



# ENERGY STAR<sup>®</sup> Connected Thermostat Products

## Discussion Document – Description of Candidate Savings Methodology & Algorithms Implemented in Software

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### OVERVIEW

This discussion document describes the software implementation for assessing Connected Thermostat field savings. The software currently includes 3 candidate methods for modeling the unique relationship between thermal load and HVAC run time in a home. EPA intends to select one of these methods for use in the Version 1.0 ENERGY STAR Connected Thermostat (CT) Program. As of this writing, the specification and test method for this program are in draft and several Alpha iterations of the software have been released. This discussion document has been developed to foster understanding of the software implementation of these methods.

### SCOPE

This document is applicable to Alpha release v0.3.4-alpha. EPA intends to issue revised versions of this document as the software is further developed.

### CANDIDATE METHODS

An overview of the candidate methods and software implementation is provided below. These methods are used to model the relationship between thermal conditions (outside and inside temperatures) and HVAC run time. Once models are established, they are used by the software to assess baseline run times, that is, what HVAC run times would be if the home were kept at the occupant's preferred comfort temperatures for heating and cooling (detailed in Section 8.a.ii).

- *Linear fit  $\Delta T$  method* – uses linear regression to characterize the relationships between  $\Delta T$  and heating run time on core heating days; and  $\Delta T$  and cooling run time on core cooling days.  $\Delta T$  is the difference between indoor and outdoor temperature.
- *Daily HTD/CTD method* – a measure of thermal demand expressed as Heating Thermal Demand (HTD) and Cooling Thermal Demand (CTD); calculated for each core heating and core cooling day using daily average temperatures. The model assumes HVAC run time is directly proportional to heating (or cooling) demand.
- *Hourly HTD/CTD method* – a measure of thermal demand expressed as Cooling Thermal Demand (CTD) and Heating Thermal Demand (HTD), calculated for each core heating and core cooling day, where daily thermal demand is the sum of hourly thermal demand values calculated for each hour using hourly average temperatures. The model assumes HVAC run time is directly proportional to heating (or cooling) demand.

### INPUT DATA

Data used to assess CT savings is necessarily limited by availability to the following:

1. Data reported by the CT

- 40 2. Installation ZIP Code
- 41 3. HVAC Type (as far as can be determined by the CT)
- 42 4. Inside Temperature
- 43 5. Set Temperature (heat & cool)
- 44 6. HVAC Run Time (primary heat, aux. heat, emerg. Heat, cool)
- 45 7. Publicly available outside temperature. Software uses values reported by the nearest weather
- 46 station in the same climate zone as the CT, as determined from the ZIP code.

#### 47 **BASELINES**

48 The software assesses savings against a baseline condition expressed as average conditioned space  
49 temperatures. This document details development of per home comfort baselines that separately  
50 assess resident's comfort preferences for heating and cooling and assume 24/7 use of these  
51 temperatures as the baseline condition.

52 Note, however, that these candidate methods may be used to assess savings relative to ANY average  
53 temperature baseline, including regional baselines that define median temperature preferences per  
54 climate zone or geographic region, or average temperatures assessed from self-reported thermal  
55 preferences.

#### 56 **ENERGY STAR CT SOFTWARE**

57 The software consists of documentation plus two modules which assess CT savings expressed as run  
58 time reduction relative to the baseline.

##### 59 ○ *Thermostat Module*

60 The thermostat module separately assesses HVAC heating and cooling savings attributed to a  
61 CT.

- 62 1. Input files consist of:
  - 63 • a metadata file that contains the unique ID, controlled HVAC type, ZIP code and interval
  - 64 data file name for each CT in the data set, and
  - 65 • an interval data file for each CT in the data set. Input file contents and format is
  - 66 detailed in the [software documentation](#).
- 67 2. The module will not assess savings for thermostat data files that are missing too much data,  
68 or if corresponding outdoor temperature data is not available. Indoor and outdoor  
69 temperature data gaps of up to 2 hours are interpolated. Days with longer gaps are not  
70 included in the analysis. If more than 5% of days are missing HVAC run time data, the  
71 thermostat is excluded.<sup>1</sup>
- 72 3. The thermostat module output is a.csv file that includes a separate row for each CT in the  
73 data set. Columns in the output file include:
  - 74 a. Unique CT ID
  - 75 b. Controlled HVAC type
  - 76 c. ZIP code in which the thermostat is installed
  - 77 d. Heating savings

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<sup>1</sup> Intent is for a subsequent software version to also filter out CTs where >5% of days are missing indoor/outdoor temperature data.

- 78 e. Cooling savings  
79 f. Resistance Heating Utilization  
80 g. Associated statistical data
- 81 A detailed description of the output data is included in the [software documentation](#)
- 82 ○ *Statistics Module*
- 83 1. A thermostat module output file comprises the input to the statistics module
  - 84 2. The statistics module outputs a .csv file that includes:
    - 85 a. Regional heating and cooling savings as average savings of multiple instances of a CT  
86 model in each of the five Energy Information Administration (EIA) climate regions. The  
87 output file includes the climate zone, decile bins, means, and standard errors of the  
88 mean for all numerical outputs in the individual thermostat output files generated by  
89 the thermostat module.
    - 90 b. National heating and cooling savings assessed as a weighted average of regional savings.  
91 Weighting is by the proportion of national heating and cooling energy, respectively,  
92 used in each of the five EIA climate regions
    - 93 c. Resistance heat utilization (%) in 5°F bins from 0°F to 60°F (applicable to heating with  
94 heat pumps only)
    - 95 d. an estimate of statistical power, in order to guide partners toward a data set that  
96 provides sufficiently certain statistics

97 Source code and detailed documentation are available at the following locations:

98 Documentation: <http://thermostat.readthedocs.org/en/latest/>

99 Source code: <https://github.com/impactlab/thermostat>

## 100 **OVERVIEW OF SOFTWARE USAGE**

101 *Step 1 – The thermostat module is used to assess savings for n CTs that comprise a sample set.*

- 102 1. *Assess Savings for CT1:*
  - 103 a. *Develop Thermal/HVAC Models* – using each of the candidate methods, the software  
104 constructs separate models of the relationship between heating and cooling HVAC  
105 run time, outside temperature, and temperature choices for the CT;
  - 106 b. *Determine Baseline Comfort Temperatures* – the software parses the CT setpoint  
107 history<sup>2</sup> to determine occupants’ preferred set temperatures for heating and  
108 cooling;
  - 109 c. *Assess Baseline Run Times* – the software uses each model to assess baseline  
110 heating and cooling run times for the CT; i.e. what run times would have been under  
111 24/7 use of baseline comfort temperatures;
  - 112 d. *Assess CT Savings* – the software generates an output file that includes CT savings;  
113 expressed as percent run time reduction, relative to the baseline; for each of the  
114 methods. For heat pumps, the software also outputs Resistance Heating Utilization

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<sup>2</sup> Intent is for a subsequent software version to parse the indoor temperature history reported by the CT to determine occupants’ preferred set temperatures for heating and cooling.

