# Supplemental Slides to accompany the article:

## Proposed Standard Test Protocols and Outcome Measures for Quantitative Comparison of Emissions from Electronic Nicotine Delivery Systems. DOI...

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**Study Objectives:**

1. Demonstrate an accurate, unbiased Emissions Model (EM) for quantifying aerosol emissions generated from pen- and pod-style ENDS across their respective operating envelope.
2. Identify characteristics of the EM which may be used to compare relative emissions between products.
3. Investigate associations between the EM characteristics and underlying product characteristics.
4. Propose characteristics likely to be effective regulatory parameters to achieve positive outcomes related to public health, reduction in harm potential and clinical guidance.

# Tobacco Product Design Characteristics

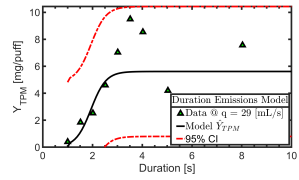
## Thirteen ENDS and ELIQUID combinations were studied.

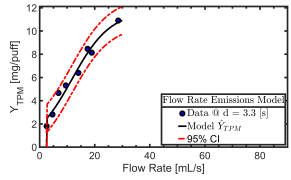
| Product ID Code | Device Manufacturer | Device Model | Consumable Manufacturer | Consumable Labeled Flavor | Unpuffed E-Liquid $f_{Nic}$ | PG Fraction [-] | Mean $R_{Coil}$ [Ω] | Max (1) $P_{Nom}$ [W] | MaxAF [mL/s] | MaxAD [s] |
|---|---|---|---|---|---|---|---|---|---|---|
| EC07-02 | JUUL LABS | Juul | JUUL LABS | Virginia Tobacco | 0.052 | 0.33 | 1.633 | 6.7 | 85 | 6.5 |
| EC10-01 | VUSE | Alto | VUSE | Original | 0.052 | N/R | 1.063 | 10.2 | 50 | 5 |
| EC12-01 | SMOK | Novo 2 | MAD HATTER JUICE | Classic Tobacco | 0.039 | 0.44 | 1.463 | 7.4 | 58 | 8 |
| EC14-01 | BLU | myblu | BLU | Classic Tobacco | 0.02 | 0.42 | 1.416 | 7.7 | 88 | 10 |
| EC15-01 | NJOY | Ace | NJOY | Classic Tobacco | 0.05 | 0.48 | 1.034 | 10.5 | 58 | 5.5 |
| EC16-01 | UWELL | Caliburn | MAD HATTER JUICE | Classic Tobacco | 0.039 | 0.44 | 1.405 | 7.8 | 88 | 10 |
| EC17-01 | ASPIRE | Breeze 2 | MAD HATTER JUICE | Classic Tobacco | 0.039 | 0.44 | 0.631 | 17.3 | 30 | 10.5 |
| EC18-01 | VAPOR4LIFE | V4L Titan | VAPOR4LIFE | Wowbacco | 0.023 | 0.73 | 2.258 | 4.8 | 50 | 10 |
| EC19-01 | LOGIC VAPES | Logic Pro | LOGIC VAPES | Tobacco | 0.016 | 0.77 | 2.443 | 4.5 | 48 | 12 |
| EC20-01 | LOONTECH | Hyde Original | LOONTECH | Spearmint | 0.061 | N/R | 1.61 | 6.8 | 86 | 10 |
| EC22-01 | VUSE | Vibe | VUSE | Original Tobacco | 0.03 | 0.23 | 2.693 | 4.0 | 68 | 6 |
| EC23-01 | SMOK | Stick Prince | MAD HATTER JUICE | Classic Tobacco | 0.052 | 0.44 | 0.174 | 62.6 | 90 | 8 |
| EC24-01 | PUFF BAR | Puff Bar | PUFF BAR | Tobacco | 0.049 | 0.54 | 1.688 | 6.5 | 50 | 3.6 |

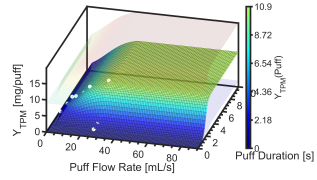
Notes: (1) Power was not experimentally measured in this investigation. Maximum nominal power was, for relative comparison only, computed from $P_{Nom} = V_{Nom}^2 / R_{Coil}$ where $V_{Nom}$ was set to a constant value of 3.3 [VDC].

