Key Variables in Assessing ENDS Devices

AND WHY THAT ISN'T "VOLTS"

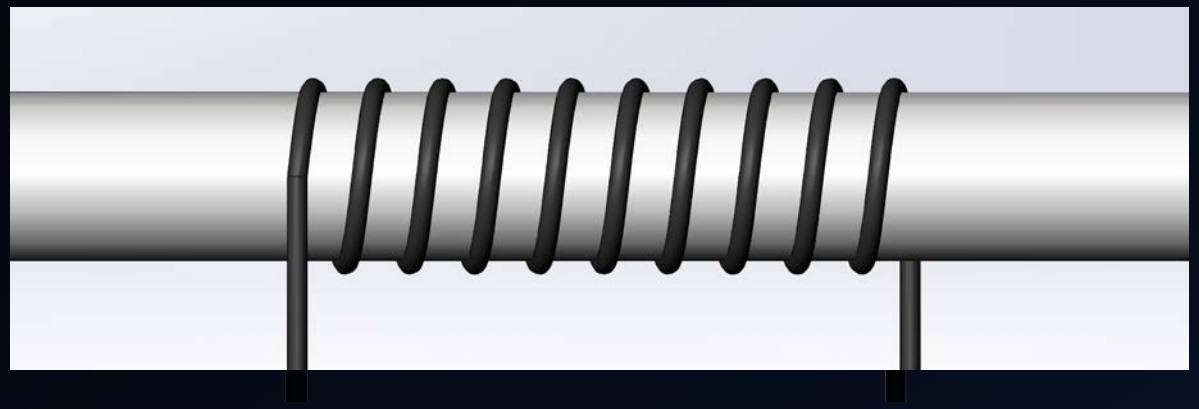
About Evolv and John Bellinger

- Evolv is the largest domestic manufacturer of ENDS control circuitry
- Founded 2010, located in Hudson, OH
- Produce 1,000,000+ controllers for large high end devices per year
- John is co-owner and Chief Technologist of Evolv
- Designed 21 ENDS controller families
- First to introduce direct wattage control for ENDS (2010)
- First to introduce direct temperature control for ENDS (2014)

ENDS Device Components

- ENDS devices consist of a battery, heating coil and control electronics
- All devices powered by Lithium Ion batteries, major difference is size
- Almost all devices have a heating coil fed with liquid by a wick
  - Wicks are typically fiberglass or cellulose
- Control electronics range from a simple mechanical switches to multi-loop PID process controllers

