ENERGY STAR Connected Thermostats

Communicating Controls for Variable Capacity HVAC

Workshop, Part 2

April 6, 2020

Webinar Audio Access

- USE YOUR TELEPHONE:

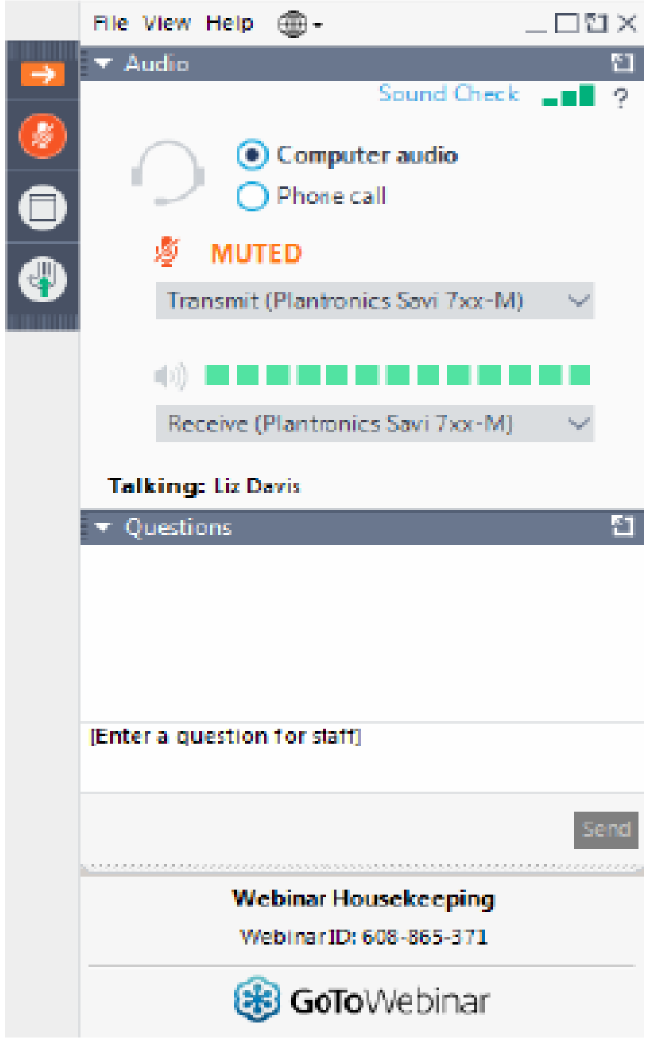
  Call-in Number: (877) 423-6338

  Passcode: 436598#

- If you are having trouble with audio connection, let us know in the chat or question boxes

Webinar Participation

- Please mute yourself when you are not speaking (use local mute or dial *6)
- Feel free to ask questions at any time by typing in the chat box or wait for the Q&A session
- Is anyone on the phone having trouble connecting to the webinar?



● Computer audio
○ Phone call

MUTED

Transmit (Plantronics Savi 7xx-M)

Receive (Plantronics Savi 7xx-M)

Talking: Liz Davis

[Enter a question for staff]