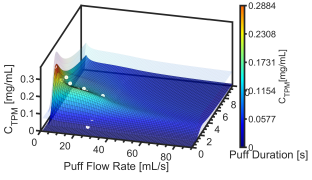
**Results:** A graphical summary of the screening emissions model for each ENDS PCU, RESERVOIR, and Consumable.

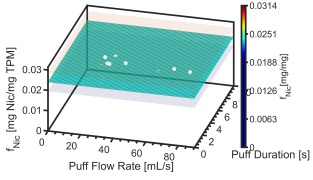
# Emissions Model: EC17-01 ASPIRE Breeze 2 with MAD HATTER JUICE Classic Tobacco

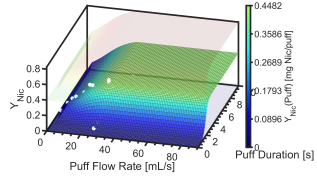



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1+\exp(B_2[q-B_3])} \cdot \frac{B_4}{1+\exp(B_5[d-B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q,d)\hat{Y}_{TPM}(Puff)$$

MinAD = 1.00 s
MaxAD = 10.5 s

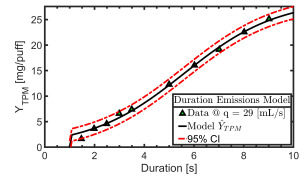
MinAF = 2.5 mL/s
MaxAF = 30. mL/s

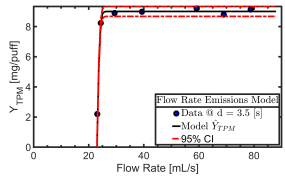
$B_1$ =11.698
$B_2$ = 0.144
$B_3$ = 11.745
$B_4$ = 5.613
$B_5$ = 3.301
$B_6$ = 1.940

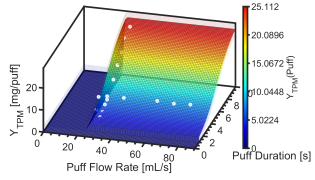
$f_{Nic} = 0.039 \pm 0.019 mg/mg$

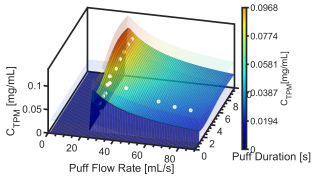
Max $Y_{TPM}(puff) = 10.9 \pm 8.97 mg/puff$
Max $Y_{Nic}(puff) = 0.425 \pm 0.406 mg/puff$
Max $C_{TPM} = 0.300 \pm 0.072 mg/mL$

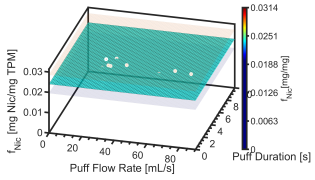
# Emissions Model: EC14-01 BLU myBlu with BLU Classic Tobacco

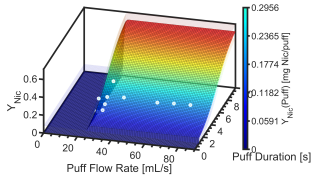



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)}\left(\frac{B_1}{1+\exp(B_2[q-B_3])}\cdot\frac{B_4}{1+\exp(B_5[d-B_6])}\right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q\cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q,d)\hat{Y}_{TPM}(Puff)$$

MinAD = 1.00 s
MaxAD = 10.0 s

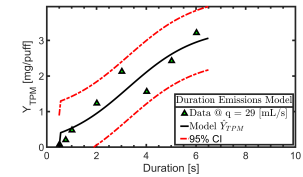
MinAF = 23. mL/s
MaxAF = 88. mL/s

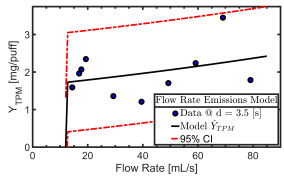
$B_1 = 9.005$ $B_2 = 2.751$ $B_3 = 23.52$ $B_4 = 28.9$ $B_5 = 0.531$ $B_6 = 5.604$