ENDS Atomizer

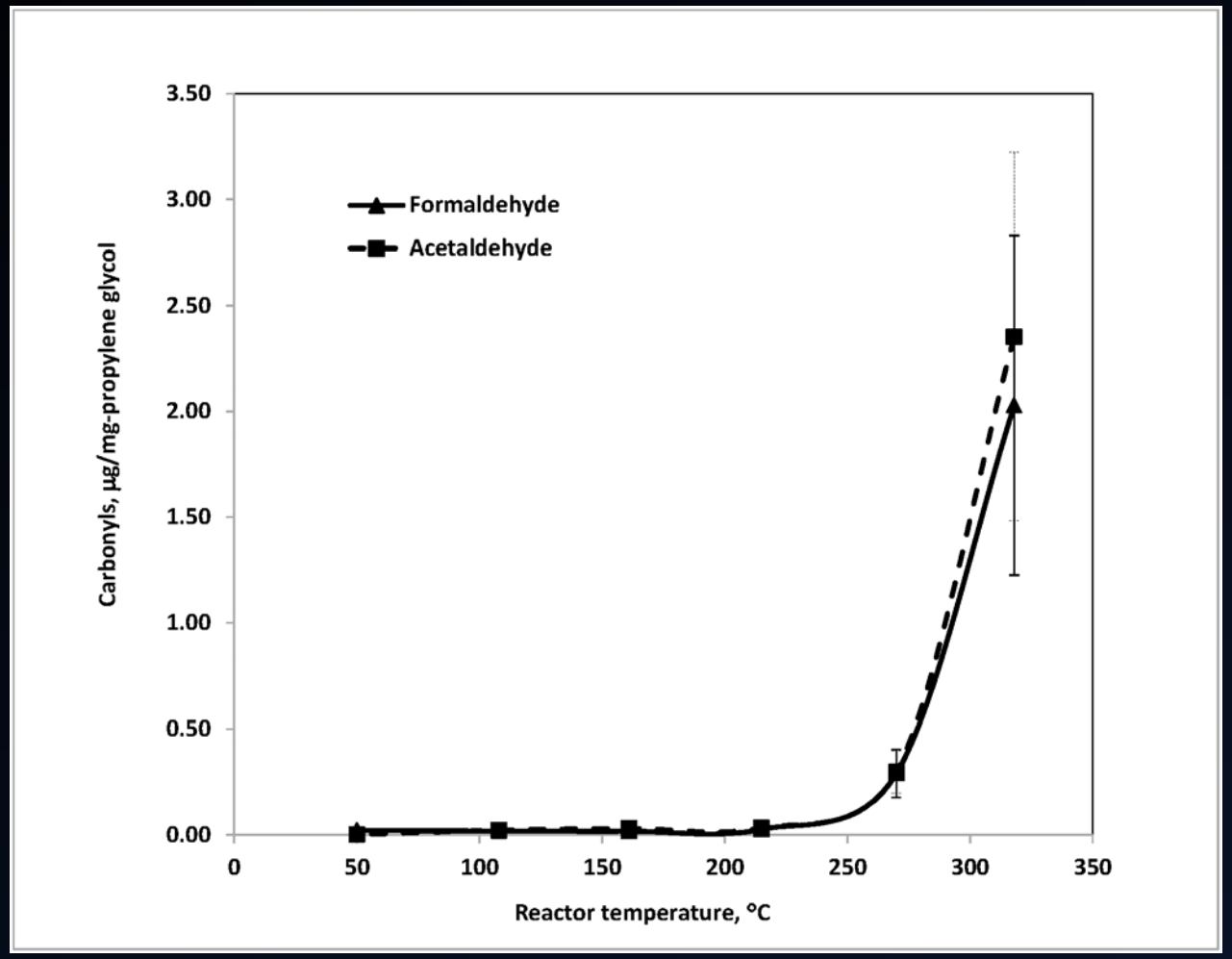


- E-liquid is held in the wicking
- Power is applied to the heating coil
- The coil rises to an operating temperature
- Air is drawn over the coil
- Liquid boils into a vapor, mixes with the air passing over coil and condenses into an aerosol

Vapor Yield

- How much e-liquid is in the aerosol the user inhales?
- Device yield is primarily a function of power (Watts), time and device efficiency
- Transient effects and thermal mass complicate yield prediction
- Users seem to be able to self-titrate for nicotine dose

