ENERGY STAR Connected Thermostats

Stakeholder Working Meeting

March 23, 2018

Attendees

Abigail Daken, EPA
Dan Baldewicz, ICF for EPA
John Clinger, ICF for EPA
Alan Meier, LBNL
Leo Rainer, LBNL
Michael Blasnik, Nest Labs
Jing Li, Carrier
Frank David, Carrier
Tai Tran, Carrier
Ray Rite, IRCO
Brian Rigg, JCI
Theresa Gillette, JCI
Shawn Hern, JCI
Diane Jakobs, Rheem
Carson Burrus, Rheem
Chris Puranen, Rheem
Ethan Rogers, ACEEE

Ulysses Grundler, EcoFactor
Brent Huchuk, ecobee
John Sartain, Emerson
Michael Siemann, WhiskerLabs
Kurt Mease, Lux Products
Steve Lazar, Lennox
Nguyen Ho, Lennox
David Bourbon, Mitsubishi Electric
Mike Lubliner, Washington State U
Alex Bosenberg, NEMA
Charles Kim, SCE
Michael Fournier, Hydro Quebec
Ed Pike, Energy Solutions for CA IOUs
Ethan Goldman, VEIC
Rober Weber, BPA
Phillip Kelsven, BPA

Agenda

- Software Development
- Status updates
- Review of Resistance Heating Utilization (RHU) results

Software Development

- Meet Intellovations,
  - Eric Floehr, Founder
  - Craig Maloney, Developer
- New developer for the ENERGY STAR Connected Thermostat Software
- Upcoming Software Improvements
  - Error Handling
  - Speed/Efficiency Improvements

Software Release Framework

- **Bugfix Release**: repair minor issues (X,X,X+1): Software -> 1.1.3
  - No changes to certification data
  - Minimal stakeholder testing needed (Developer + Automated tests)
- **Feature Release:** add procedures/features (X,X + 1,X): Software -> 1.2.1
  - No changes to certification data
  - Testing and validation of approach/results via EPA, ICF, Developer and Stakeholders. Stakeholder testing process. Can be alpha/beta release.
  - After Stakeholder testing, set as current software.
- **Major Release:** changes certification data/core calculations (X + 1, X, X): Software -> 2.0.0
  - Changes certification data, core thermostat calculations.
  - Should go live in conjunction with major specification changes, with specification development process and transition period between finalization and effective date (usually about 9 months).
  - Stakeholder involvement/metrics calls, testing, results discussion.

Software Discussion

- Can we revisit the requirement for using a particular sorting algorithm?
  - Causes a bunch of problems for some Partners
  - The goal in specifying a specific sorting algorithm was to enhance reproducibility
  - Can we use a sort that's available in one of the other modules we use?
  - Maybe, let's discuss offline
- Improvements to RHU meaningfulness tabled for later in call

Status Updates - Specification

- Certifications
  - 23 products
  - 7 brands
  - Several other potential partners
- Utility program reliance on ENERGY STAR continues to grow – now including utilities serving about 16 million households
- Renewed request to consider line voltage thermostats
  - Adding would require some work developing appropriate requirements
  - Not sure when EPA will be able to move on this

Status Updates - Metric

- Regional Baselines
  - LBNL continues to work on this
  - Interim results in 2018 to discuss on a later metrics call
  - Intended completion 2019

- Including installations controlling staged and variable capacity equipment
  - Open data call, currently have two data sets submitted
  - Considering ways to move forward this summer even without additional data

Resistance Heat Utilization

- Data from software output
  - Calculates minutes of resistance heat as percentage of total heating run time of any kind for each day of the year
  - Bins data by average outdoor temperature during that day
  - Results available regionally and nationally (unweighted sum)
- Four data sets submitted, but one doesn't make sense
  - Data input problem? Working with stakeholder to fix.
- Expected results (if any):
  - Use of resistance heat at very low outdoor temps equipment dependent, not control dependent
  - Use of resistance heat rare at higher ambient for all solutions
  - Most likely to see differentiation in use at intermediate temperatures

RHU Calculation Details

For heat pump systems only, calculate RHU in 12 (daily average) outdoor temperature bins (0≤T<5°F, 5≤T<10°F,…, 55≤T≤60°F). For example $RHU_{0\text{-}5F}$ is calculated as follows:

$$RHU_{0-5F} = \frac{(t_{emerg_{0-5F}} + t_{aux_{0-5F}})}{(t_{emerg_{0-5F}} + t_{comp_{0-5F}})}$$

where,

$t_{emerg_{0-5F}}$ = total emergency resistance heating run time in the interval data file that occurs on core heating days where 0°F ≤ average daily outdoor temperature < 5°F.