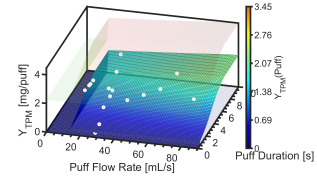
$f_{Nic} = 0.024 \pm 0.005 mg/mg$

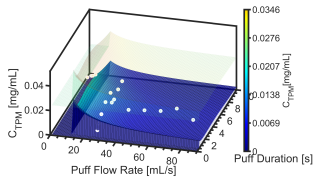
Max $Y_{TPM}(puff) = 23.3 \pm 2.71 mg/puff$
Max $Y_{Nic}(puff) = 0.634 \pm 0.081 mg/puff$
Max $C_{TPM} = 0.110 \pm 0.023 mg/mL$

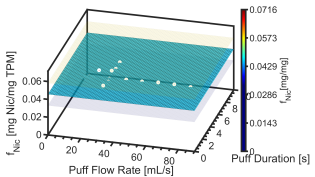
# Emissions Model: EC7-02 JUUL LABS Juul with JUUL LABS Virginia Tobacco

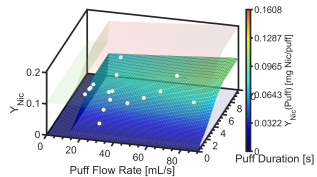


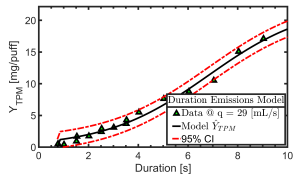

$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

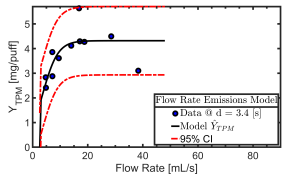
MinAD = 0.5 s MinAF = 12. mL/s $B_1 = 84.69$ $B_4 = 3.359$ $f_{Nic} = 0.046 \pm 0.012 mg/mg$ Max $Y_{TPM}(puff) = 2.210 \pm 2.25 mg/puff$

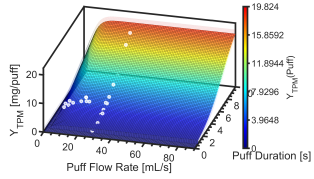
MaxAD = 6.5 s MaxAF = 85. mL/s $B_2 = 0.0048$ $B_5 = 0.726$ Max $Y_{Nic}(puff) = 0.101 \pm 0.104 mg/puff$

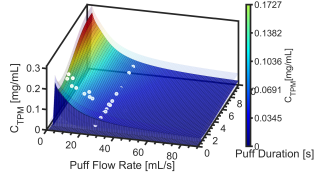
$B_3 = 822.4$ $B_6 = 3.288$ Max $C_{TPM} = 0.028 \pm 0.024 mg/mL$

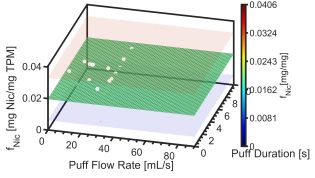
# Emissions Model: EC19-01 LOGIC VAPES Logic Pro with LOGIC VAPES Tobacco

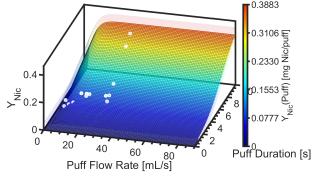



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

MinAD = 0.75 s
MaxAD = 12. s

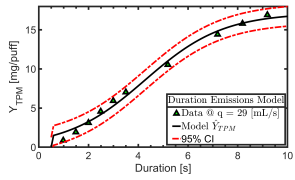
MinAF = 2.4 mL/s
MaxAF = 48. mL/s

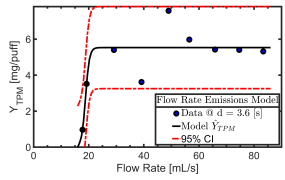
$B_1 = 4.319$ $B_2 = 0.361$ $B_3 = 3.661$ $B_4 = 22.614$ $B_5 = 0.484$ $B_6 = 6.818$