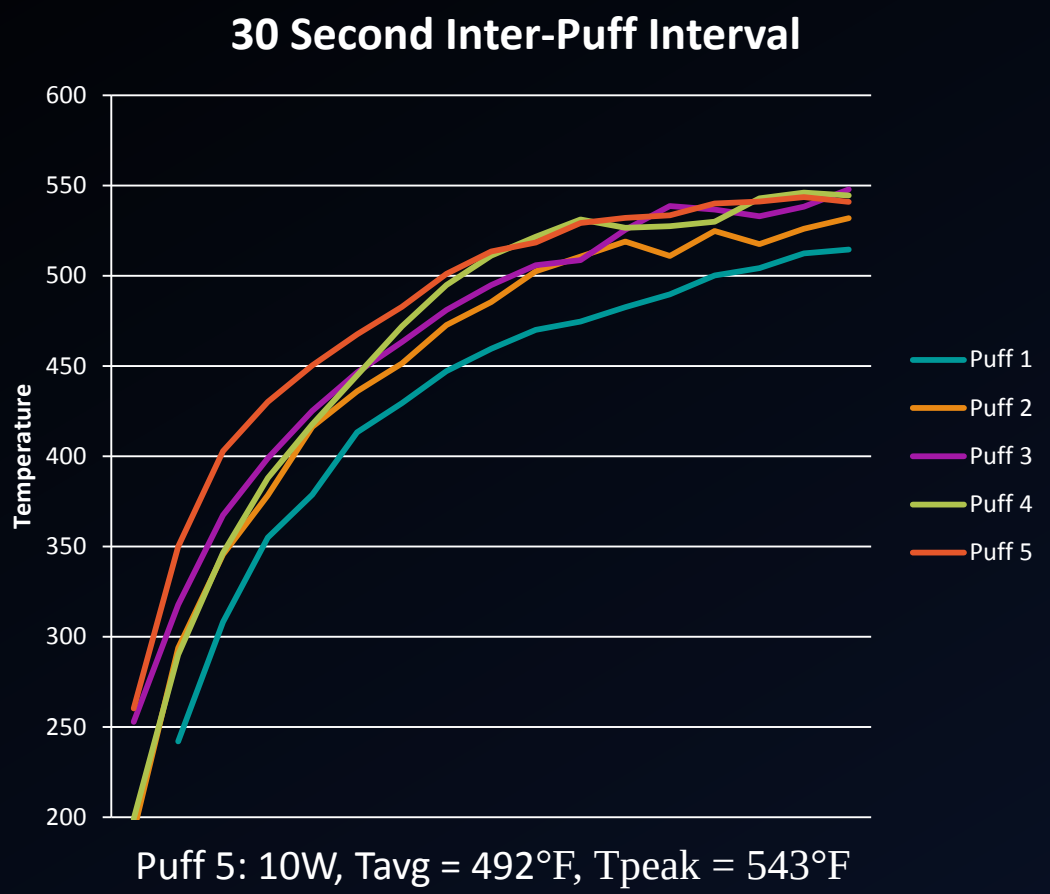
Vapor Constituents



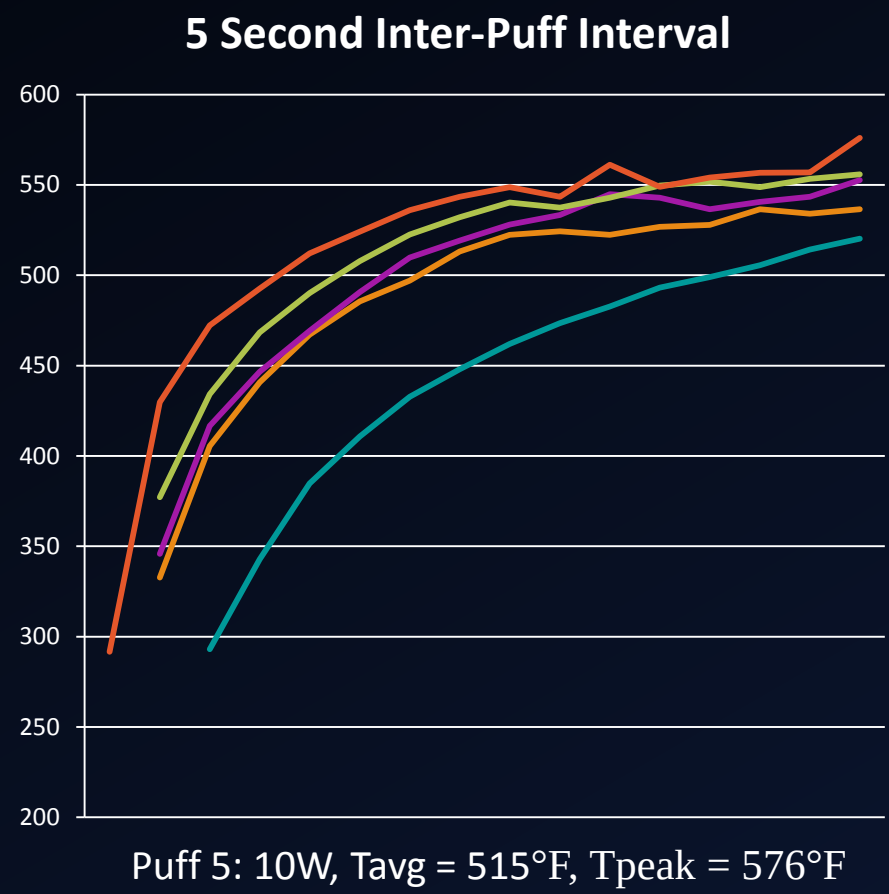
- Primarily a function of coil temperature
- Ideally, the only vapor constituents are what's in the liquid
- Carbonyls, oxidation products form at elevated temperatures
- Coil temperature, for a particular atomizer design, is a function of power, airflow and time

Wang P, Chen W, Liao J, Matsuo T, Ito K, Fowles J, et al. (2017) A Device-Independent Evaluation of Carbonyl Emissions from Heated Electronic Cigarette Solvents. PLoS ONE 12(1): e0169811. doi:10.1371/journal.pone.0169811

Is reported data inherent to the device?