115 (RHU), the proportion of total heating run time that includes auxiliary and  
116 emergency heating.  
117 e. Repeat for each of the remaining CTs in the sample set. Once evaluation of the  
118 sample set is complete, the output file will include  $n$  rows of data, one row for each  
119 of the  $n$  CTs in the sample set.

120 *Step 2 – The statistics module is used to assess aggregate national and regional savings*

- 121 1. *Regional CT savings* – With a thermostat module output file serving as the input, the  
122 statistics module outputs average regional HVAC savings for each candidate method in  
123 the (5) U.S. climate zones defined by the EIA<sup>3</sup>.
- 124 2. *National CT savings* – for each of the candidate methods, the software also outputs  
125 national heating and cooling savings as a weighted average of regional savings. Regional  
126 savings are weighted by the proportion of national heating or cooling energy consumed  
127 in each EIA climate zone.
- 128 3. *Resistance heating utilization (RHU)* – for heat pumps, the statistics module also outputs  
129 average regional and national RHU.

### 130 **THERMOSTAT MODULE – ASSESSMENT OF SAVINGS FOR A CT**

131 As noted, the thermostat module currently assesses savings for an individual CT using three  
132 candidate methods, as detailed below.

#### 133 *Common Terms and Calculations*

134 The following terms and calculations are common to all (3) candidate methods:

- 135 ■ *Core Days*
  - 136 ● Core heating days – days where daily heating run time  $\geq 1$  h with no cooling, excluding  
137 days that exceed the missing data thresholds, as previously noted.
  - 138 ● Core cooling days – days where daily cooling  $\geq 1$  h with no heating, excluding days that  
139 exceed the missing data thresholds, as previously noted.

140 Note: Only primary heating source run times are assessed to determine core heating days.  
141 That is, auxiliary and emergency heat run times associated with heat pumps are not  
142 included.

- 143 ■ *Baseline Assessment* – occupant’s preferred comfort temperatures for heating and cooling<sup>4</sup>:
  - 144 ● Using data reported by the CT for core heating days, determine the preferred comfort  
145 set point for heating:

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<sup>3</sup> [https://www.eia.gov/consumption/residential/reports/images/climatezone\\_eere-lg.jpg](https://www.eia.gov/consumption/residential/reports/images/climatezone_eere-lg.jpg)

<sup>4</sup> Method described in paragraph 3.1.2 of “[A DATA-DRIVEN FRAMEWORK FOR COMPARING RESIDENTIAL THERMOSTAT ENERGY PERFORMANCE.](#)” Bryan Urban and Kurt Roth. Fraunhofer USA. July 2014.

146  $T$  base heat ( $^{\circ}F$ ) = 90th percentile of user heating set point (CT target temperature)  
147 history for core heating days.<sup>5</sup> Not a Number (NaN) values are ignored.

148 • Using data reported by the CT for core cooling days, determine the preferred comfort  
149 set point for cooling:

150  $T$  base cool ( $^{\circ}F$ ) = 10th percentile of user cooling set point (CT target temperature)  
151 history for core cooling days.<sup>5</sup> NaN values are ignored.

152 **METRIC 1 – Linear fit  $\Delta T$  method**

153 ■ Assess Heating Savings

154 • Develop the CT/home’s unique thermal/HVAC heating run time model (Linear fit  $\Delta T$   
155 method)

156 ○ Calculate the average daily indoor minus outdoor temperature difference  
157 ( $daily \Delta T_d$ ) for each core heating day. Note that  $daily \Delta T_d$  is demand  $\Delta T$  in the  
158 thermostat module.

159  $daily \Delta T_d$  ( $^{\circ}F$ ) =  $\frac{\sum_{n=1}^{24}(\text{hourly indoor } T_{d,n} - \text{hourly outdoor } T_{d,n})}{24}$ , where

160  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ), and

161  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ).

162 ○ For the set of all core heating days, perform a linear regression to determine the  
163 relationship between  $\Delta T$  and heating run time. The Thermostat Module uses a least  
164 squares optimization to determine and record the values of  $\tau_h$  and  $\alpha_h$  which best fit  
165 the data.<sup>6</sup>

166  $Daily RT heat_d$  (minutes) =  $\alpha_h * (daily \Delta T_d - \tau_h)$  where

167  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),

168  $\alpha_h$  is the slope of the line (expected to be positive), and

169  $\tau_h$  is the  $\Delta T$  associated with zero run time (expected to be positive).

170 • Calculate the cumulative baseline heating run time for the set of all core heating days in  
171 the CT interval data file (i.e. cumulative baseline heating run time is what would have  
172 occurred over the set of all core heating days in the reporting period, had the home been  
173 held constant at  $T$  base heat, the preferred heating comfort temperature):

174 ○ For each core heating day in the CT interval data file, calculate the average daily  
175 indoor baseline minus outdoor temperature difference ( $daily \Delta T$  base heat $_d$ ) that  
176 would have occurred had the home been held constant at  $T$  base heat:

177  $daily \Delta T$  base heat $_d$  ( $^{\circ}F$ ) =  $\frac{\sum_{n=1}^{24}(T \text{ base heat} - \text{hourly outdoor } T_{d,n})}{24}$ , where

178  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),

179  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ), and

180  $T$  base heat is the occupant’s preferred comfort temperature for heating.

181 ○ Calculate baseline run time as the sum of daily baseline run times for the set of core

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<sup>5</sup> Intent is for a subsequent software version to parse the indoor temperature history reported by the CT to determine occupants’ preferred set temperatures for heating and cooling.

