Energy Star Connected Thermostat (CT) Data Request
Staged & Modulating/Variable-Capacity HVAC

Objective of this Data Request:

EPA and our CT stakeholders are developing methods to assess savings for CTs controlling staged and modulating/variable-capacity HVAC. During the most recent CT variable Capacity Equipment Metrics Meeting held on July 10, 2017 stakeholders agreed to pursue one particular idea for including these installations in the CT field savings metrics.

The approach relies on calculating *equivalent full-capacity run times* (ERT), that is, what run times would have been if only full-capacity was used. Once ERT is calculated; resulting interval data files may be used to assess field savings using the open-source ENERGY STAR CT field savings software. We ask that interested stakeholders, with relevant CT interval data, help us to assess how well this approach might work.

The first step is to examine the relationship between the equivalent full capacity run time and the indoor minus outdoor temperature difference. Those stakeholders who have the ENERGY STAR CT field savings software installed in their data environment can use it to examine the question in Option 1 (ENERGY STAR CT field savings software), and stakeholders that do not can also contribute significantly by evaluating their data in Option 2 (Home by home plots/analysis). Stakeholders are encouraged to participate in any part of the exercise that they are able to.

Summary:

After performing calculations *(see page 2)* for converting daily run-time data to daily equivalent full-capacity run time (daily ERT):

1. Follow Option 1 (ENERGY STAR CT field savings software) and/or Option 2 (Home by home plots/analysis)
    a. Option 1 – use the ENERGY STAR CT field savings software to assess average heating and cooling savings for sets of homes with CTs controlling staged or modulating/variable-capacity HVAC.
    b. Option 2 – alternately, or in addition to Option 1:
        i. Develop separate heating and cooling scatter plots of ERT vs ΔT for a few homes using interval data for a 1-year period.
        ii. Perform a linear regression, and calculate CVRMSE or other goodness-of-fit statistics for each home.
        iii. Calculate the average CVRME or other goodness-of-fit statistic for the set of homes analyzed.
2. Report back on whatever you were able to do
    a. Option 1 – provide the summary statistics output file
    b. Option 2 (or in addition to Option 1)
        i. Provide sample scatter plots of ERT vs ΔT for individual homes. If you were able to do linear fits, also include the line of best fit as well as CVRSME or other goodness-of-fit statistics on each plot.
        ii. Provide the average CVRME or other goodness-of-fit statistic for the set of homes.
    c. For both options 1 & 2, also provide:

i. The ratio of average heating ERT to total (unweighted) heating run time over a 1 year period (Option 1 – average for each data set or Option 2 – average for each home)
ii. The ratio of average cooling ERT to total (unweighted) cooling run time over a 1 year period (Option 1 – average for each data set or Option 2 – average for each home)

Details:

Option 1 (ENERGY STAR CT field savings software) – Analyze savings of homes with CTs controlling staged or modulating/variable-capacity HVAC using the ENERGY STAR CT field savings software.

a. Install and configure the most recent V1.1.1 release of the ENERGY STAR CT Field Savings Software at:
   - Documentation: http://thermostat.readthedocs.org/en/latest/
   - Source code: https://github.com/impactlab/thermostat

b. Assemble one or more data sets (based on data availability) consisting of 50 or more homes/CTs in the Mixed-Humid and the combined Cold/Very Cold climate zones to be run through the ENERGY STAR CT field savings software. More specifically:
   i. *Data Set 1:* 12 months of interval data for 50 or more homes in the Cold/Very Cold climate zone with CTs controlling two-stage furnaces and boilers. *(Goal is to examine results for heating.)*
   ii. *Data Set 2:* 12 months of interval data for 50 or more homes in the Cold/Very Cold climate zone with CTs controlling modulating/variable-capacity furnaces and boilers. *(Goal is to examine results for heating.)*
   iii. *Data Set 3:* 12 months of interval data for 50 or more homes in the Mixed-Humid climate zone with CTs controlling either two-stage central AC or two-stage heat pumps. *(Goal is to examine results for both heating and cooling.)*
   iv. *Data Set 4:* 12 months of interval data for 50 or more homes in the Mixed-Humid climate zone with CTs controlling modulating/variable-capacity heat pumps or central AC. *(Goal is to examine results for both heating and cooling.)*

c. Assemble Thermostat Summary Metadata and Thermostat Interval Data files using the requisite format described in the software documentation. As detailed below, enter calculated *daily ERT* values in the "cool_runtime" and "heat_runtime" fields:
   i. 2-stage heat pumps & central air conditioners:
      1. *Daily ERT-heating = high-speed daily heating run time + (0.72 * low-speed daily heating run time)*[1]
      2. *Daily ERT-cooling = high-speed daily cooling run time + (0.72 * low-speed daily cooling run time)*[1]
   ii. 2-stage non-heat pumps (furnaces & boilers)
      1. *Daily ERT-heating = high-speed daily heating run time + (0.65 * low-speed daily heating run time)*[1]