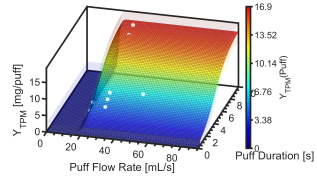
$f_{Nic} = 0.013 \pm 0.412 mg/mg$

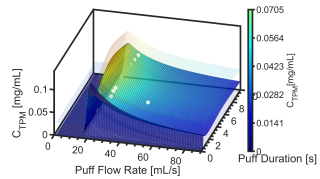
Max $Y_{TPM}(puff) = 20.9 \pm 1.45 mg/puff$
Max $Y_{Nic}(puff) = 0.412 \pm 0.054 mg/puff$
Max $C_{TPM} = 0.276 \pm 0.036 mg/mL$

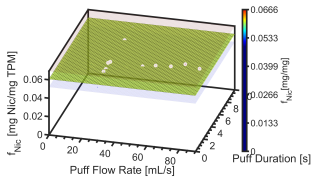
# Emissions Model: EC20-01 LOONTECH Hyde Original with LOONTECH Spearmint

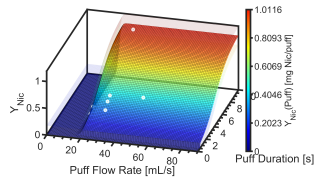



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

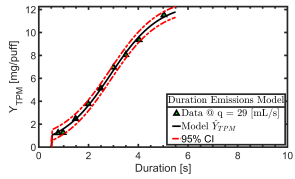
MinAD $= 0.5$ s
MaxAD $= 10.$ s
MinAF $= 16.$ mL/s
MaxAF $= 86.$ mL/s

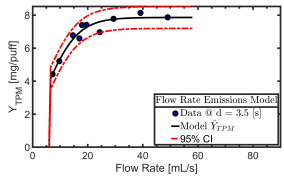
$B_1 = 5.532$ $B_2 = 1.430$ $B_3 = 18.85$ $B_4 = 17.15$ $B_5 = 0.6373$ $B_6 = 4.273$

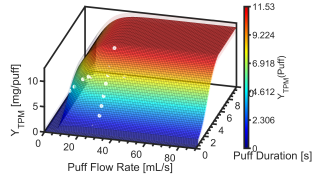
$f_{Nic} = 0.061 \pm 0.009 mg/mg$

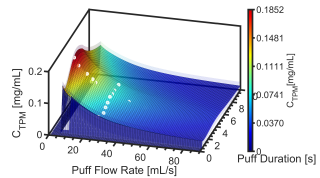
Max $Y_{TPM}(puff) = 16.7 \pm 2.65 mg/puff$
Max $Y_{Nic}(puff) = 0.015 \pm 0.177 mg/puff$
Max $C_{TPM} = 0.114 \pm 0.027 mg/mL$

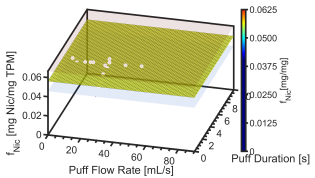
# Emissions Model: EC15-01 NJOY Ace with NJOY Classic Tobacco

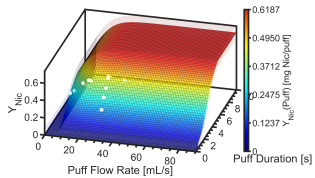



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

MinAD $= 0.5$ s
MaxAD $= 5.5$ s

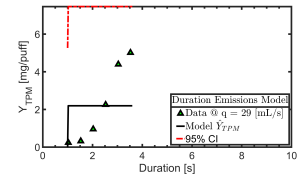
MinAF $= 6.$ mL/s
MaxAF $= 58.$ mL/s

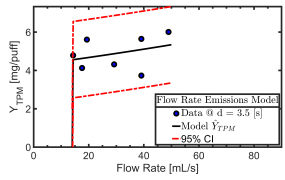
$B_1 = 7.860$ $B_4 = 12.60$
$B_2 = 0.181$ $B_5 = 1.020$
$B_3 = 5.814$ $B_6 = 2.876$