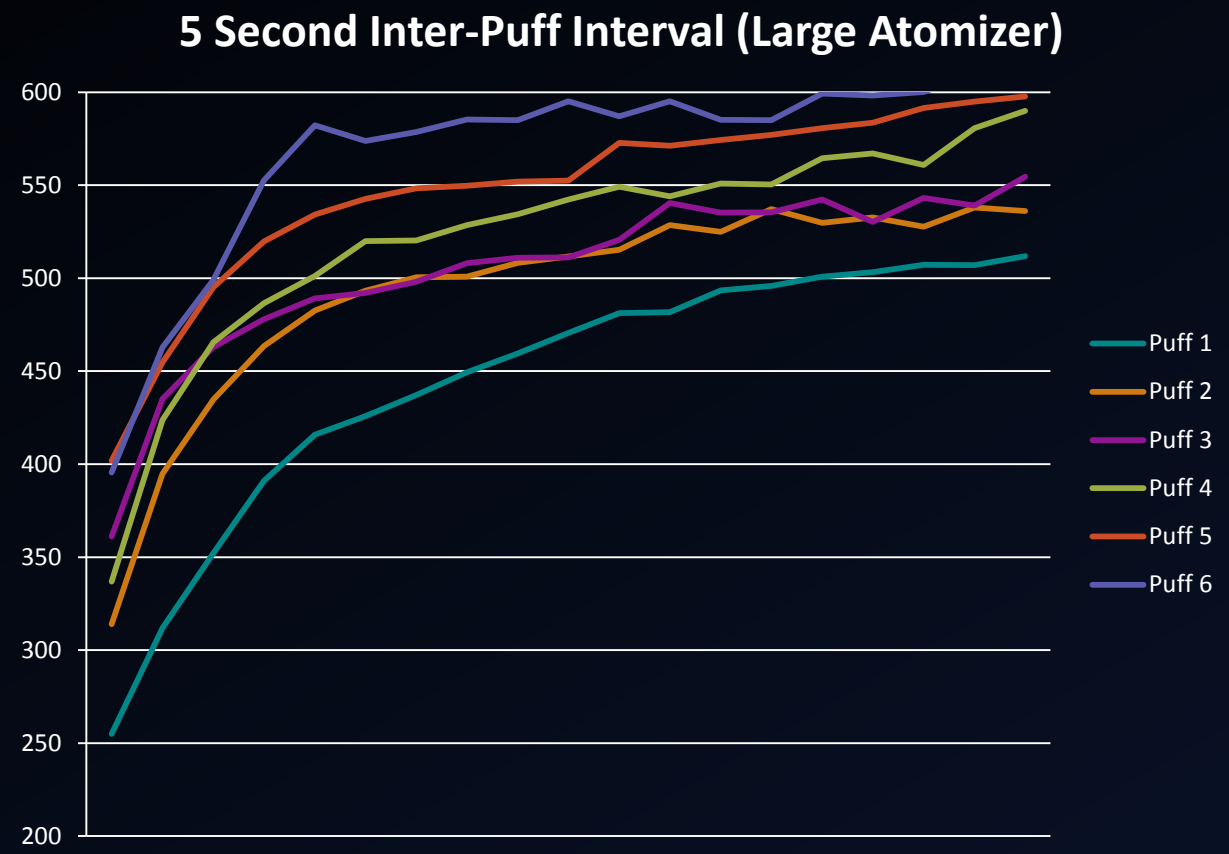
Puff 5: 10W, Tavg = 492°F, Tpeak = 543°F



Puff 5: 10W, Tavg = 515°F, Tpeak = 576°F

- Many data points in the literature are anecdotal: they apply only to the chosen test parameters