[1] Stakeholder on the July 10, 2017 ENERGY STAR CT metrics call agreed that typical relative capacities for low stage could be used for two stage equipment. Based on stakeholder comments and on this NREL report [add real reference], we will use 72% for CAC and ASHP, and 65% for furnaces for this data call.

2. *Daily ERT-cooling = high-speed daily cooling run time + (0.65 * low-speed daily cooling run time)*[1]

iii. Modulating/variable-capacity heat pumps, central AC, furnaces, and boilers:

$$Daily\ ERT\ heating = \sum_{t=1}^{x} (proportion\ of\ full\ capacity_t * interval\ heating\ run\ time_t)$$

$$Daily\ ERT\ cooling = \sum_{t=1}^{x} (proportion\ of\ full\ capacity_t * interval\ cooling\ run\ time_t)$$

where t is the set of CT reporting intervals for a calendar day[2]

Enter the following as the "equipment_type" in the Thermostat Summary Metadata file:

i. CTs controlling two-stage furnaces and boilers – use equipment_type = 3

ii. CTs controlling either two-stage central AC or two-stage heat pumps – use equipment_type = 1

iii. CTs controlling modulating/variable-capacity heat pumps – use equipment_type = 1

d. Process each data set ***individually*** using the latest ENERGY STAR CT field savings software.

e. Deliver to Doug Frazee, ICF dfrazee@icfi.com the following:

i. Summary statistics output file for ***each data set*** that adds appropriate identifying metadata. For example "Data Set 1 (Cold/Very Cold – two-stage furnaces and boilers)".

ii. The ratio of average heating ERT to total (unweighted) heating run time for each data set over the 1-year period.

iii. The ratio of average cooling ERT to total (unweighted) cooling run time for each data set over the 1-year period.

Option 2 (Home by home plots/analysis) – For a few representative homes with a year of CT data in:

- Cold/Very Cold climate zone with CTs controlling two-stage furnaces and boilers
- Cold/Very Cold climate zone with CTs controlling modulating/variable-capacity furnaces and boilers
- Mixed-Humid climate zone with CTs controlling either two-stage central AC or two-stage heat pumps
- Mixed-Humid climate zone with CTs controlling modulating/variable-capacity heat pumps or central AC

a. Calculate *Daily ERT-heating and Daily ERT-cooling* as described prior *(see page 2)*.

[2] Note that the length of interval *t* will depend on how data is stored by each CT service provider. For the purposes of this data call, EPA asks that stakeholders use a method that will fairly represent the concept of equivalent full capacity run time. If this method is ultimately implemented, it may make sense for controllers to accumulate equivalent full capacity run time directly, limiting the data that needs to be stored.

b. Develop scatter plots of ERT vs ΔT for each home using interval data from the 1 year period. Plot the line of best fit (linear regression), and record average CVRMSE or other goodness-of-fit statistics on each plot.

c. Calculate the average CVRME or other goodness-of-fit statistic over the set of homes you examined.

d. Deliver to Doug Frazee, ICF dfrazee@icfi.com the following:

   i. Scatter plots of ERT vs ΔT for these homes, that identify the HVAC type, include the line of best fit and CVRSME.

   ii. Average CVRME or other goodness-of-fit statistic for the set of homes analyzed (for each HVAC type)

   iii. The ratio of average cooling ERT to total (unweighted) cooling run time for each home over the 1year period

   iv. The ratio of average cooling ERT to total (unweighted) cooling run time for the set of homes you examined, for each HVAC type, over the 1 year period

   v. The ratio of average heating ERT to total (unweighted) heating run time for each home over the 1 year period

   vi. The ratio of average heat ERT to total (unweighted) heating run time for the set of homes you examined, for each HVAC type, over the 1year period

Data Confidentiality

EPA respects confidentiality of submitted data. Submitted summary statistics files and associated data include only aggregate savings, and do not include any individual CT data or any personally identifiable information. All submitted data will be anonymized by ICF prior to sharing with EPA and with CT stakeholders, e.g. identified as Data Set 1, Data Set 2, Data Set 3, and Data Set 4, etc. without product names or nomenclature.