<sup>6</sup> Thermostat module calls [Scipy Function leastsq](#), which uses [Levenberg-Marquardt](#) as implemented in MINPACK: LMDIF 1980

182 heating days in the CT interval data file:  
 183  $RT \text{ base heat (minutes)} = \sum_{d=1}^x [\alpha_h * (\text{daily } \Delta T \text{ base heat}_d - \tau_h)]_+$ , where  
 184  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ), and  
 185  $\alpha_h$ , and  $\tau_h$ , determined above, are constants that define the CT/home's  
 186 thermal/HVAC heating run time model.  
 187  $[ ]_+$  indicates that the term is zero if its value would be negative.

188 • CT heating savings is the percent heating run time reduction relative to the baseline, for  
 189 the reporting period in the CT interval data file

190  $HS (\% RT \text{ reduction}) = 100 * \frac{(RT \text{ base heat} - RT \text{ actual heat})}{RT \text{ base heat}}$ , where

191  $RT \text{ base heat}$  is the sum of baseline heating run times for all core heating days in  
 192 the CT interval data file, as detailed for each method, and

193  $RT \text{ actual heat}$  is the sum of heating run times for all core heating days in the CT  
 194 interval data file.

195 ■ Assess Cooling Savings

196 • Develop the CT/home's unique thermal/HVAC cooling run time model (Linear fit  $\Delta T$   
 197 method)

198 ○ Calculate the average daily indoor minus outdoor temperature difference  
 199 ( $\text{daily } \Delta T_d$ ) for each core cooling day. Note that  $\text{daily } \Delta T_d$  is  $- \text{demand } \Delta T$  in the  
 200 thermostat module.

201  $\text{daily } \Delta T_d (\text{ }^\circ F) = \frac{\sum_{n=1}^{24} (\text{hourly indoor } T_{d,n} - \text{hourly outdoor } T_{d,n})}{24}$ , where

202  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ), and  
 203  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ).

204 ○ For the set of all core cooling days, perform a linear regression to determine the  
 205 relationship between  $\Delta T$  and cooling run time. The Thermostat Module uses a least  
 206 squares optimization to determine and record the values of  $\tau_c$  and  $\alpha_c$  which best fit  
 207 the data.<sup>7</sup>

208  $\text{Daily } RT \text{ cool}_d (\text{minutes}) = \alpha_c * (\tau_c - \text{daily } \Delta T_d)$  where

209  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),

210  $\alpha_c$  is the slope of the line (expected to be positive),

211  $\tau_c$  is the  $\Delta T$  associated with zero run time (expected to be positive), and  
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213 • Calculate the cumulative baseline cooling run time for the set of all core cooling days in  
 214 the CT interval data file (i.e. cumulative baseline cooling run time is what would have  
 215 occurred over the set of all core cooling days in the reporting period, had the home been  
 216 held constant at  $T \text{ base cool}$ , the preferred cooling comfort temperature):

217 ○ For each core cooling day in the CT interval data file, calculate the average daily  
 218 indoor baseline minus outdoor temperature difference ( $\text{daily } \Delta T \text{ base cool}_d$ ) that  
 219 would have occurred had the home been held constant at  $T \text{ base cool}$ :

<sup>7</sup> Thermostat module calls [Scipy Function leastsq](#), which uses [Levenberg-Marquardt](#) as implemented in MINPACK: LMDIF 1980

220  $daily \Delta T base cool_d (\text{°F}) = \frac{\sum_{n=1}^{24}(T base cool - hourly outdoor T_{d,n})}{24}$ , where  
 221  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),  
 222  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ), and  
 223  $T base cool$  is the occupant's preferred comfort temperature for cooling.

224 ○ Calculate baseline run time as the sum of daily baseline run times for the set of core  
 225 cooling days in the CT interval data file:

226  $RT base cool (minutes) = \sum_{d=1}^x [\alpha_c * (\tau_c - daily \Delta T base cool_d)]_+$ , where  
 227  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ), and  
 228  $\alpha_c$ , and  $\tau_c$ , determined above, are constants that define the CT/home's  
 229 thermal/HVAC cooling run time model.  
 230  $[ ]_+$  indicates that the term is zero if its value would be negative.

231 • CT cooling savings is the percent cooling run time reduction relative to the baseline, for  
 232 the reporting period in the CT interval data file

233  $CS (\% RT reduction) = 100 * \frac{(RT base cool - RT actual cool)}{RT base cool}$ , where

234  $RT base cool$  is the sum of baseline cooling run times for all core cooling days in  
 235 the CT interval data file, as detailed for each method, and

236  $RT actual cool$  is the sum of cooling run times for all core cooling days in the CT  
 237 interval data file.

238 **METRIC 2 – Daily HTD/CTD method**

239 ■ Assess Heating Savings

240 • Develop the CT/home's unique thermal/HVAC heating run time model (daily HTD  
 241 method)

242 ○ Calculate daily Heating Thermal Demand ( $HTD_d$ ) for each core heating day in the CT  
 243 interval data file:

244 ■ Calculate the average daily indoor minus outdoor temperature difference  
 245 ( $daily \Delta T_d$ ) for each core heating day

246  $daily \Delta T_d (\text{°F}) = \frac{\sum_{n=1}^{24}(hourly indoor T_{d,n} - hourly outdoor T_{d,n})}{24}$ , where

247  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ), and  
 248  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ).

249 ■ Starting with an assumed value of zero for Tau ( $\tau_h = 0$ ), calculate the daily  
 250 Heating Thermal Demand ( $HTD_d$ ), as follows:

251  $daily HTD_d (\text{°F}) = [daily \Delta T_d - \tau_h]_+$ , where

252  $daily HTD_d$  is the daily Heating Thermal Demand (°F),

253  $d$  is the core heating day; ( $d = 001, 002, 003 \dots x$ ),

254  $\tau_h$  is the  $\Delta T$  associated with  $HTD = 0$  (zero heating run time), and

255  $[ ]_+$  indicates that the term is zero if its value would be negative.