$t_{aux_{0-5F}}$ = total annual auxiliary resistance heating run time in the interval data file that occurs on core heating days where 0°F ≤ average daily outdoor temperature < 5°F.

$t_{comp_{0-5F}}$ = total compressor heating run time in the interval data file that occurs on core heating days where 0°F ≤ average daily outdoor temperature < 5°F.

Note: highest value is 1.00 (resistance heat in use for all heating minutes), lowest is 0.00 (no resistance heat use in any heating hour); lower is better.

RHU Discussion

- On emergency heat: if the compressor has a cut-out at some temperature, does it count as emergency heat?
  - Yes
  - If the cutout is 30F or whatever, service providers would be penalized for that?
- Note that two units, both using resistance heat all minutes of the day, but one using the compressor also: both would score RHU 1, but the one using the compressor also would have effectively higher efficiency. Not captured in RHU.
- Sizing would effect this, but it also effects RHU otherwise
- Can we distinguish when the compressor is locked out by temperature vs. actually not working?
- In some thermostats, “emergency heat” is used only when the compressor is broken, and must be set deliberately by a user.

RHU Discussion

- Compressor lockout T and temperature when aux heat comes on set by installer and would not be changed by the CT service provider, generally (need permission)
- But CT vendors can set a default, which may affect where installations end up
- The lockouts are a critical issue for energy efficiency programs – installers often don't set them where programs recommend
  - Is there a way for us to use the spec to make it easier to verify that the setting is where programs expect it to be?
  - At the installation (for an inspector) or via CT service provider data reporting? Both valuable.
  - Do vendors have the ability to *read* these values? Yes.

RHU Discussion

- Electric resistance heating can also be staged. Do we take that into account?
  - Not at the moment.
  - Which systems tend to have this? You typically need a thermostat intended to control a multistage compressor to use this, but do not need to have a multistage compressor
  - Under the control of the installer – how common? Little data but we think could be rare
  - Table; include in discussion of multistage/variable capacity systems

Specific questions we hoped to answer

- Are there differences between products in their resistance heating (Aux/Emergency) use results?
  - Are these differences statistically significant?
  - What would the energy impact of the differences be?
- Will products that perform better in some conditions show equivalent superior performance at other conditions?
  - RHU optimization at different Temp. bins for different products
  - Differentiation at moderate temperatures?
- Are there temperature bins where all products are effectively equal, when outdoor temperature is the primary driver of Aux/Emergency usage (Cold/Very Cold Temperatures)?