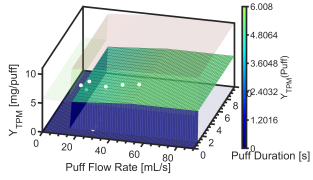
$f_{Nic} = 0.056 \pm 0.019 mg/mg$

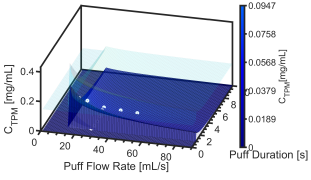
Max $Y_{TPM}(puff) = 11.79 \pm 8.97 mg/puff$
Max $Y_{Nic}(puff) = 0.663 \pm 0.010 mg/puff$
Max $C_{TPM} = 0.190 \pm 0.012 mg/mL$

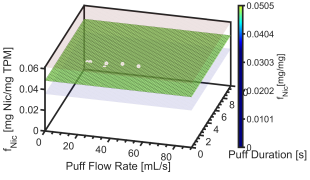
# Emissions Model: EC24-01 PUFF BAR Puff Bar with PUFF BAR Tobacco

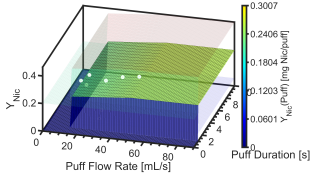



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1+\exp(B_2[q-B_3])} \cdot \frac{B_4}{1+\exp(B_5[d-B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q,d)\hat{Y}_{TPM}(Puff)$$

MinAD = 1.0 s
MaxAD = 3.6 s

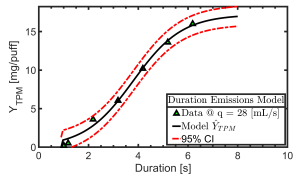
MinAF = 14.mL/s
MaxAF = 50. mL/s

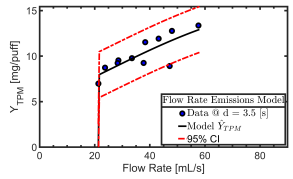
$B_1$ =230.1
$B_2$ = 0.0045
$B_3$ = 876.1
$B_4$ = 2.198
$B_5$ = -5255.4
$B_6$ = 4.365

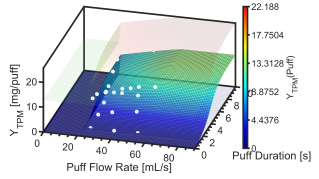
$f_{Nic} = 0.049 \pm 0.013 mg/mg$

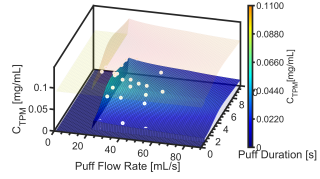
Max $Y_{TPM}(puff) = 5.343 \pm 5.721 mg/puff$
Max $Y_{Nic}(puff) = 0.260 \pm 0.204 mg/puff$
Max $C_{TPM} = 0.288 \pm 0.144 mg/mL$

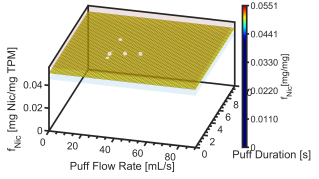
# Emissions Model: EC12-01 SMOK Novo 2 with MAD HATTER JUICE Classic Tobacco

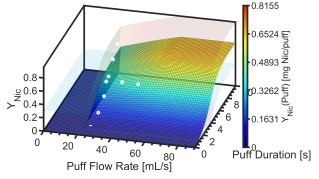



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)}\left(\frac{B_1}{1+\exp(B_2[q-B_3])}\cdot\frac{B_4}{1+\exp(B_5[d-B_6])}\right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q\cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q,d)\hat{Y}_{TPM}(Puff)$$

MinAD $= 0.9$ s
MaxAD $= 8.0$ s

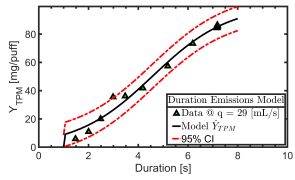
MinAF $= 21.3$ mL/s
MaxAF $= 58.$ mL/s

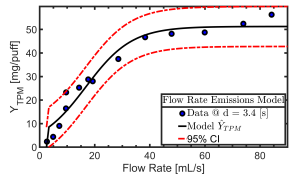
$B_1$ =17.113
$B_2 = 0.0348$
$B_3 = 25.603$
$B_4 = 17.206$
$B_5 = 1.017$
$B_6 = 3.798$