256 ○ For the set of all core heating days in the CT interval data file, use ratio estimation to  
 257 calculate  $\alpha_h$ , the homes responsiveness to heating, which should be positive

258  $\alpha_h (minutes/\text{°F}) = RT actual heat / \sum_{d=1}^x daily HTD_d$ , where

259  $d$  is the core heating day; ( $d = 001, 002, 003 \dots x$ ), and

260 *RT actual heat* is the sum of heating run times for all core heating days in the CT  
261 interval data file.<sup>8</sup>

- 262 ○ For the set of all core heating days in the CT interval data file, optimize  $\tau_h$  that results  
263 in minimization of the sum of squares of the difference between daily run times  
264 reported by the CT, and calculated daily heating run times. Next recalculate  $\alpha_h$  (iaw  
265 the above step) and record the model's parameters ( $\tau_h$ ,  $\alpha_h$ )<sup>9</sup>:  
266  $\sum_{d=1}^x (\text{actual } RT \text{ heat}_d - \text{daily } RT \text{ heat}_d)^2$  is minimized, where  
267  $\text{daily } RT \text{ heat}_d = \alpha_h * \text{daily } HTD_d$   
268  $\text{actual } RT \text{ heat}_d$  is the total daily heating run time reported by the CT for that  
269 core heating day  
270  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ )  
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272 Note that  $\alpha_h$  characterizes the response of the home to heating and  $\tau_h$  is the  
273 difference between inside and outside temperatures when heating run time = 0

- 274 • Calculate the cumulative baseline run time for the collection of all core heating days in  
275 the CT interval data file (i.e. what would have occurred over the set of all core heating  
276 days in the reporting period, had the home been held constant at the preferred heating  
277 comfort temperature).
- 278 ○ Calculate the Heating Thermal Demand for each core heating day in the CT interval  
279 data file
- 280 ▪ Calculate the average daily indoor baseline minus outdoor temperature difference  
281 ( $\text{daily } \Delta T \text{ base heat}_d$ ) that would have occurred had the home been held  
282 constant at  $T \text{ base heat}$ :
- 283  $\text{daily } \Delta T \text{ base heat}_d (\text{°F}) = \frac{\sum_{n=1}^{24} (T \text{ base heat} - \text{hourly outdoor } T_{dn})}{24}$ , where  
284  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),  
285  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ),  
286  $T \text{ base heat}$  is the occupant's preferred comfort temperature for heating,  
287 and  
288  $\text{daily outdoor } T_d$  is the average daily outdoor temperature calculated  
289 above.
- 290 ▪ Calculate the baseline Heating Thermal Demand ( $HTD \text{ base}_d$ ) for that day  
291  $HTD \text{ base}_d (\text{°F}) = [\text{daily } \Delta T \text{ base heat}_d - \tau_h]_+$ , where  
292  $\tau_h$ , determined above, is a constant that is part of CT/home's  
293 thermal/HVAC heating run time model,  
294  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ), and  
295  $[ ]_+$  indicates that the term is zero if its value would be negative
- 296 ○ Calculate baseline run time as the sum of daily baseline run times for the set of core  
297 heating days in the CT interval data file

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<sup>8</sup> For CTs that control heat pumps, *RT actual heat* includes only compressor-based heating, i.e. emergency and auxiliary heating run times are not included

<sup>9</sup> Thermostat module calls [Scipy Function leastsq](#), which uses [Levenberg-Marquardt](#) as implemented in MINPACK: LMDIF 1980

298  $RT \text{ base heat (minutes)} = \sum_{d=1}^x \alpha_h * HTD \text{ base}_d (\text{°F})$ , where  
299  $\alpha_h$ , determined above, is a constant that is part of CT/home's thermal/HVAC  
300 heating run time model

301  $HTD \text{ base}_d$  is the baseline daily Heating Thermal Demand  
302  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ )

303 ○ CT heating savings is the percent heating run time reduction relative to the baseline,  
304 for the reporting period in the CT interval data file.

305  $HS (\% RT \text{ reduction}) = 100 * \frac{(RT \text{ base heat} - RT \text{ actual heat})}{RT \text{ base heat}}$ , where

306  $RT \text{ base heat}$  is the sum of baseline heating run times for all core heating days  
307 in the CT interval data file, as detailed for each method, and

308  $RT \text{ actual heat}$  is the sum of heating run times for all core heating days in the  
309 CT interval data file.

310 ■ Assess Cooling Savings

311 • Develop the CT/home's unique thermal/HVAC cooling run time model (daily CTD  
312 method)

313 ○ Calculate daily Cooling Thermal Demand ( $CTD_d$ ) for the each core cooling day in the  
314 CT interval data file:

315 ■ Calculate the average daily indoor temperature

316  $\text{daily indoor } T_d (\text{°F}) = \frac{\sum_{n=1}^{24} \text{hourly indoor } T_{d,n}}{24}$ , where

317  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),

318  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ), and

319  $\text{hourly indoor } T_{d,n}$  are the conditioned space temperatures reported by the  
320 CT.

321 ■ Calculate average daily outdoor temperatures for each core cooling day. Using  
322 the ZIP code included in the metadata file, look up hourly temperatures from the  
323 closest NOAA weather station, within same climate zone.

324  $\text{daily outdoor } T_d (\text{°F}) = \frac{\sum_{n=1}^{24} \text{hourly outdoor } T_{d,n}}{24}$ , where

325  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),

326  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ),

327  $\text{hourly outdoor } T_{d,n}$  are hourly outdoor temperatures.

328 ■ Calculate the average daily indoor minus outdoor temperature difference  
329 ( $\text{daily } \Delta T_d$ ) for each core cooling day

330  $\text{daily } \Delta T_d (\text{°F}) = \frac{\sum_{n=1}^{24} (\text{hourly indoor } T_{d,n} - \text{hourly outdoor } T_{d,n})}{24}$ , where

331  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ), and

332  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ).

333 ■ Starting with an assumed value of zero for Tau ( $\tau_c = 0$ ), calculate the daily  
334 Cooling Thermal Demand ( $CTD_d$ ), as follows:

335  $\text{daily } CTD_d (\text{°F}) = [\tau_c - \text{daily } \Delta T_d]_+$ , where

336 ( $\text{daily } CTD_d$  is the daily Cooling Thermal Demand (°F),

337  $d$  is the core cooling day; ( $d = 001, 002, 003 \dots x$ ),

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$\tau_c$  is the  $\Delta T$  associated with  $CTD = 0$  (zero cooling run time), and  
[ ]<sub>+</sub> indicates that the term is zero if its value would be negative.

