecs/contents.html.

Data Filters

Four types of filters are applied to define the peer group for comparison and to overcome any technical limitations in the data: Building Type Filters, EPA Program Filters, Data Limitation Filters, and Analytical Filters. A complete description of each of these categories is provided in Section V of the general technical description document: *Energy Performance Ratings – Technical Methodology*. **Table 1** presents a summary of each filter applied in the development of the Hotel model, the rationale behind the filter, and the resulting number of observations after the filter is applied. After all filters are applied, the remaining data set has 142 observations.

The reasons for applying filters on the use and quantity of propane are worthy of additional discussion. In CBECS, major fuel use is reported in exact quantities of consumption. However, if a building uses propane, the amount of propane is reported according to the variable PRAMT8,

[1] Periodic updates to the model occur to reflect the most current available market data. The original model was developed using The Hospitality Research Group's (HRG) Trends in the Hotel Industry® database, which contained energy consumption data from 1999. The most current update of February 2009 reflects the CBECS 2003 database.

which uses ranges rather than exact quantities (e.g. less than 100 gallons, 100 to 500 gallons, etc). Therefore, the quantity must be estimated within the range. To limit error associated with this estimation, EPA applies two restrictions to the propane quantity.

1. The quantity of propane expressed by PRAMT8 must be 1000 gallons or smaller.
2. The value of propane cannot account for more than 10% of the total source energy use. Because the exact quantity of propane is not reported, this cap ensures that the quantity of propane entered will not introduce undue error into the calculation of total energy consumption. In order to apply this 10% limitation, the value at the high end of the propane category is employed (e.g. for the category of less than 100, a value of 99 is used). If the 10% cap is not exceeded, then EPA will use the value at the middle of the range to calculate total energy use (e.g. for the category of less than 100, a value of 50 is used).

Table 1 Summary of Hotel Model Filters		
Condition for Including an Observation in the Analysis	**Rationale**	**Number Remaining**
PBAPLUS8 = 38 or 39	Building Filter – CBECS defines building types according to the variable "PBAPLUS8." Hotels are coded as PBAPLUS=38 and Motels are coded as PBAPLUS=39.	195
Must have at least 1 room	EPA Program Filter – Baseline condition for being a full time Hotel.	195
Must operate for 168 hours per week	EPA Program Filter – Baseline condition for being a full time Hotel.	192
Must have at least 1 worker	EPA Program Filter – Baseline condition for being a full time Hotel.	190
Must operate for at least 10 months per year	EPA Program Filter – Baseline condition for being a full time Hotel.	182
A single activity must characterize greater than 50% of the floor space[2]	EPA Program Filter – In order to be considered part of the Hotel peer group, more than 50% of the building must be defined as a Hotel.	180
If propane is used, the amount category (PRAMTC8) must equal 1, 2, or 3	Data Limitation Filter – Cannot estimate propane use if the quantity is "greater than 1000" or unknown.	161
If propane is used, the maximum estimated propane amount must be 10% or less of the total source energy	Data Limitation Filter – Because propane values are estimated from a range, propane is restricted to 10% of the total source energy.	159
Must not use chilled water	Data Limitation Filter – CBECS does not collect quantities of chilled water.	157
Must be at least 5,000 square foot	Analytical Filter – Analysis could not model behavior for buildings smaller than 5,000ft^2.	149
Must have Source EUI less than or equal to 600 kBtu/ft^2	Analytical Filter – Values determined to be statistical outliers.	147
Must have Source EUI greater than or equal to 10 kBtu/ft^2	Analytical Filter – Values determined to be statistical outliers.	146
Must have fewer than 5 rooms per 1,000 square foot	Analytical Filter – Values determined to be statistical outliers.	143
Must have fewer than 0.5 commercial refrigeration units per 1,000 square foot[3]	Analytical Filter – Values determined to be statistical outliers.	142

[2] This filter is applied by a set of screens. If the variable ONEACT8=1, then one activity occupies 75% or more of the building. If the variable ONEACT8=2, then the activities in the building are defined by ACT1, ACT2, and ACT3. One of these activities must be coded as lodging (PBAX=21), with a corresponding percent (ACT1PCT8, ACTPCT8, ACT3PCT8) that is greater than 50.