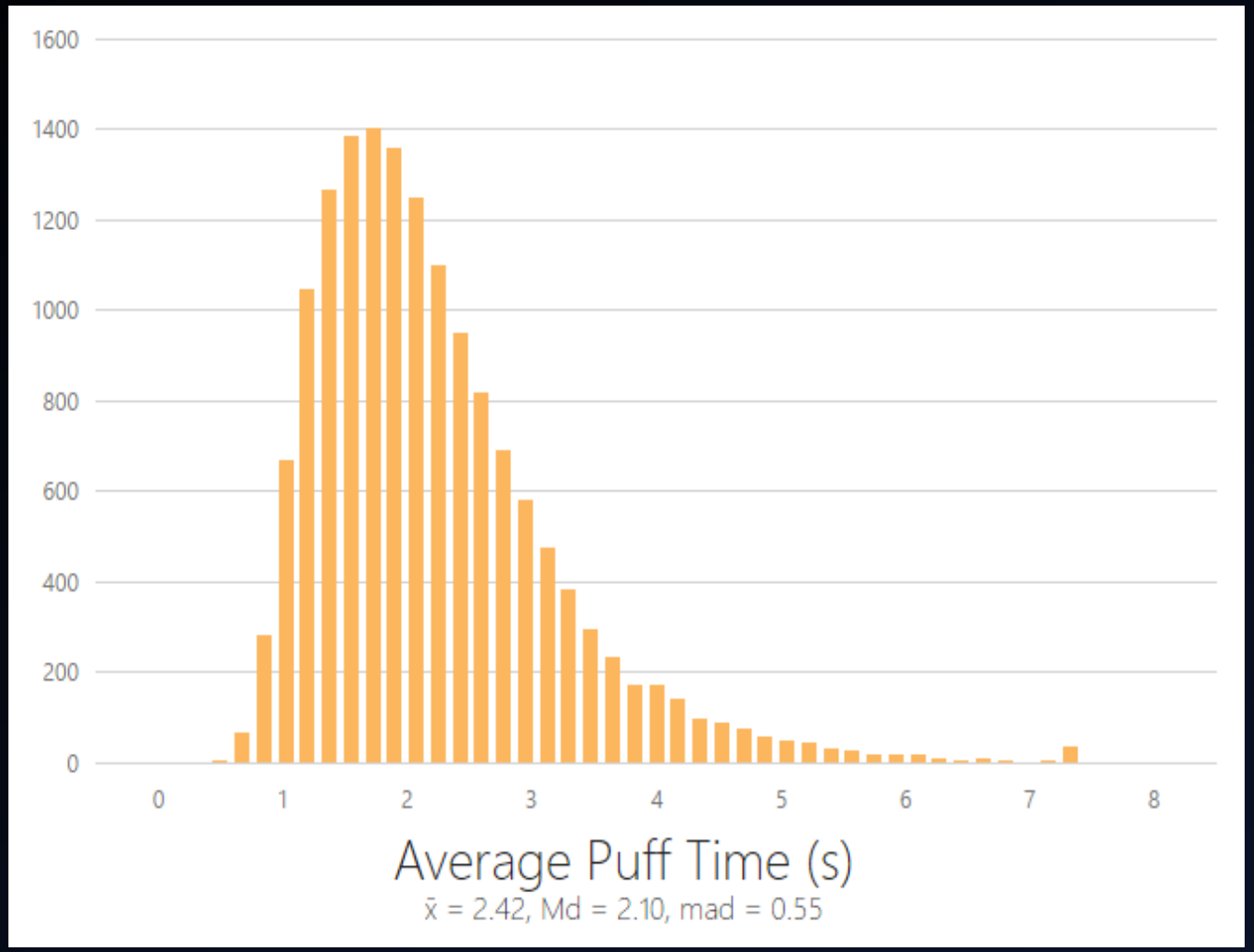
Can results be extrapolated between devices?