- For the set of all core cooling days in the CT interval data file, use ratio estimation to calculate  $\alpha_c$ , the homes responsiveness to cooling, which should be positive  
 $\alpha_c(\text{minutes}/^\circ\text{F}) = RT \text{ actual cool} / \sum_{d=1}^x \text{daily } CTD_d$ , where  
 $d$  is the core cooling day; ( $d = 001, 002, 003 \dots x$ ) and  
 $RT \text{ actual cool}$  is the sum of cooling run times for all core cooling days in the CT interval data file.
- For the set of all core cooling days in the CT interval data file, optimize  $\tau_c$  that results in minimization of the sum of squares of the difference between daily run times reported by the CT, and calculated daily cooling run times. Next recalculate  $\alpha_c$  (in accordance with the above step) and record the model's parameters ( $\tau_c, \alpha_c$ )<sup>10</sup>:  
where  $\sum_{d=1}^x (\text{actual } RT \text{ cool}_d - \text{daily } RT \text{ cool}_d)^2$  is minimized, where  
 $\text{daily } RT \text{ cool}_d = \alpha_c * \text{daily } CTD_d$   
 $\text{actual } RT \text{ cool}_d$  is the total daily cooling run time reported by the CT for that core cooling day  
 $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ )

Note that  $\alpha_c$  characterizes the response of the home to cooling and  $\tau_c$  is the difference between inside and outside temperatures when cooling run time = 0

- Calculate the cumulative baseline run time for the collection of all core cooling days in the CT interval data file (i.e. what would have occurred over the set of all core cooling days in the reporting period, had the home been held constant at the preferred cooling comfort temperature).
  - Calculate the Cooling Thermal Demand for each core cooling day in the CT interval data file
    - Calculate the average daily indoor baseline minus outdoor temperature difference ( $\text{daily } \Delta T \text{ base cool}_d$ ) that would have occurred had the home been held constant at  $T \text{ base cool}$ :  
 $\text{daily } \Delta T \text{ base cool}_d (^\circ\text{F}) = \frac{\sum_{n=1}^{24} (T \text{ base cool} - \text{hourly outdoor } T_{d,n})}{24}$ , where  
 $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),  
 $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ )  
 $T \text{ base cool}$  is the occupant's preferred comfort temperature for cooling, and  
 $\text{daily outdoor } T_d$  is the average daily outdoor temperature calculated above.
    - Calculate the baseline Cooling Thermal Demand ( $CTD \text{ base}_d$ ) for that day  
 $CTD \text{ base}_d (^\circ\text{F}) = [\tau_c - \text{daily } \Delta T \text{ base cool}_d]_+$ , where  
 $\tau_c$ , determined above, is a constant that is part of CT/home's thermal/HVAC cooling run time model,

<sup>10</sup> Thermostat module calls [Scipy Function leastsq](#), which uses [Levenberg-Marquardt](#) as implemented in MINPACK: LMDIF 1980

- 378  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ), and  
 379  $[ ]_+$  indicates that the term is zero if its value would be negative
- 380 ○ Calculate baseline run time as the sum of daily baseline run times for the set of core  
 381 cooling days in the CT interval data file

382  $RT\ base\ cool\ (minutes) = \sum_{d=1}^x \alpha_c * CTD\ base_d\ (^{\circ}F)$ , where  
 383  $\alpha_c$ , determined above, is a constant that is part of CT/home's thermal/HVAC  
 384 cooling run time model  
 385  $CTD\ base_d$  is the baseline daily Cooling Thermal Demand  
 386  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ )

- 387 ○ CT cooling savings is the percent cooling run time reduction relative to the baseline,  
 388 for the reporting period in the CT interval data file.

389  $CS\ (\% RT\ reduction) = 100 * \frac{(RT\ base\ cool - RT\ actual\ cool)}{RT\ base\ cool}$ , where

390  $RT\ base\ cool$  is the sum of baseline cooling run times for all core cooling days  
 391 in the CT interval data file, as detailed for each method, and

392  $RT\ actual\ cool$  is the sum of cooling run times for all core cooling days in the  
 393 CT interval data file.

394 **METRIC 3 – Hourly HTD/CTD method**

- 395 ■ Assess Heating Savings
  - 396 • Develop the CT/home's unique thermal/HVAC heating run time model (hourly HTD  
 397 method)
    - 398 ○ Calculate daily Heating Thermal Demand ( $daily\ HTD_d$ ) for each core heating day in  
 399 the interval data file:
      - 400 ■ Calculate the average hourly indoor minus outdoor temperature difference  
 401 ( $hourly\ \Delta T_{d,n}$ ) for each core heating day:
        - 402 • Using the ZIP code included in the metadata file, determine the closest NOAA  
 403 weather station that is in the same climate zone as the CT and look up hourly  
 404 outdoor temperatures:  
 405  $hourly\ outdoor\ T_{d,n}\ (^{\circ}F)$ , where  
 406  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),  
 407  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ )
        - 408 •  $hourly\ \Delta T_{d,n}\ (^{\circ}F) = hourly\ indoor\ T_{d,n} - hourly\ outdoor\ T_{d,n}$ , where  
 409  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ), and  
 410  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ).
      - 411 ■ Starting with an assumed value of zero for Tau ( $\tau_h = 0$ ), calculate the daily  
 412 Heating Thermal Demand ( $daily\ HTD_d$ ), as follows:  
 413  $daily\ HTD_d\ (^{\circ}F) = \frac{\sum_{n=1}^{24} [hourly\ \Delta T_{d,n} - \tau_h]_+}{24}$ , where  
 414  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),  
 415  $n$  is the hour; ( $n = 01, 02, 03, \dots 24$ ),  
 416  $\tau_h$  is the  $\Delta T$  associated with  $HTD = 0$  (zero heating run time), and  
 417  $[ ]_+$  indicates that the term is zero if its value would be negative