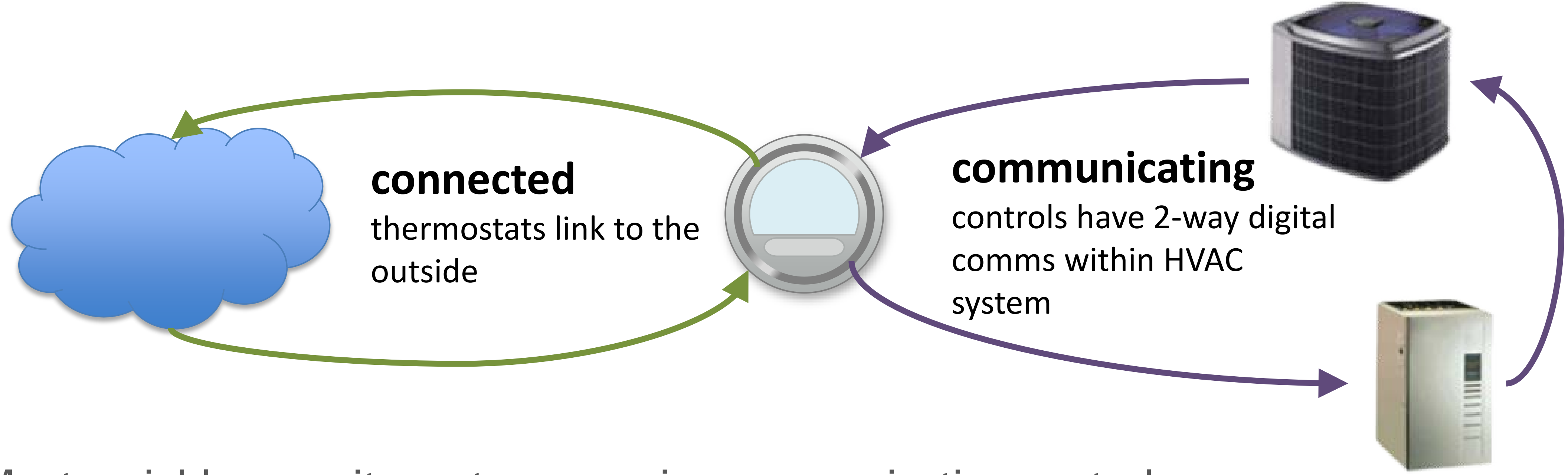
Webinar Housekeeping

Webinar ID: 608-865-371

Agenda

- Review of 4/3 workshop
- (note CVP as proposed for CAC/HP not applicable to controllers)
- What other spec criteria need adjustment, e.g. standby power?
  - Device criteria
  - Product (Control + Device)
- Discussion: How a program might be designed that would apply to whole systems, not just controls, or how do we define a “control” for this purpose?
- Discussion: For a few savings mechanisms that feel worthwhile and possible, metric ideas.
  - Note: in the flow of discussion, ended up not presenting many of these slides
- Wrap up, Next Steps: Looking Ahead

Clarification of Terms: Connected vs. Communicating



connected
thermostats link to the outside

communicating
controls have 2-way digital comms within HVAC system

- Most variable capacity systems require communicating controls
- Communicating controls can also be used to control any HVAC, and have some advantages for such
- Ductless mini-splits often have a remote which is only a user interface; all other control functions are in the HVAC, so "communication" is not applicable.

Review of background: The Current Connected Thermostat Specification, since 2016

- Certification relies on three types of criteria
  - Device criteria, applying to the physical hardware, including standby power and temperature accuracy
  - Product criteria (device and service), including scheduling, energy feedback, etc.
- Savings metric is % run time reduction compared to run time for constant comfort temperature for that particular home
  - The choice of metric and of baseline means that only set up and set back are rewarded, compared to keeping the house at a comfort temp all the time
  - Overestimates and underestimates savings, but is good enough
- Several assumptions in the EPA method do not apply to variable capacity systems; field data analysis only includes installations controlling fixed capacity systems
- From beginning, have advised using proprietary, non-ENERGY STAR certified controls for variable capacity HVAC; now trying to do better

Discussion review: Meaningfully different system types

- Discussed how communicating controls installed with different types of systems may need to be treated differently
  - Single and dual capacity systems
  - Modulating fossil fuel fired heating equipment (warm air furnaces, possibly boilers if we can ignore zoning)
  - Variable capacity centrally ducted compressor-based heating and cooling (CAC, air source heat pumps, GHP) and 1:1 mini-splits with separate controllers
  - 1:1 mini-splits with controls inherent to device (out of scope?)
- Many zoned systems: multi-splits, zoned ducted systems, possibly baseboard resistive or hydronic heating, etc. Please contribute ideas about how to capture savings
- Idea of dual fuel installations/controllers meant to address came up – who wants to work on this?

Discussion review: Data available from controllers

- Temperatures: Indoor, set points, often local outdoor
- Modes and run times: fan, heating, cooling, backup or aux, defrost, etc.
- Zip code (allows outdoor weather lookup)
- Home/away/asleep & if applicable occupancy sensor feedback
- Types of controlled equipment (not from wiring, for a communicating control – how does this work if some controlled equipment is not communicating?)
- Compressor speed (AC and HP) or input rate (furnace or boiler)
- Lockout temperatures
- Fault codes
- Fan speed/airflow
- Indoor humidity
- Estimated power draw
- Information about zones for zones systems – at least temperature and mode

Discussion 1: Changes to Other Spec Criteria

- Device criteria:
    - Standby power
    - Static temperature accuracy
    - Work as “dumb thermostat” when disconnected
- Product (control hardware + software)
    - Provide mechanism for scheduling
    - Energy feedback to consumer
    - Data collection as needed for field savings evaluation
    - DR capability (AHRI 1380 for communicating controls?)
- Discussion: which of these likely to be problematic?
- Discussion: anything else that we should add for communicating controllers?