[3] This filter is based on the variable Commercial Refrigeration Density: RfgCommDen. This variable is defined in *Table 2*.

Dependent Variable

The dependent variable in the Hotel analysis is source energy use intensity (source EUI). Source EUI is equal to the total source energy use of the facility divided by the gross floor area. By setting source EUI as the dependent variable, the regressions analyze the key drivers of source EUI – those factors that explain the variation in source energy per square foot in a Hotel.

Independent Variables

General Overview:

The CBECS data contains numerous building operation questions that EPA identified as potentially important for Hotels. Based on a review of the available variables in the CBECS data, in accordance with the EPA criteria for inclusion[4], EPA analyzed the following variables[5]:

- SQFT8 – Square footage
- LODGRM8 – Number of guest rooms
- NWKER8 – Number of employees during the main shift
- COOK8 – Energy used for cooking (yes/no)
- FDRM8 – Commercial food preparation area (yes/no)
- SNACK8 – Snack bar (yes/no)
- FASTFD8 – Fast food or small restaurant (yes/no)
- CAF8 – Cafeteria or large restaurant (yes/no)
- FDPREP8 – Food preparation area (yes/no)
- KITCHN8 – Small kitchen area (yes/no)
- OTFDRM8 – Other food prep area (yes/no)
- RFGWIN8 – Number of walk-in refrigeration units
- RFGOPN8 – Number of open refrigerated cases
- RFGRSN8 – Number of residential refrigerators
- RFGCLN8 – Number of closed refrigerated cases
- RFGVNN8 – Number of refrigerated vending machines
- PCNUM8 – Number of personal computers
- SVRNUM8 – Number of servers
- TRNGRM8 – Computer-based training room (yes/no)
- STDNRM8 – Student or public computer center (yes/no)
- OTPCRM8 – Other computer area (yes/no)
- POOL8 – Pool (yes/no)
- HWTRM8 – Large amounts of hot water used (yes/no)
- LAUNDR8 – Laundry onsite (yes/no)
- NFLOOR8 – Number of floors
- ELEVTR8 – Elevators (yes/no)
- NESLTR8 – Number of escalators
- SRVNUM8 – Number of servers

[4] For a complete explanation of these criteria, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf).

[5] Note that the 8 at the end of all variables indicates that the 2003 CBECS survey is the eighth survey conducted by the Energy Information Administration.

- HEATP8 – Percent heated
- COOLP8 – Percent cooled
- HDD658 – Heating degree days
- CDD658 – Cooling degree days

EPA performed extensive review on all of these operational characteristics. In addition to reviewing each characteristic individually, characteristics were reviewed in combination with each other (e.g., Heating Degree Days * Percent Heated). As part of the analysis, some variables were reformatted to reflect the physical relationships of building components. For example, the number of workers on the main shift is typically evaluated in a density format. The number of workers *per square foot* (not the gross number of workers) is expected to be correlated with the energy use per square foot. In addition, based on analytical results and residual plots, variables were examined using different transformations (such as the natural logarithm). The analysis consisted of multiple regression formulations. These analyses were structured to find the combination of statistically significant operating characteristics that explained the greatest amount of variance in the dependent variable: source EUI.

Based on the Hotel regression analysis, the following six characteristics were identified as key explanatory variables that can be used to estimate the expected average source EUI (kBtu/ft^2) in a Hotel:

- Number of lodging rooms per 1,000 square feet
- Natural log of the number of workers per 1,000 square feet
- Presence of a commercial food preparation area (yes/no)
- Number of commercial refrigeration units (walk-in, open, and closed) per 1,000 square feet
- Heating degree days times Percent of the building that is heated
- Cooling degree days times Percent of the building that is cooled

The regression analyses did not reveal a statistically significant relationship between the presence of a pool and the energy use at a Hotel. However, it is of note that pools can be separately entered into Portfolio Manager. In those cases an engineered adjustment is applied to account for the energy requirements of a pool.