Puff 5: 75W, Tavg = 547°F, Tpeak = 598°F

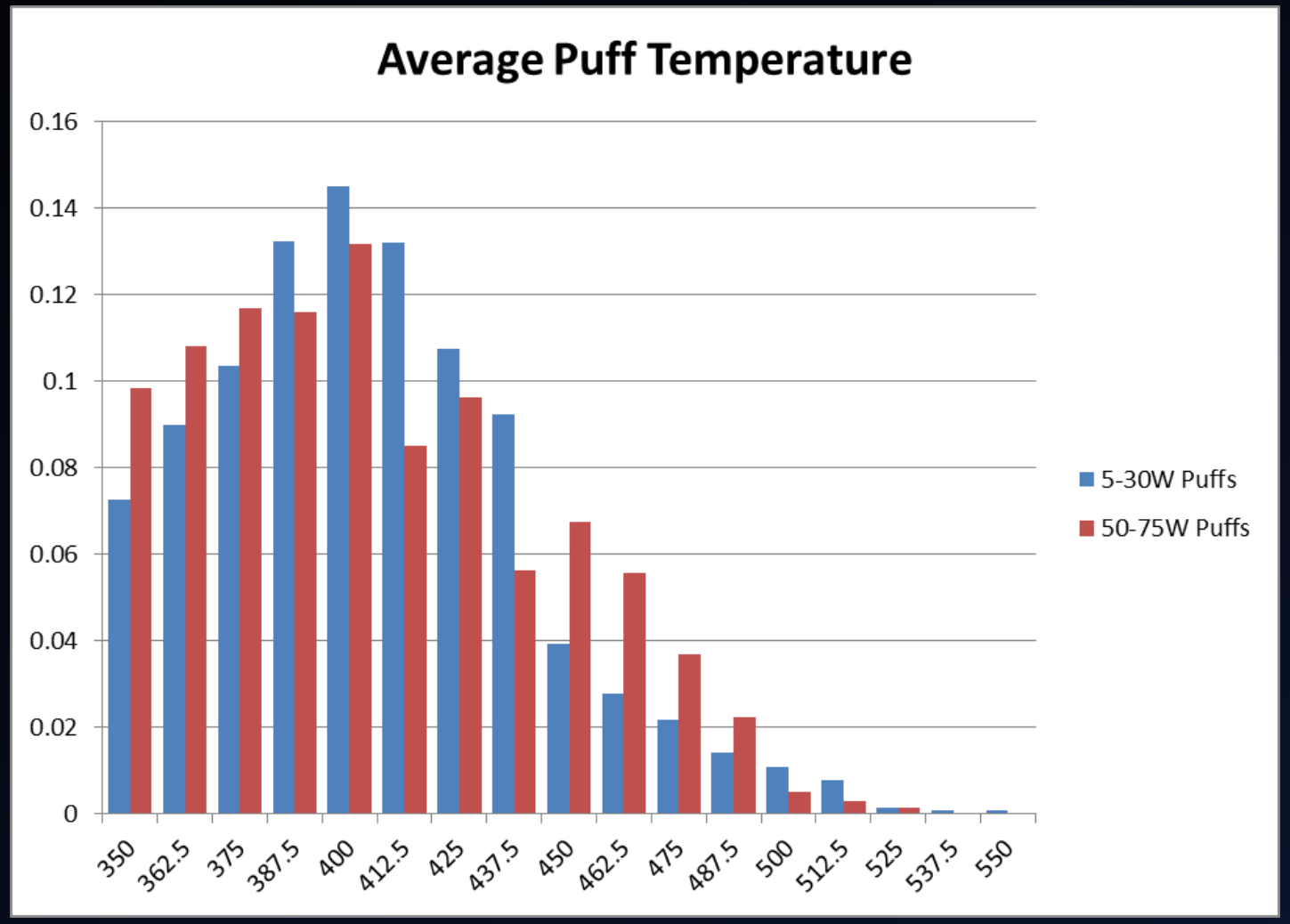
- Three puff steady-state fallacy
- Consider thermal mass, especially with “mod” devices
- Temperature-sensing devices extrapolate across devices well

How do we know what users are doing?



- All Evolv devices since 2015 record statistical data
- All Evolv devices since 2014 can measure and control coil temperature
- Users can opt to share recorded data
- 180,000+ reporting devices, 1.5 billion recorded puffs
- Daily snapshots publicly available at www.ecigstats.org

Higher power devices are not necessarily hotter



- 3 months of recorded data
- Only devices exclusively run in a temperature sensing mode above 350°F
- 5-30W : 7,476,508 puffs
- 50-75W: 2,961,785 puffs

Temperature Sensing Devices

- Temperature controlled devices on the market currently are more precise than accurate

Constituents	Yield
Record puff temperature	Record puff power
Characterize device temperature accuracy	Record puff time
	Calculate coil thermal mass
	Characterize device efficiency

Power Controlled Devices

- Power controlled (Variable Wattage) devices are repeatable for yield, but not necessarily for temperature

Constituents	Yield
Record power	Record puff power
Record airflow	Record puff time
Record puff and inter-puff times	Calculate coil thermal mass
Record atomizer construction	Characterize device efficiency
Independently measure coil temperature	

Voltage Controlled Devices

- If coil resistance is carefully measured, equivalent to power control
- Otherwise a black box

Constituents	Yield
Measure coil resistance	Measure coil resistance
Measure coil voltage	Measure coil voltage
Calculate puff power	Calculate puff power
Record airflow	Record puff time
Record puff and inter-puff times	Calculate coil thermal mass
Record atomizer construction	Characterize device efficiency
Independently measure coil temperature	

Unregulated devices

- Unregulated devices pass battery voltage straight through to the heating coil
- Power varies by a factor of 2 between full and empty.

Constituents	Yield
Measure coil resistance	Measure coil resistance
Measure output voltage for each puff	Measure output voltage for each puff
Calculate puff power	Calculate puff power
Record airflow	Record puff time
Record puff and inter-puff times	Calculate coil thermal mass
Record atomizer construction	Characterize device efficiency
Independently measure coil temperature	

Questions?