Discussion 2: Outlines of a Program for Whole Systems

- Separate spec, called “High Efficiency Connected HVAC” or something
- The recognized product would be a combination of heating and cooling equipment, control algorithms which might include cloud services, and optionally controls hardware.
  - Would this only include compressor driven HVAC?
  - If so, what about the main blower fan for ducted systems?
- Easy to think of clear equipment and controls criteria
  - Heating and cooling efficiency (SEER, EER, HSPF, COP, AFUE, as applicable), or rely on ENERGY STAR certification
  - Fan efficiency (FER) or fan prescriptive criteria?
  - Standby power for wired controls
  - Ability to set schedule, etc., similar to CT specification
- Field data showing performance as per savings mechanisms as discussed

Harder Question for Whole Systems: Product Families

- For several connected product types, we’ve recently set up a structure where the product finder can indicate, “This product has connected functionality when used with the following controllers”, however there is no field data involved in that
- The listings would be complicated because of the number of possible combinations
- If products can be grouped together, it would mitigate this problem.
- One level of grouping: What would be covered by a single certification?
- Second level of grouping: Would several certified products be grouped together into one population for field data analysis?
  - We do this for connected thermostats: all products using similar algorithms may be analyzed as a single population
  - Can work if the savings method applies to many systems, and the metric can be averaged between homes
- Discussion (I need to figure out how to structure this)

Complicated discussion – keeping on track

- This will be a complicated discussion, because we are trying to solve a hard problem. Some principles that we've found useful in the technical discussions of the current specification, to avoid rabbit holes:
  - Do not let the perfect be the enemy of the good: we are looking for a solution that is good enough, not a perfect solution. To that end…
  - Does this introduce a bias between vendors?
  - What are the FIRST ORDER effects? If we are considering the need to capture an effect, first ask how substantial the energy savings/cost is compared to other effects.
- We will maintain a parking/charging lot, and there will be an opportunity to comment broadly.

Discussion 3: Savings mechanisms to focus on

- Four that were clearly ahead of the others:
  - **Keep HVAC in lower capacity states when possible (19 votes)**
  - Set back and set up when possible (13 votes)
  - Avoid short cycling (12 votes)
  - Fan control (12 votes)
- We will be talking about each of these in more detail
- After today, the EPA team will work to develop specific metrics for at least one, maybe several of these, and reach out to vendors to talk about details
- First, does anyone have hard data about relative energy savings available from these?
- Second, is there anyone who feels they have a strong case for one not on this list (keeping in mind that there were several variations of each [I need to list them so people have them in front of them])

Evaluating which savings mechanisms to focus on

- When thinking about this, here are some ideas about what make a particular mechanism a good choice:
  - Affected by control strategies and algorithms
  - Able to be examined with either prescriptive requirements (better to avoid) or with data as we’ve talked about it
  - Can identify a reasonable baseline to compare data to
  - Some products on the market are significantly better at it than others
  - Actual savings are significant in each home and/or apply to every home so that the total savings are significant
- Do we need to consider different mechanisms for different equipment types?

Reminder: What we need in a metric

- “Good enough” means
  - Representative of HVAC energy use
  - Demonstrates acceptable performance; able to ID a level considered “good”
  - Applicable to the majority of installations using the product
  - Fairly compares one vendor to another
- Would be nice but do not need
  - Absolute measurement of energy savings
  - Can distinguish excellent performance
- What do we have to start with?
  - Data that can be known about the operation of the system, to sufficient precision to differentiate
  - Need not necessarily be stored in the cloud

Keep HVAC in lower capacity state (and variations)

- Quick poll: is keeping HVAC in lower capacity state and avoiding short cycling two sides of the same coin?
- Most variations mentioned Friday for keeping HVAC in low capacity state also related to avoiding short cycling:
  - Average capacity fraction (or similar) as described in the pre-work
  - Temperature (or temperature difference/load?) at which starts running uninterrupted for long periods of time (not including defrost)
  - When cycling to maintain temp, unit comes on at a lower capacity (is this a specific solution, or an indication of good algorithms?)
  - Is there a way to detect “short cycling” in a data trace?
- [ACF explanation if needed and] feedback on average capacity fraction
- Other proposals

Metrics for controllers of staged and variable capacity systems (did not end up presenting)

- Discussion from previous meetings:
  - Depending on the type of equipment, there is a small or medium sized efficiency advantage from using a lower capacity for a longer time
  - Also comfort and equipment longevity advantages
- Metrics to use field data to distinguish units that do a better job
- As with RHU, start with a basic calculation, and then look for where the results are meaningful
- Straw man metric, feel free to suggest something better: Average Capacity Fraction (ACF)

$$ACF = \frac{ERT}{RT} = \frac{\sum_{time} run\ time * relative\ capacity}{\sum_{time} run\ time}$$