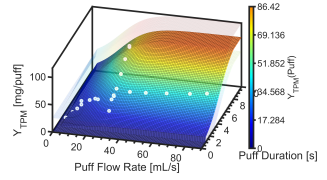
$f_{Nic} = 0.051 \pm 0.005 mg/mg$

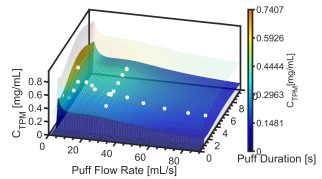
Max $Y_{TPM}(puff) = 12.8 \pm 12.9 mg/puff$
Max $Y_{Nic}(puff) = 0.65 \pm 0.31 mg/puff$
Max $C_{TPM} = 0..057 \pm 0.091 mg/mL$

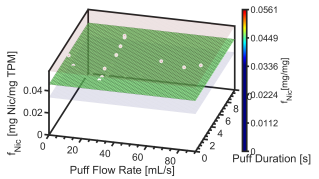
# Emissions Model: EC23-01 SMOK Stick Prince MAD HATTER JUICE Classic Tobacco

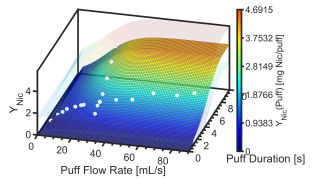



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

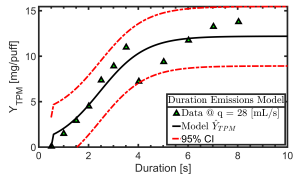
MinAD $= 2.5$ s
MaxAD $= 8.$ s
MinAF $= 2.5$ mL/s
MaxAF $= 90.$ mL/s

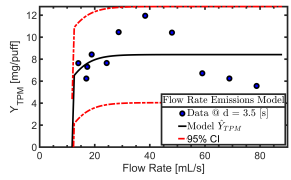
$B_1 = 51.253$ $B_4 = 100.66$
$B_2 = 0.120$ $B_5 = 0.654$
$B_3 = 16.803$ $B_6 = 4.581$

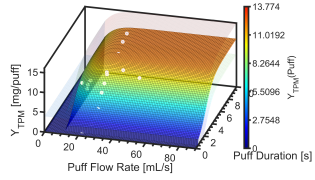
$f_{Nic} = 0.046 \pm 0.012 mg/mg$

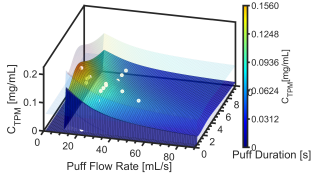
Max $Y_{TPM}(puff) = 90.94 \pm 25.94 mg/puff$
Max $Y_{Nic}(puff) = 4.175 \pm 1.688 mg/puff$
Max $C_{TPM} = 0.651 \pm 0.312 mg/mL$

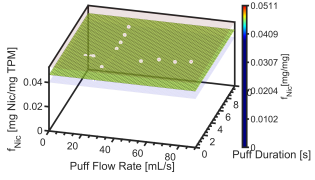
# Emissions Model: EC16-01 UWELL Caliburn MAD HATTER JUICE Classic Tobacco

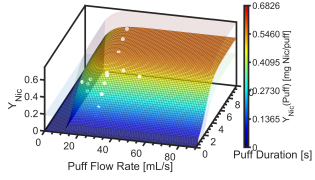



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)}\left(\frac{B_1}{1+\exp(B_2[q-B_3])}\cdot\frac{B_4}{1+\exp(B_5[d-B_6])}\right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q\cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q,d)\hat{Y}_{TPM}(Puff)$$

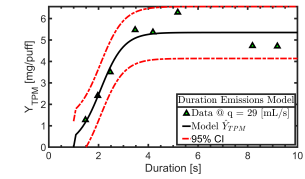
MinAD $= 0.5$ s
MaxAD $= 10.$ s
MinAF $= 11.8$ mL/s
MaxAF $= 88.$ mL/s