Model Testing:
In addition to the analysis of CBECS data, EPA performed subsequent testing on supplemental data shared with EPA for 64 hotels, which represented four major brands and a number of independent hotels. The results of testing and analysis of this dataset showed that the performance distribution of the test hotels was similar to that of the CBECS 2003 observations. This analysis provided a second level of confirmation that the final regression model produces robust results that are unbiased with respect to key operational characteristics such as building size, room density, worker density, and heating and cooling degree days. Additionally, the data showed that the model is unbiased with respect to characteristics that are not included in the model, such as the presence of laundry.

It is important to reiterate that the final regression model is based on the nationally representative CBECS data, not the supplemental data collected by EPA. The supplemental data served to verify

that the CBECS-based regression model provides a valid assessment of energy performance across a variety of hotel types.

Regression Modeling Results

The final regression is a weighted ordinary least squares regression across the filtered data set of 142 observations. The dependent variable is source EUI. Each independent variable is centered relative to the mean value, presented in **Table 2**. The final model is presented in **Table 3**. All model variables are significant at the 90% confidence level or better, as shown by the significance levels (a p-level of less than 0.10 indicates 90% confidence). The model has an R^2 value of 0.367, indicating that this model explains 36.7% of the variance in source EUI for Hotel buildings. Because the final model is structured with energy per square foot as the dependent variable, the explanatory power of square foot is not included in the R^2 value, thus this value appears artificially low. Re-computing the R^2 value in units of source energy[6], demonstrates that the model actually explains 87.3% of the variation of source energy of Hotels. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach, the methodology for performing weather adjustments, and the independent variable centering technique is available in the technical document: *Energy Performance Ratings – Technical Methodology*.

[6] The R^2 value in Source Energy is calculated as: 1 – (Residual Variation of Y) / (Total Variation of Y). The residual variation is sum of (Actual Source $Energy_i$ – Predicted Source $Energy_i)^2$ across all observations. The Total variation of Y is the sum of (Actual Source $Energy_i$ – Mean Source Energy)^2 across all observations.

Table 2
Descriptive Statistics for Variables in Final Regression Model

Variable	Full Name	Mean	Minimum	Maximum
SrcEUI	Source Energy per Square Foot	182.5	49.08	544.3
RoomDen	Number of Lodging Rooms per 1000 ft^2	1.951	0.5195	4.237
LNWkrDen	Natural Log of Number of Workers per 1000 ft^2	-1.395	-3.245	1.008
FDRM	Presence of a Commercial Food Preparation area (0 for yes; 1 for no)	0.2056	0.000	1.000
RfgCommDen	Number of Commercial Refrigeration Units (Walk-in, Open, and Closed) per 1000 ft^2	0.0227	0.000	0.3125
HDDxPH	Heating Degree Days x Percent Heated	4120	31.90	9928
CDDxPC	Cooling Degree Days x Percent Cooled	1224	0.000	4871

Note:
- *Statistics are computed over the filtered data set (n=142 observations).*
- *Values are weighted by the CBECS variable ADJWT8.*
- *The mean values are used to center variables for the regression.*

Table 3
Final Regression Modeling Results

Dependent Variable	Source Energy Intensity (kBtu/ft^2)			
Number of Observations in Analysis	142			
Model R^2 value	0.3669			
Model F Statistic	13.04			
Model Significance (p-level)	0.0000			
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	169.1	7.457	22.68	0.0000
C_RoomDen	33.22	9.330	3.560	0.0005
C_LNWkrDen	20.81	10.38	2.004	0.0471
FDRM	65.14	18.64	3.494	0.0006
C_RfgCommDen	249.8	147.2	1.697	0.0920
C_HDDxPH	0.0107	0.0029	3.653	0.0004
C_CDDxPC	0.0169	0.0085	1.988	0.0488

Note:
- *The regression is a weighted ordinary least squares regression, weighted by the CBECS variable "ADJWT8".*
- *The prefix C_ on each variable indicates that it is centered. The centered variable is equal to difference between the actual value and the observed mean. The observed mean values are presented in **Table 2**.*
- *Unlike other variables, the yes/no variable FDRM is not centered. The coefficient adjustment represents the adjustment for Hotels with cooking facilities.*
- *Full variable names and definitions are presented in **Table 2.***