- 418 ○ For the set of all core heating days in the CT interval data file, use ratio estimation to  
 419 calculate  $\alpha_h$ , the homes responsiveness to heating, which should be positive  
 420  $\alpha_h(\text{minutes}/\text{°F}) = \text{RT actual heat} / \sum_{d=1}^x \text{daily HTD}_d$ , where  
 421  $\text{RT actual heat}$  is the sum of heating run times for all core heating days in the CT  
 422 interval data file.
- 423 ○ For the set of all core heating days in the CT interval data file, optimize  $\tau_h$  that results  
 424 in minimization of the sum of squares of the difference between daily run times  
 425 reported by the CT, and calculated daily heating run times. Next recalculate  $\alpha_h$  (iaw  
 426 the above step) and record the model's parameters ( $\tau_h$ ,  $\alpha_h$ )<sup>11</sup>:  
 427  $\sum_{d=1}^x (\text{actual RT heat}_d - \text{daily RT heat}_d)^2$  is minimized, where  
 428  $\text{daily RT heat}_d = \alpha_h * \text{daily HTD}_d$   
 429  $\text{actual RT heat}_d$  is the total daily heating run time reported by the CT for that  
 430 core heating day  
 431  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ )  
 432  
 433 Note that  $\alpha_h$  characterizes the response of the home to heating and  $\tau_h$  is the  
 434 difference between inside and outside temperatures when heating run time = 0
- 435 ● Calculate the cumulative baseline run time for the collection of all core heating days in  
 436 the CT interval data file (i.e. what would have occurred over the set of all core heating  
 437 days in the reporting period, had the home been held constant at the preferred heating  
 438 comfort temperature).
- 439 ○ Calculate the baseline daily Heating Thermal Demand ( $\text{daily HTD base}_d$ ) for each  
 440 core heating day in the CT interval data file
- 441 ■ Calculate the difference between the occupant's preferred comfort temperature  
 442 for heating and the average outside temperature for each hour of each core  
 443 heating day ( $\text{hourly } \Delta T \text{ base heat}_{d,n}$ ):  
 444  $\text{hourly } \Delta T \text{ base heat}_{d,n} (\text{°F}) = T \text{ base heat} - \text{hourly outdoor } T_{d,n}$ , where  
 445  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),  
 446  $n$  is the hour ( $n = 01, 02, 03, \dots 24$ ),  
 447  $T \text{ base heat}$  is the occupant's preferred comfort temperature for heating,  
 448 and  
 449  $\text{hourly outdoor } T_{d,n}$  is the average outdoor temperature for that hour  
 450 reported by the nearest NOAA weather station in the same climate  
 451 zone as the CT.
- 452 ■ Calculate baseline daily Heating Thermal Demand ( $\text{daily HTD base}_d$ )  
 453  $\text{daily HTD base}_d = \frac{\sum_{n=1}^{24} [\text{hourly } \Delta T \text{ base heat}_{d,n} - \tau_h]_+}{24}$ , where  
 454  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),  
 455  $n$  is the hour ( $n = 01, 02, 03, \dots 24$ ),  
 456  $\tau_h$ , determined above, is a constant that is part of CT/home's  
 457 thermal/HVAC heating run time model, and

<sup>11</sup> Thermostat module calls [Scipy Function leastsq](#), which uses [Levenberg-Marquardt](#) as implemented in MINPACK: LMDIF 1980

458

[ ]<sub>+</sub> indicates that the term is zero if its value would be negative.

459

- Calculate baseline run time as the sum of daily baseline run times for the set of core heating days in the CT interval data file

460

$$RT \text{ base heat (minutes)} = \sum_{d=1}^x \alpha_h * \text{daily HTD base}_d (\text{°F}), \text{ where}$$

461

$\alpha_h$ , determined above, is a constant that is part of CT/home's thermal/HVAC

462

heating run time model

463

*daily HTD base<sub>d</sub>* is the baseline daily Heating Thermal Demand

464

*d* is the core heating day (*d* = 001, 002, 003 ... *x*)

465

466

- CT heating savings is the percent heating run time reduction, for the reporting period in the CT input file.

467

$$HS (\% RT \text{ reduction}) = 100 * \frac{(RT \text{ base heat} - RT \text{ actual heat})}{RT \text{ base heat}}, \text{ where}$$

468

*RT base heat* is the sum of baseline heating run times for all core heating days in the CT interval data file, and

469

470

*RT actual heat* is the sum of heating run times for all core heating days in the CT interval data file.

471

472

473

- Assess Cooling Savings

474

- Develop the CT/home's unique thermal/HVAC cooling run time model (hourly CTD method)

475

476

- Calculate daily Cooling Thermal Demand (*daily CTD<sub>d</sub>*) for each core cooling day in the interval data file:

477

478

- Calculate the average hourly indoor minus outdoor temperature difference (*hourly ΔT<sub>d,n</sub>*) for each core heating day:

479

- Using the ZIP code included in the metadata file, determine the closest NOAA weather station that is in the same climate zone as the CT and look up hourly outdoor temperatures:

480

481

482

*hourly outdoor T<sub>d,n</sub>*, where

483

*d* is the core cooling day (*d* = 001, 002, 003 ... *x*),

484

*n* is the hour; (*n* = 01, 02, 03, ... 24)

485

- $\text{hourly } \Delta T_n (\text{°F}) = \text{hourly indoor } T_{d,n} - \text{hourly outdoor } T_{d,n}$ , where

486

487

*d* is the core heating day (*d* = 001, 002, 003 ... *x*), and

488

*n* is the hour; (*n* = 01, 02, 03, ... 24)

489

- Starting with an assumed value of zero for Tau ( $\tau_c = 0$ ), calculate the daily Cooling Thermal Demand (*daily CTD<sub>d</sub>*), as follows:

490

$$\text{daily CTD}_d (\text{°F}) = \frac{\sum_{n=1}^{24} [\tau_c - \text{hourly } \Delta T_{d,n}]_+}{24}, \text{ where}$$

491

*d* is the core cooling day (*d* = 001, 002, 003 ... *x*),

492

*n* is the hour; (*n* = 01, 02, 03, ... 24)

493

$\tau_c$  is the  $\Delta T$  associated with  $CTD = 0$  (zero cooling run time), and

494

[ ]<sub>+</sub> indicates that the term is zero if its value would be negative

495

- For the set of all core cooling days in the CT interval data file, use ratio estimation to calculate  $\alpha_c$ , the homes responsiveness to cooling, which should be positive