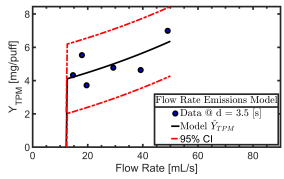
$B_1 = 8.416$ $B_2 = 0.215$ $B_3 = 6.813$ $B_4 = 12.196$ $B_5 = 1.093$ $B_6 = 2.454$

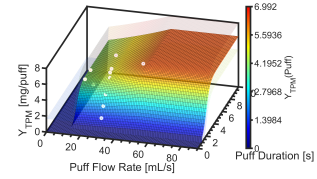
$f_{Nic} = 0.046 \pm 0.006 mg/mg$

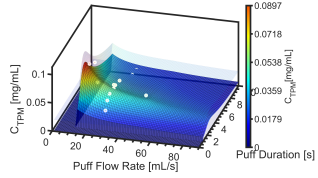
Max $Y_{TPM}(puff) = 12.2 \pm 3.96 mg/puff$
Max $Y_{Nic}(puff) = 0.565 \pm 0.186 mg/puff$
Max $C_{TPM} = 0.167 \pm 0.059 mg/mL$

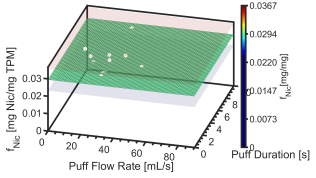
# Emissions Model: EC18-01 VAPOR4LIFE Titan VAPOR4LIFE Wowbacco

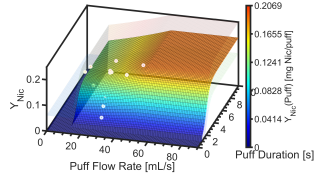



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)}\left(\frac{B_1}{1+\exp(B_2[q-B_3])}\cdot\frac{B_4}{1+\exp(B_5[d-B_6])}\right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q\cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q,d)\hat{Y}_{TPM}(Puff)$$

MinAD = 1.00 s
MaxAD = 10. s

MinAF = 12.2 mL/s
MaxAF = 50. mL/s

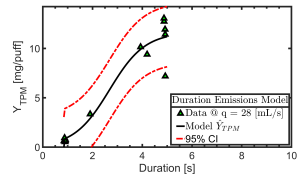
$B_1$ =349.59
$B_2$ = 0.012
$B_3$ = 386.3

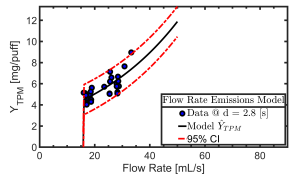
$B_4$ = 5.350
$B_5$ = 2.125
$B_6$ = 2.081

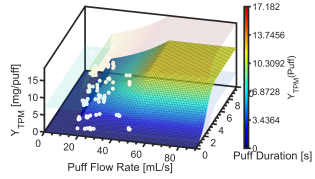
$f_{Nic} = 0.0296 \pm 0.030 mg/mg$

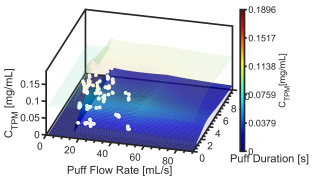
Max $Y_{TPM}(puff) = 6.365 \pm 1.664 mg/puff$
Max $Y_{Nic}(puff) = 0.188 \pm 0.061 mg/puff$
Max $C_{TPM} = 0.094 \pm 0.019 mg/mL$

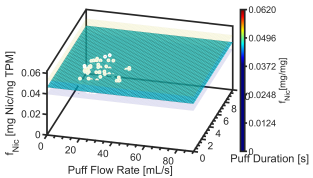
# Emissions Model: EC10-01 VUSE Alto VUSE Original