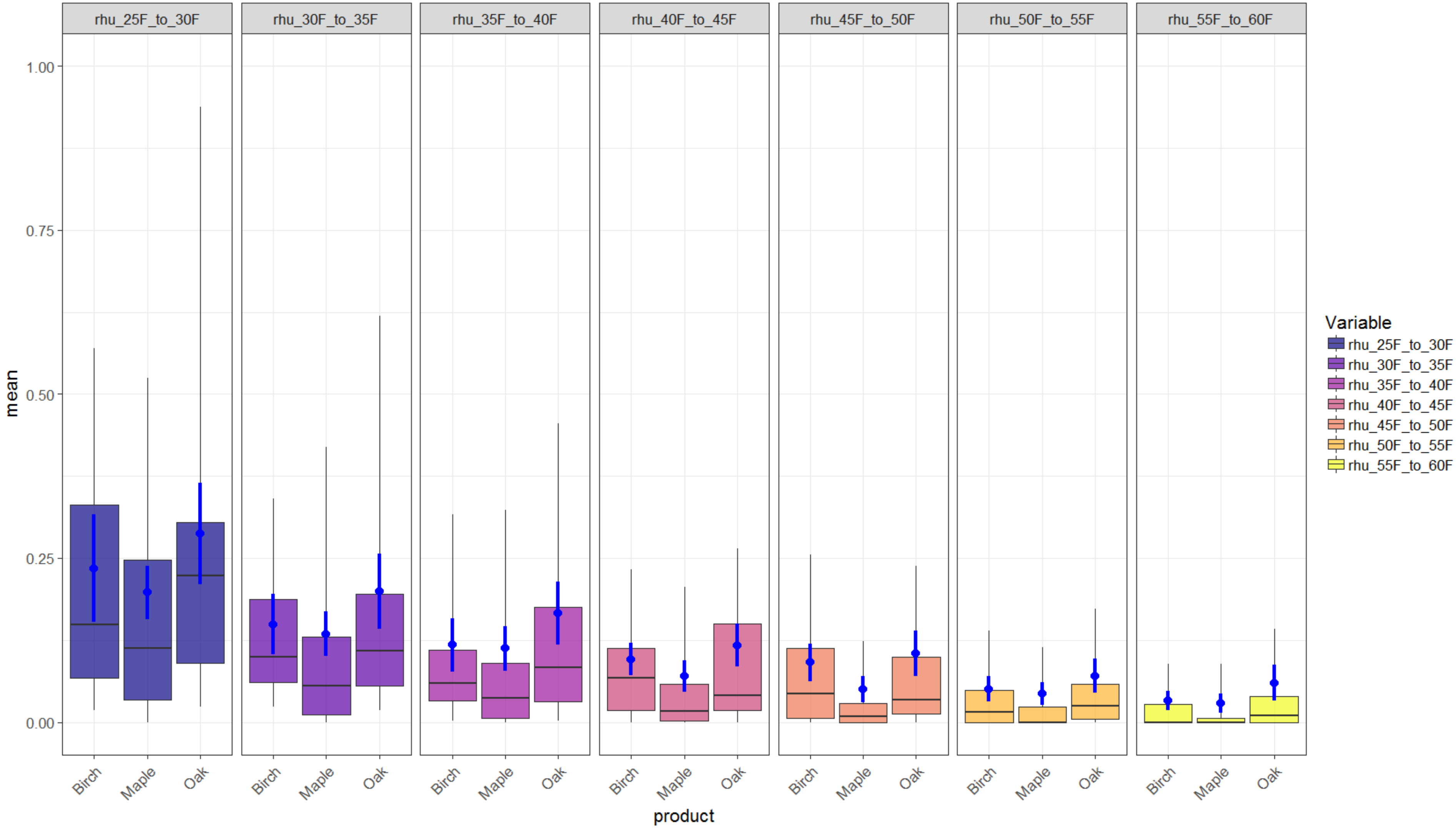
Primarily found in Mixed Humid and Hot Humid climates

Climate	Birch	Maple	Oak	Spruce
Hot Humid	127	138	217	462
Marine	< 10	< 10	88	117
Mixed Humid	184	893	273	535
Very Cold – Cold	< 10	70	< 10	< 10
Mixed Dry – Hot Dry	< 10	< 10	< 10	129

- Expected result
- Obviously affects which temperature bins have more data
  - Hot Humid never has days in the low temperature bins

All, N >= 10

Boxplot Upper and Lower Bounds q90 and q10, solid line mean and conf 95 bounds



Statistical Significance Results: All Climate Zones (N >= 10)

NA: Not Measured	** P < 0.05	* 0.05 <= P <= 0.10		NS 1: 0.10 < P <= 0.25		NS 2: P > 0.25	
	ABS(Maple-Birch)	ABS(Oak-Birch)	ABS(Oak-Maple)	Notes	Count: NA's	Count: **	Count: * and **
	p (α = 0.05)	p (α = 0.05)	p (α = 0.05)				
Climate Zone: All							
rhu_00F_to_05F	NA	NA	NA	Exclude T Bin	**3**	-	-
rhu_05F_to_10F	NA	NA	NA	Exclude T Bin	**3**	-	-
rhu_10F_to_15F	NA	NA	NS 2	Exclude T Bin	**2**	-	-
rhu_15F_to_20F	NA	NA	NS 2	Exclude T Bin	**2**	-	-
rhu_20F_to_25F	NS 1	NS 2	NS 2		-	-	**-**
rhu_25F_to_30F	NS 2	NS 2	**		-	1	1
rhu_30F_to_35F	NS 2	NS 1	*		-	-	1
rhu_35F_to_40F	NS 2	NS 1	*		-	-	1
rhu_40F_to_45F	NS 1	NS 2	**		-	1	1
rhu_45F_to_50F	**	NS 2	**		-	2	2
rhu_50F_to_55F	NS 2	NS 1	*		-	-	1
rhu_55F_to_60F	NS 2	*	**		-	1	2