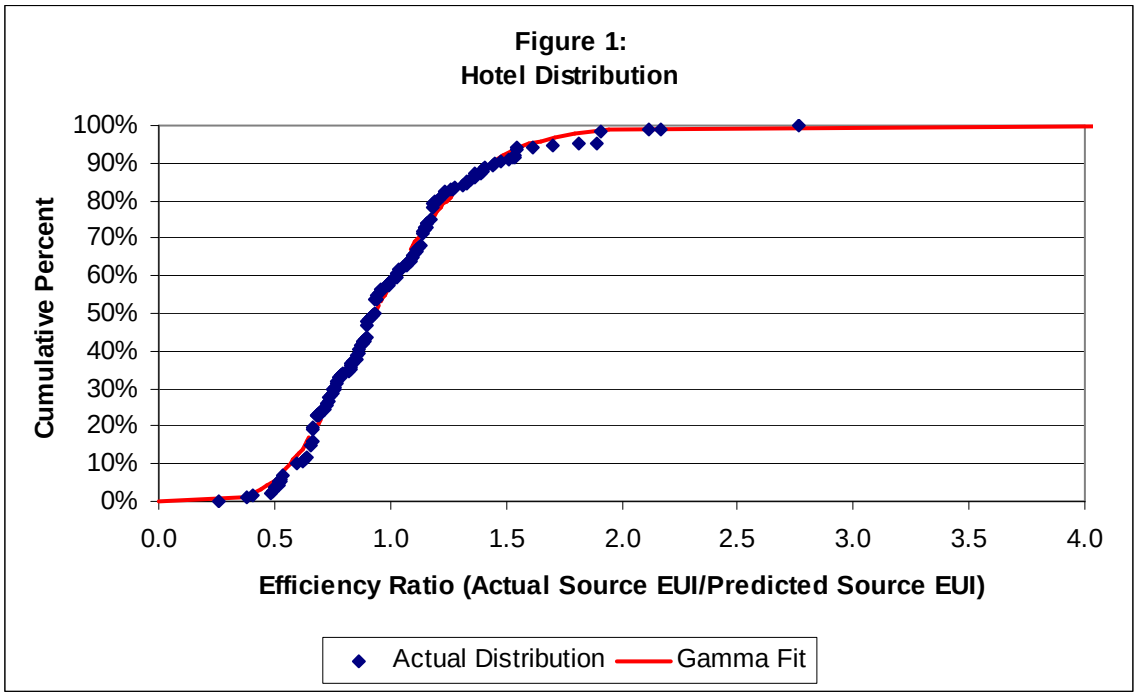
Hotel Lookup Table

The final regression model (presented in **Table 3**) yields a prediction of source EUI based on a building's operating constraints. Some buildings in the CBECS data sample use more energy than predicted by the regression equation, while others use less. The *actual* source EUI of each CBECS observation is divided by its *predicted* source EUI to calculate an energy efficiency ratio:

Energy Efficiency Ratio = Actual Source EUI / Predicted Source EUI

A lower efficiency ratio indicates that a building uses less energy than predicted, and consequently is more efficient. A higher efficiency ratio indicates the opposite.

The efficiency ratios are sorted from smallest to largest and the cumulative percent of the population at each ratio is computed using the individual observation weights from the CBECS dataset. **Figure 1** presents a plot of this cumulative distribution. A smooth curve (shown in red) is fitted to the data using a two parameter gamma distribution. The fit is performed in order to minimize the sum of squared differences between each building's actual percent rank in the population and each building's percent rank with the gamma solution. The final fit for the gamma curve yielded a shape parameter (alpha) of 8.0805 and a scale parameter (beta) of 0.1205. For this fit, the sum of the squared error is 0.0485.