496

497

- 498  $\alpha_c(\text{minutes}/^\circ\text{F}) = RT \text{ actual cool} / \sum_{d=1}^x \text{daily CTD}_d$ , where  
 499  $RT \text{ actual cool}$  is the sum of cooling run times for all core cooling days in the CT  
 500 interval data file.
- 501 ○ For the set of all core cooling days in the CT interval data file, optimize  $\tau_c$  that results  
 502 in minimization of the sum of squares of the difference between daily run times  
 503 reported by the CT, and calculated daily cooling run times. Next recalculate  $\alpha_c$  (iaw  
 504 the above step) and record the model's parameters ( $\tau_c$ ,  $\alpha_c$ )<sup>12</sup>:  
 505  $\sum_{d=1}^x (\text{actual RT cool}_d - \text{daily RT cool}_d)^2$  is minimized, where  
 506  $\text{daily RT cool}_d = \alpha_c * \text{daily CTD}_d$   
 507  $\text{actual RT cool}_d$  is the total daily cooling run time reported by the CT for that  
 508 core cooling day  
 509  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ )  
 510  
 511 Note that  $\alpha_c$  characterizes the response of the home to cooling and  $\tau_c$  is the  
 512 difference between inside and outside temperatures when cooling run time = 0
- 513 • Calculate the cumulative baseline run time for the collection of all core cooling days in  
 514 the CT interval data file (i.e. what would have occurred over the set of all core cooling  
 515 days in the reporting period, had the home been held constant at the preferred cooling  
 516 comfort temperature).
- 517 ○ Calculate the baseline daily Cooling Thermal Demand ( $\text{daily CTD base}_d$ ) for each  
 518 core cooling day in the CT interval data file
- 519 ■ Calculate the difference between the occupant's preferred comfort temperature  
 520 for cooling and the average outside temperature for each hour of each core  
 521 cooling day ( $\text{hourly } \Delta T \text{ base cool}_{d,n}$ ):  
 522  $\text{hourly } \Delta T \text{ base}_n (^\circ\text{F}) = T \text{ base cool} - \text{hourly outdoor } T_n$ , where  
 523  $d$  is the core heating day ( $d = 001, 002, 003 \dots x$ ),  
 524  $n$  is the hour ( $n = 01, 02, 03, \dots 24$ ),  
 525  $T \text{ base cool}$  is the occupant's preferred comfort temperature for cooling,  
 526 and  
 527  $\text{hourly outdoor } T_n$  is the average outdoor temperature for that  
 528 hour reported by the nearest NOAA weather station in the same climate  
 529 zone as the CT.
- 530 ■ Calculate baseline daily Cooling Thermal Demand ( $\text{daily CTD base}_d$ )  
 531  $\text{daily CTD base}_d = \frac{\sum_{n=1}^{24} [\tau_c - \text{hourly } \Delta T \text{ base cool}_{d,n}]_+}{24}$ , where  
 532  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ ),  
 533  $n$  is the hour ( $n = 01, 02, 03, \dots 24$ ),  
 534  $\tau_c$ , determined above, is a constant that is part of CT/home's  
 535 thermal/HVAC cooling run time model, and  
 536  $[ ]_+$  indicates that the term is zero if its value would be negative.
- 537 ○ Calculate baseline run time as the sum of daily baseline run times for the set of core

<sup>12</sup> Thermostat module calls [Scipy Function leastsq](#), which uses [Levenberg-Marquardt](#) as implemented in MINPACK: LMDIF 1980

538 cooling days in the CT interval data file  
 539  $RT \text{ base heat (minutes)} = \sum_{d=1}^x \alpha_c * \text{daily CTD base}_d (\text{°F})$ , where  
 540  $\alpha_c$ , determined above, is a constant that is part of CT/home's thermal/HVAC  
 541 cooling run time model  
 542  $\text{daily CTD base}_d$  is the baseline daily Cooling Thermal Demand  
 543  $d$  is the core cooling day ( $d = 001, 002, 003 \dots x$ )

544 ○ CT cooling savings is the percent cooling run time reduction for the reporting period  
 545 in the CT input file.

546  $CS(\% RT \text{ reduction}) = 100 * \frac{(RT \text{ base cool} - RT \text{ actual cool})}{RT \text{ base cool}}$ , where

547  $RT \text{ base cool}$  is the sum of baseline cooling run times for all core cooling days  
 548 in the CT interval data file, as detailed for each method, and

549  $RT \text{ actual cool}$  is the sum of cooling run times for all core cooling days in the  
 550 CT interval data file.

551 ○ Resistance Heating Utilization (RU) – for heat pump systems only, calculate RU in twelve  
 552 outdoor temperature bins ( $0 \leq T < 5^\circ\text{F}$ ,  $5 \leq T < 10^\circ\text{F}$ , ...,  $55 \leq T \leq 60^\circ\text{F}$ ):

553 
$$RU = \frac{(t_{emerg} + t_{aux})}{(t_{emerg} + t_{comp})}$$

554 where,

555  $t_{emerg}$  = total emergency resistance heating run time in the interval data file,  $t_{emerg}$  is  
 556 in lieu of compressor operation, e.g. use of electric resistance strip-heat under  
 557 fault conditions or when the outside temperature is very low,

558  $t_{aux}$  = total annual auxiliary resistance heating run time in the interval data file,  $t_{aux}$  is  
 559 supplemental to compressor operation, e.g. use of electric resistance strip-heat  
 560 to increase heating capacity, and

561  $t_{comp}$  = total compressor heating run time in the interval data file. A proportion of  
 562  $t_{comp}$  may also include auxiliary resistance heating.

563 **ASSESSMENT OF AGGREGATE NATIONAL AND REGIONAL SAVINGS**

564 After the thermostat module generate an output file for the sample set, the statistics module  
 565 leverages these files to assess average savings, expressed as percent run time reduction.

566 ○ Assess average heating savings, cooling savings, and RU for each of the five EIA climate regions,  
 567 for example

568  $CT \text{ Savings}_{\text{heat Mixed-Humid}} = \sum CT_i \text{ Savings}_{\text{heat Mixed-Humid}} / n$ , where

569  $i = 1$  thru  $n$ , and

570  $n$  = the number of CTs in the EIA Mixed-Humid climate region (min. 250)

571 ○ Nationally – from regional savings, national savings are calculated as weighted averages for  
 572 heating and cooling. Weighting is by the proportion of national energy used in each of the five  
 573 EIA climate regions, as follows:

574

Heating	
Climate Region	%BTU vs National
Very Cold/Cold	54.9%
Mixed-Humid	31.2%
Mixed-Dry/Hot-Dry	5.4%
Hot-Humid	4.9%
Marine	3.6%

575

Cooling	
Climate Region	%BTU vs National
Very Cold/Cold	9.6%
Mixed-Humid	33.8%
Mixed-Dry/Hot-Dry	14.3%
Hot-Humid	41.8%
Marine	0.5%

576

577 ○ All other National outputs, including National RHU, are calculated as an unweighted average  
578 over all CTs in the sample set.