N, Effect Sizes, Standard Error of Effect (seNet)

** P < 0.05	* 0.05 <= P <= 0.10								
Item	Row Labels	rhu_20F_to_25F	rhu_25F_to_30F	rhu_30F_to_35F	rhu_35F_to_40F	rhu_40F_to_45F	rhu_45F_to_50F	rhu_50F_to_55F	rhu_55F_to_60F
Birch	N (nearest 10)	20	30	40	50	60	70	70	70
Maple	N (nearest 10)	110	120	130	140	140	150	150	150
Oak	N (nearest 10)	50	60	70	80	90	100	100	100
ABS(Maple-Birch)	Effect	**0.07**	0.04	0.01	0.01	0.03	0.04	0.01	0.00
	Se Net	0.06	0.05	0.03	0.03	0.02	0.02	0.01	0.01
ABS(Oak-Birch)	Effect	**0.07**	**0.05**	**0.05**	**0.05**	0.02	0.01	0.02	0.03
	Se Net	0.06	0.06	0.04	0.03	0.02	0.02	0.02	0.02
ABS(Oak-Maple)	Effect	0.00	**0.09**	**0.06**	**0.05**	**0.05**	**0.05**	0.03	0.03
	Se Net	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	Significance	NS	**	*	*	**	**	*	**

- Notes:
  - N reaches low counts in colder bins. More data -> Less Error
  - Effect sizes often ≥ 0.05 RHU (bold in table).

Results Summary

- Relatively little data at very cold outdoor temps – heat pumps not typically installed in those climates.
  - Did not spend time looking at bins with less than 10 thermostat-days in the bin total for that product.
- Most installations in Hot-Humid and Mixed-Humid climates, as expected
- Significant variation within each temperature bin, as expected based on differences in controlled equipment
- Little statistically significant differentiation, and not all where we expected to see it