The final gamma shape and scale parameters are then used to calculate the efficiency ratio at each percentile (1 to 100) along the curve. For example, the ratio on the gamma curve at 1% corresponds to a rating of 99; only 1% of the population has a ratio this small or smaller. The ratio on the gamma curve at the value of 25% is 0.7350. The ratio on the gamma curve at the value of 25% will correspond to the ratio for a rating of 75; only 25% of the population has ratios

this small or smaller. The complete lookup table is presented at the end of the document. In order to read this lookup table, note that if the ratio is less than 0.3559 the rating for that building should be 100. If the ratio is greater than or equal to 0.3559 and less than 0.4047 the rating for the building should be 99, etc.

Example Calculation

As detailed in the document *Energy Performance Ratings – Technical Methodology*, there are five steps to compute a rating. The following is a specific example with the Hotel model:

Step 1 – User enters building data into Portfolio Manager

For the purposes of this example, sample data is provided.

- Energy data
  - Total annual electricity = 4,500,000 kWh
  - Total annual natural gas = 110,000 therms
  - Note that this data is actually entered in monthly meter entries
- Operational data
  - Gross floor area (ft^2) = 300,000
  - Rooms = 360
  - Workers on main shift = 180
  - Commercial Food Preparation = Yes
  - Number of Commercial Refrigeration Units = 20
  - Percent heated = 100
  - Percent cooled = 100
  - HDD (provided by Portfolio Manager, based on zip code) = 4532
  - CDD (provided by Portfolio Manager, based on zip code) = 1388

Step 2 – Portfolio Manager computes the Actual Source Energy Use Intensity

In order to compute actual source EUI, Portfolio Manager must convert each fuel from the specified units (e.g. kWh) into Site kBtu, and must convert from Site kBtu to Source kBtu.

- Convert the meter data entries into site kBtu
  - Electricity: (4,500,000 kWh)*(3.412kBtu/kWh) = 15,354,000 kBtu Site
  - Natural gas: (110,000 therms)*(100kBtu/therm) = 11,000,000 kBtu Site
- Apply the source-site ratios to compute the source energy
  - Electricity:
    15,354,000 Site kBtu*(3.34 Source kBtu/Site kBtu) = 51,282,360 kBtu Source
  - Natural Gas:
    11,000,000 Site kBtu *(1.047 Source kBtu/Site kBtu) = 11,517,000 kBtu Source
- Combine source kBtu across all fuels
  - 51,282,360 kBtu + 11,517,000 kBtu = 62,799,360 kBtu
- Divide total source energy by gross floor area
  - Source EUI = 62,799,360 kBtu/300,000 ft^2 = 209.3 kBtu/ft^2

Step 3 – Portfolio Manager computes the Predicted Source Energy Intensity

Portfolio Manager uses the building data entered under Step 1 to compute centered values for each operating parameter. These centered values are entered into the Hotel regression equation to obtain a predicted source EUI.

- Calculate centered variables
  - Use the operating characteristic values to compute each variable in the model. (e.g. RoomDen = 360 / 300,000 * 1000 = 1.200)
  - Subtract the reference centering value from calculated variable (e.g. RoomDen – 1.951 = 1.200 – 1.951 = -0.7510)
  - These calculations are summarized in **Table 4**
- Compute predicted source energy use intensity
  - Multiply each centered variable by the corresponding coefficient in the model (e.g. Coefficient*CenteredRoomDen = 33.22*-0.7510 = -24.95)
  - Take the sum of these products (i.e. coefficient*CenteredVariable) and add to the constant (this yields a predicted Source EUI of 245.9 kBtu/ft^2)
  - This calculation is summarized in **Table 5**

Step 4 – Portfolio Manager computes the energy efficiency ratio
The energy efficiency ratio is equal to: Actual Source EUI/ Predicted Source EUI.

- Ratio = 209.3/245.9 = 0.8512

Step 5 – Portfolio Manager looks up the efficiency ratio in the lookup table
Starting at 100 and working down, Portfolio Manager searches the lookup table for the first ratio value that is larger than the computed ratio for the building.