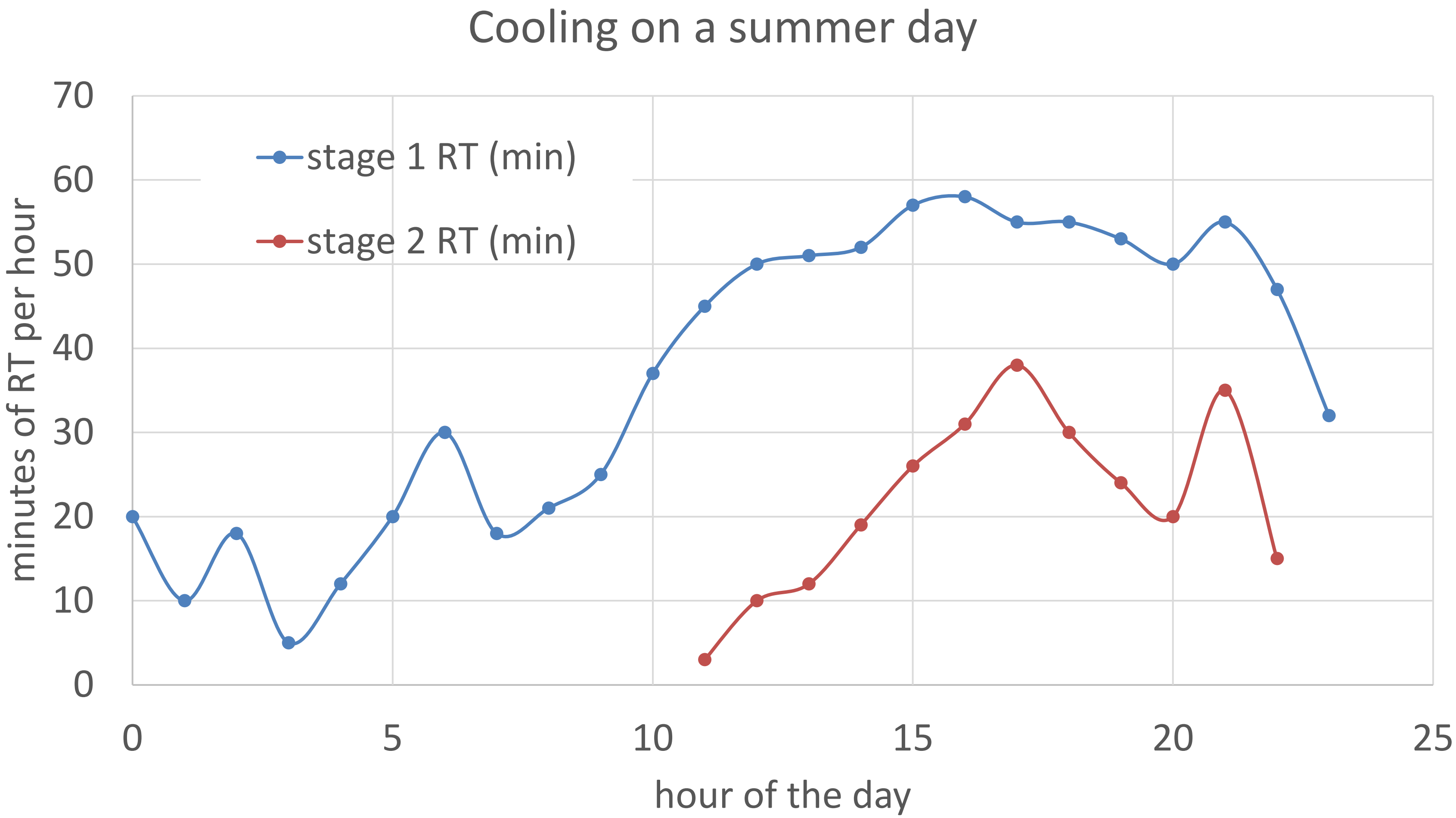
Average Capacity Fraction (ACF) for 2 stage systems (did not end up presenting)

- Simple calculation, given run time minutes of each stage in each hour, and the relative capacity of the lower stage (ρ)

$$ACF = \frac{ERT}{RT} = \frac{\sum_{hours}(stage\ 1\ RT - stage\ 2\ RT) * \rho + \sum_{hours} stage\ 2\ RT}{\sum_{hours} stage\ 1\ RT}$$

- This would be a second use of ERT, in addition to use to estimate savings for installations with staged capacity systems, at least fossil fuel powered
- As per previous discussion, ERT equation depends on meaning of stage 1 and stage 2 run time

Average Capacity Fraction (ACF) for 2 stage systems (did not end up presenting)



These data were just made up to play with.