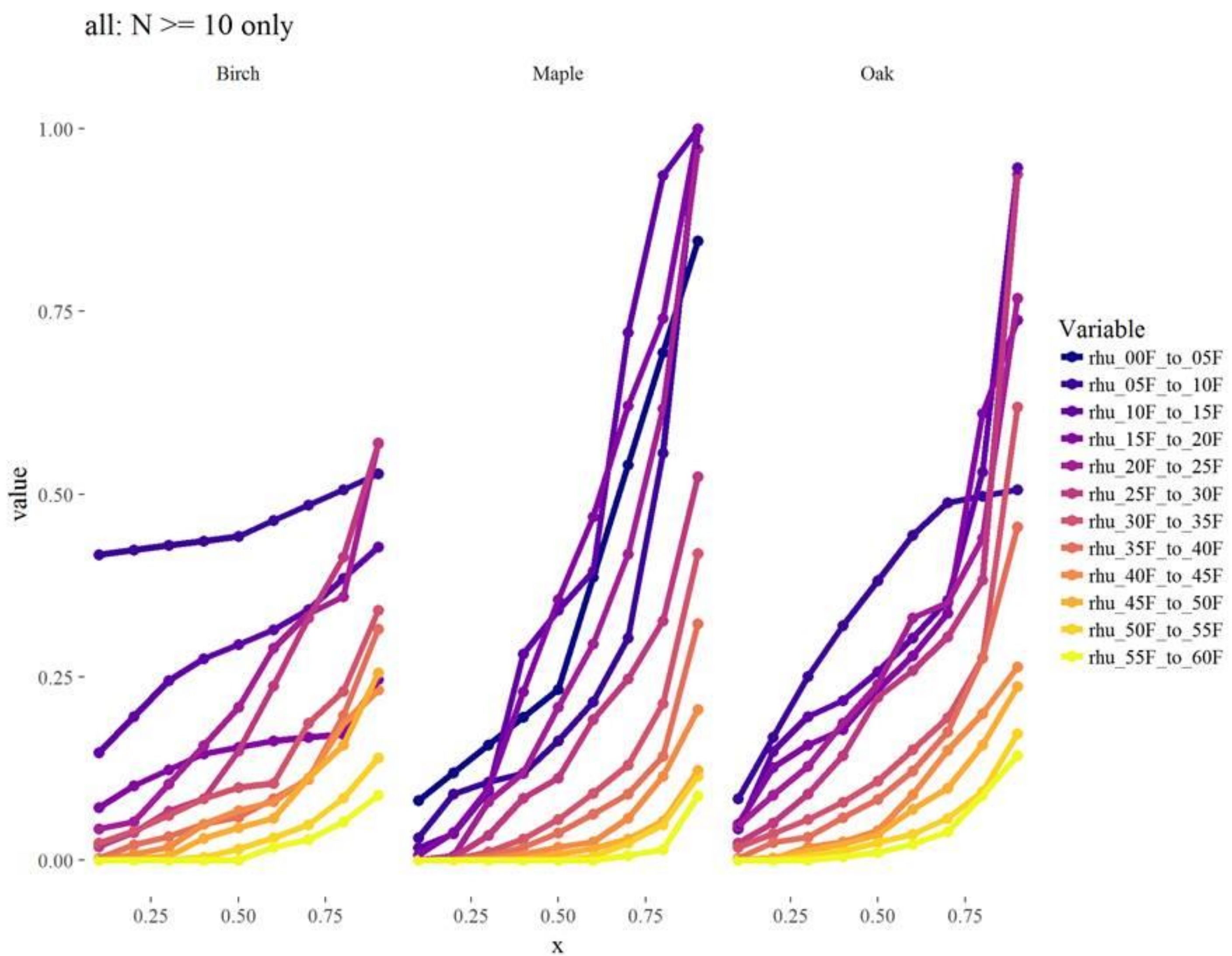
RHU Discussion

- The whole analysis is underpowered
- Wider temperature bins? Oversample heat pumps?
- Did not do a linear regression (RHU vs. Tout) b/c expected to be non-linear
- Not a normal distribution – should be use something other than T-test? Non-parametric analysis might help – need a statistician who knows more. May need more data.
- Can we sum subsequent resubmissions to increase our data?
- Increase sample size, oversample heat pumps, etc… More work for vendors – but if the software is faster, it might make up for it!
- Back of the envelope estimate of how much energy we are talking about: not uncommon to have 800 hours of heating run time, so 5% of that is 40 hours. If it's a 20kW backup is common (in the mid-atlantic), that would be 800 kWh/year. Actually, might be half, b/c the compressor would've needed some energy to deliver that heat. Even if it's 10 kW back up and we assume the compressor would have used half the energy, it would be 200 kWh/year.
- CONSENSUS: there appears to be enough energy in play here to matter: several hundred kWh/year

RHU Discussion

- Larger sample size vs. oversampling heat pumps in Marine and Very Cold – Cold?
  - Total number of runs would be larger for larger sample size than to add additional sample with all heat pumps that would be used just for heat pump calculations.
  - How will this work for vendors with smaller deployed base?
- Would hourly data have less noise?
  - Instead of average outdoor temp, could bin by degree days based on hourly temperatures
  - Thermal inertia makes
- Fewer temperature bins?
  - 10 degree bins where we expect differentiation, also large bins under 20 or over 50
  - Will autocorrelation in each home mean that wider bins don't give more power?
  - Temperature variations inside the bin will tend to increase variation; introduces distortion if different vendors have a different distribution with the bin.
- Can we output the weather data being used when we output thermostat data?

True that RHU is not linear with outdoor tempera-ture



RHU Future Considerations

- More Data -> More Climate Zones + Higher Signal to Noise Ratio
  - Mixed Humid #1 Zone for RHU, other zones greatly under-represented (equipment preferences by region).
  - Sampling randomly from populations in climate zones makes this issue even more pronounced.
  - Possible Datacall: Send all available equipment type 1 into tool, to maximize RHU calculation accuracy.
  - Would the data be cleaner if we use hourly temperature bins and run times instead?

- Data Reminder:
  - Auxiliary Heating is resistance heat when Compressor is operational.
  - Emergency Heating is resistance heat when Compressor is offline/non-operational.

Statistical Significance Calculations

- Comparing mean ($\bar{X}$) and standard error (se) of Item A and Item B
- Effect: $X_{EFF} = abs(\overline{X_A} - \overline{X_B})$
- SE of the Effect: $se_{EFF} = \sqrt{se_A^2 + se_B^2}$
- Z-score: $\mathrm{z} = \frac{X_{EFF}}{se_{EFF}}$
- P-value: $p(\alpha = 0.05) = \exp(-0.717 * \mathrm{z} - 0.416 * z^2)$