579 • **SOFTWARE DEVELOPMENT ROADMAP**

580 **Beta** – EPA is developing a Beta version of the software which will be used for a data call to inform  
581 the Draft 3 Version 1.0 ENERGY STAR Connected Thermostat specification. Some or all of the  
582 following features will be included:

583 1. The baseline heating comfort temperature will be the 90<sup>th</sup> percentile of the indoor  
584 temperature history reported by the CT on core heating days.

585 2. Similarly, the baseline cooling comfort temperature will be the 10<sup>th</sup> percentile of the  
586 indoor temperature history reported by the CT on core cooling days.

587 EPA believes that  $T_{\text{indoor}}$  is more indicative of comfort preferences and the change from using  
588  $T_{\text{setpoint}}$  will further establish consistency with  $T_{\text{indoor}}$  being used to both assess comfort  
589 preferences and to develop home's thermal/HVAC run time models. This change is expected  
590 to improve the savings assessment as the majority of HVAC load is driven by the difference  
591 between  $T_{\text{indoor}}$  and  $T_{\text{outdoor}}$  rather than between  $T_{\text{setpoint}}$  and  $T_{\text{outdoor}}$ .

592 3. CT savings will continue to be assessed using the 3 candidate methods described in this  
593 document.

594 4. CT savings will be assessed against two baselines, as follows<sup>13</sup>:

---

<sup>13</sup> This feature will be implemented if it can be accomplished without undue schedule impact

595 a. Baseline run times calculated from 90<sup>th</sup> (10<sup>th</sup>) percentiles of heating (cooling) indoor  
596 temperature history.

597 b. Baseline run times calculated from regional average comfort temperatures<sup>14</sup>.

598

EIA Climate Zone	Very Cold/Cold	Mixed Humid	Mixed Dry/Hot Dry	Hot Humid	Marine	
599						
600						
601	Baseline heating temp (°F)	68	69	69	70	67
602	Baseline cooling temp (°F)	73	73	75	75	–
603						

604  
605 Note: The 2009 RECS does not include statistically significant data to inform the  
606 average baseline cooling temperature for the Marine climate zone.

607 Inclusion of this additional baselining method is informational. EPA intends to launch  
608 the version 1.0 ENERGY STAR CT program that assesses savings against baseline run  
609 times calculated from 90<sup>th</sup> (10<sup>th</sup>) percentiles of heating (cooling) indoor temperature  
610 history.

611 5. Mean regional and weighted average national savings will be assessed both with and  
612 without data filtering. Data filtering will be used to exclude CTs from assessing mean  
613 savings. Savings data will be separately output with:

614 a. No filtering,

615 b. Exclusion of CTs where Tau < 0°F or >25°F,

616 c. In addition to filtering on Tau, CTs will also be excluded where CV(RSME) >0.6; that  
617 is, the error associated with the thermal / HVAC run time model exceeds 0.6

618 d. In addition to filtering on Tau and CV(RSME), CTs will also be excluded where %  
619 savings is:

620 i. in the top or bottom 1% of all CTs in that EIA climate zone,

621 ii. in the top or bottom 2% of all CTs in that EIA climate zone, and

622 iii. in the top or bottom 5% of all CTs in that EIA climate zone

623 EPA collaboration with CT stakeholders has identified the need to filter out CTs where  
624 the thermal / HVAC run time models are poor. EPA reserves the right to adjust the  
625 above filtering parameters based on additional feedback from CT stakeholders.

626 6. Additional outputs:

627 a. Percentage of CTs removed by each filter (by region and nationally)

628 b. Output lower bound of 95% confidence interval for each % RT reduction output

---

<sup>14</sup> Average comfort temperatures for heating and cooling were developed from the 2009 EIA Residential Energy Consumption Survey (RECS)

629 **V1.0** – EPA is planning a version 1.0 release in the November 2016 timeframe. Version 1.0 will  
630 include a single CT savings methodology and is intended to be used by CT Service Providers for  
631 qualification of Connected Thermostats as ENERGY STAR.

632 **V1.x** – EPA may develop version 1.x releases. “Dot” releases after launch of the ENERGY STAR CT  
633 program will not impact assessment of savings for qualification as ENERGY STAR, but may include  
634 minor user experience bug fixes, enhancements or additional features to inform future  
635 development of CT field energy savings assessment methods.

636 • **PROGRAM IMPLEMENTATION**

637 As EPA currently envisions the program implementation, ENERGY STAR CT partners will use the  
638 software to assess savings from their CT products for initial product certification, for periodic  
639 reporting and optionally for internal use.

640 Submission of the software output file will be required for both initial product certification and  
641 periodic reporting. Initial product certification will be through a Certification Body (CB) while  
642 periodic reporting will be with EPA.

643 Partners must strictly adhere to input data requirement for both initial ENERGY STAR certification  
644 and for ongoing annual reporting. These requirements will be included in the ENERGY STAR CT  
645 Method to Demonstrate Savings and in the software documentation. At this time, EPA anticipates  
646 input data requirements will include:

647 **INITIAL PRODUCT CERTIFICATION**

- 648 1. Submitted output file uses  $\geq 150$  CTs in each of the five EIA climate regions,  
649 (or more if needed to provide sufficient certainty of the statistical results)
- 650 2. Same start and stop dates for each CT interval data file
- 651 3.  $\geq 6$  months duration between start and stop dates

652 **PERIODIC REPORTING**

- 653 1. Submitted output file uses  $\geq 150$  CTs in each of the five EIA climate regions,  
654 (or more if needed to provide sufficient certainty of the statistical results)
- 655 2. Same start and stop dates for each CT interval data file, as specified in the Partner  
656 Requirements
- 657 3. 12 month duration between start and stop dates

658