With $\rho = 0.72$, ACF for this day is 0.80.

Average Capacity Fraction (ACF) for modulation/variable systems (did not end up presenting)

- Application of equivalent full load run time gets more complicated to apply
- In theory,

$$ERT = \int_{time} \rho(time)\, dtime$$

- Obviously not practical to apply: Test method would define minimum sampling frequency, for instance 1 minute
- Each sample would be RT (yes or no, 1 or 0) and capacity, giving ERT in minutes as

$$hourly\ ERT = \sum_{minutes} RT_{minute} * \rho_{minute}$$

$$ACF = {\sum_{hours} ERT}\Big/{\sum_{hours} RT}$$

Definition of Savings Degree-Hours (SDH) (did not end up presenting)

The savings degree-hours metric measures the extent and duration to which the indoor temperature deviates from a reference temperature.

$$SDH = \sum_{each\ heating\ hour} (T_{ref} - T_{obs})$$

$$T_{ref} = reference\ thermostat\ setting$$

$$T_{obs} = observed\ thermostat\ setting$$

Set up and set back when useful (and variations) (did not end up presenting)

- This is of course what we do for single capacity systems

1. Savings degree hours (simple metric for how long and how deeply set up/back) useful for modulating fossil fuel systems?
2. Count sleep and away hours; trust control is wise about recovery?
3. Don’t count hours, but DO test for wise recovery being in use – how would we do that?

- Discussion

SDH = “Area Under the Curve” (did not end up presenting)

Gray areas correspond to the number of Savings Degree-Hours

Source : Source: Nest thermostat nest.com (2013). Nest Thermostat. Saving energy with Auto-Schedule.

Heating and Cooling SDH Calculations (did not end up presenting)

The calculation of SDH differs slightly for heating and cooling conditions.

For Heating Hours:

$$SDH_h = \sum_{all\ heating\ hours}^{\square} (T_{refh} - T_{obs})$$

For Cooling Hours:

$$SDH_c = \sum_{all\ cooling\ hours}^{\square} (T_{obs} - T_{refc})$$

Where,

T_{refh} = reference temperature for heating

T_{obs} = observed indoor temperature

T_{refc} = reference temperature for cooling

Examples of SDH Calculation (did not end up presenting)

Example 1: For heating, 5 Savings Degree-Hours would be accumulated when the RCCS lowered the indoor temperature to 65° from for one hour (assuming a 70° reference temperature)

Example 2: A programmable thermostat: 100 days of night setback from 72°F → 65°F for 8 hours

$\text{SDH}_{heating}$ = 100 days x 8 hours x 72-65 = 5600*

Notes:

- A larger number of SDH indicates a more successful RCCS control strategy
- Typical values for annual heating SDH will be ~ 5000 – 10,000
- An RCCS needs to achieve more than 5600 SDH to outperform an ordinary programmable thermostat (in this example)

* This calculation assumes indoor temperature moves instantaneously from one setpoint to another

Fan control

- What would we be looking for in fan control?
- Humidity control was mentioned
  - Only applied to cooling, right?
  - Is this something all variable capacity can be expected to do?
- Discussion

Circling back to savings mechanisms

- After this discussion, is there anyone who feels they have a strong case for one not on this list?
- Do any of these plug holes in the others? (e.g. do not set up or set back at the cost of greater energy use by using high capacity states)
- Vote now for which EPA should pursue further [update poll based on discussion]
  - **Keep HVAC in lower capacity states when possible/ avoid short cycling**
  - Set back and set up when possible
  - Fan control

Wrap up and Next Steps

- EPA (and ICF and LBL) will develop proposed metrics for one or more of these savings mechanisms; likely to reach out to stakeholders
- EPA will consider internally whether to pursue system recognition option; may reach out to stakeholders
- If champions have stepped forward for dual fuel or zoned systems, discuss moving forward in a separate forum
- EPA expects to release either a discussion guide or Draft 1 this summer
- A note about software:
  - Data analysis for sample of fixed capacity installations performed by EPA-produced open source Python modules on GitHub
  - Product providers install software in their own data environments and run it themselves to maintain customer privacy, send output to EPA
  - Any data analysis software needed will be developed as part of the specification development, with test versions released along with spec documents