- A ratio of 0.8512 is less than 0.8517 (requirement for 61) but greater than 0.8436 (requirement for 62)
- ***The rating is 61***

Table 4 Example Calculation – Computing Building Centered Variables				
Operating Characteristic	Formula to Compute Variable	Building Variable Value	Reference Centering Value	Building Centered Variable (Variable Value - Center Value)
RoomDen	#Rooms/ft^2*1000	1.200	1.951	-0.7510
LNWkrDen	LN(#Workers/ft^2*1000)	-0.5110	-1.395	0.8840
FDRM	FDRM	1.000	NA	1.000
RfgCommDen	#Refrigerators/ft^2*1000	0.0667	0.0227	0.0440
HDDxPH	(HDD*Percent Heated)	4532	4120	412.0
CDDxPC	(CDD*Percent Cooled)	1388	1224	164.0

Note
- *Densities are always expressed as the number per 1,000 square feet.*
- *The center reference values are the weighted mean values from the CBECS population, show in* ***Table 2.***
- *FDRM is not centered.*

Table 5 Example Calculation – Computing predicted Source EUI			
Operating Characteristic	Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	NA	169.1	169.1
RoomDen	-0.7510	33.22	-24.95
LNWkrDen	0.8840	20.81	18.40
FDRM	1.000	65.14	65.14
RfgCommDen	0.0440	249.8	10.99
HDDxPH	412.0	0.0107	4.408
CDDxPC	164.0	0.0169	2.772
Predicted Source EUI (kBtu/ft^2)			***245.9***

Attachment

Table 6 lists the energy efficiency ratio cut-off point for each rating, from 1 to 100.

Table 6 Lookup Table for Hotel Rating					
Rating	**Cumulative Percent**	**Ratio**	**Rating**	**Cumulative Percent**	**Ratio**
100	0%	<0.3559	50	50%	0.9422
99	1%	0.4047	49	51%	0.9507
98	2%	0.4380	48	52%	0.9592
97	3%	0.4643	47	53%	0.9678
96	4%	0.4865	46	54%	0.9765
95	5%	0.5060	45	55%	0.9852
94	6%	0.5236	44	56%	0.9940
93	7%	0.5396	43	57%	1.0030
92	8%	0.5546	42	58%	1.0120
91	9%	0.5685	41	59%	1.0211
90	10%	0.5817	40	60%	1.0303
89	11%	0.5943	39	61%	1.0397
88	12%	0.6063	38	62%	1.0492
87	13%	0.6179	37	63%	1.0588
86	14%	0.6290	36	64%	1.0686
85	15%	0.6398	35	65%	1.0786
84	16%	0.6503	34	66%	1.0887
83	17%	0.6605	33	67%	1.0990
82	18%	0.6704	32	68%	1.1096
81	19%	0.6801	31	69%	1.1203
80	20%	0.6897	30	70%	1.1313
79	21%	0.6990	29	71%	1.1425
78	22%	0.7082	28	72%	1.1540
77	23%	0.7173	27	73%	1.1658
76	24%	0.7262	26	74%	1.1779
75	25%	0.7350	25	75%	1.1903
74	26%	0.7438	24	76%	1.2031
73	27%	0.7524	23	77%	1.2163
72	28%	0.7609	22	78%	1.2300
71	29%	0.7694	21	79%	1.2442
70	30%	0.7778	20	80%	1.2589
69	31%	0.7861	19	81%	1.2742
68	32%	0.7944	18	82%	1.2902
67	33%	0.8027	17	83%	1.3070
66	34%	0.8109	16	84%	1.3245
65	35%	0.8191	15	85%	1.3431
64	36%	0.8273	14	86%	1.3628
63	37%	0.8354	13	87%	1.3837
62	38%	0.8436	12	88%	1.4061
61	39%	0.8517	11	89%	1.4303
60	40%	0.8598	10	90%	1.4567
59	41%	0.8680	9	91%	1.4856
58	42%	0.8761	8	92%	1.5179
57	43%	0.8843	7	93%	1.5545
56	44%	0.8925	6	94%	1.5969
55	45%	0.9007	5	95%	1.6477
54	46%	0.9089	4	96%	1.7115
53	47%	0.9172	3	97%	1.7987
52	48%	0.9255	2	98%	1.9417
51	49%	0.9338	1	99%	>=1.9417