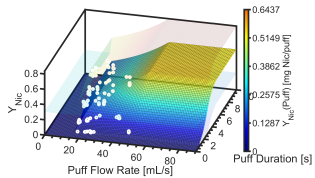



$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

MinAD = 0.85 s
MaxAD = 5. s

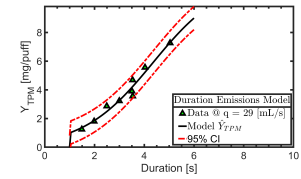
MinAF = 15.8 mL/s
MaxAF = 50. mL/s

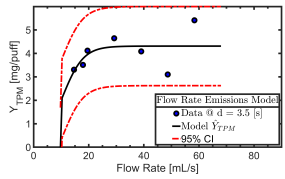
$B_1$ =298.59
$B_2$ = 0.029
$B_3$ = 158.37
$B_4$ = 11.636
$B_5$ = 1.404
$B_6$ = 2.686

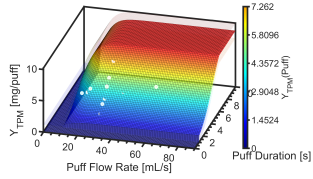
$f_{Nic} = 0.046 \pm 0.007 mg/mg$

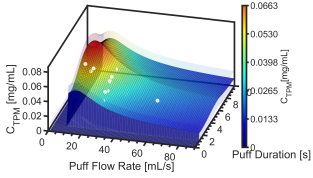
Max $Y_{TPM}(puff) = 11.43 \pm 7.23 mg/puff$
Max $Y_{Nic}(puff) = 0.531 \pm 0.305 mg/puff$
Max $C_{TPM} = 0.061 \pm 0.085 mg/mL$

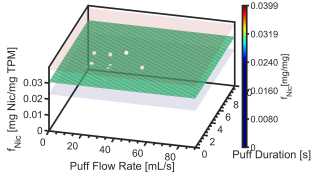
# Emissions Model: EC22-01 VUSE Vibe VUSE Original

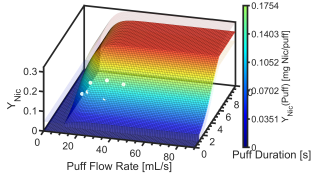


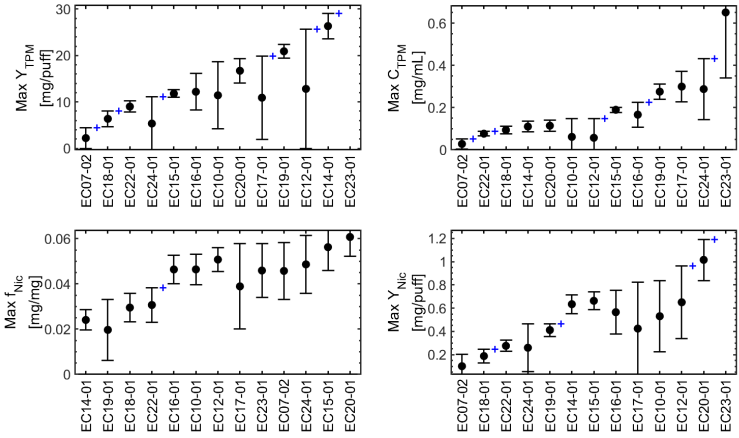

$$\hat{Y}_{TPM}(Puff) = \frac{1}{\min(B_1, B_4)} \left( \frac{B_1}{1 + \exp(B_2[q - B_3])} \cdot \frac{B_4}{1 + \exp(B_5[d - B_6])} \right); \quad \hat{C}_{TPM} = \frac{\hat{Y}_{TPM}(Puff)}{q \cdot d}; \quad \hat{Y}_{Nic}(Puff) = f_{Nic}(q, d)\hat{Y}_{TPM}(Puff)$$

MinAD = 1. s  MinAF = 9.75 mL/s  $B_1 = 4.310$  $B_4 = 11.788$  $f_{Nic} = 0.031 \pm 0.008 mg/mg$  Max $Y_{TPM}(puff) = 8.998 \pm 1.21 mg/puff$

MaxAD = 6. s  MaxAF = 68. mL/s  $B_2 = 0.265$  $B_5 = 0.711$  Max $Y_{Nic}(puff) = 0.276 \pm 0.048 mg/puff$

$B_3 = 10.538$  $B_6 = 4.353$  Max $C_{TPM} = 0.077 \pm 0.010 mg/mL$

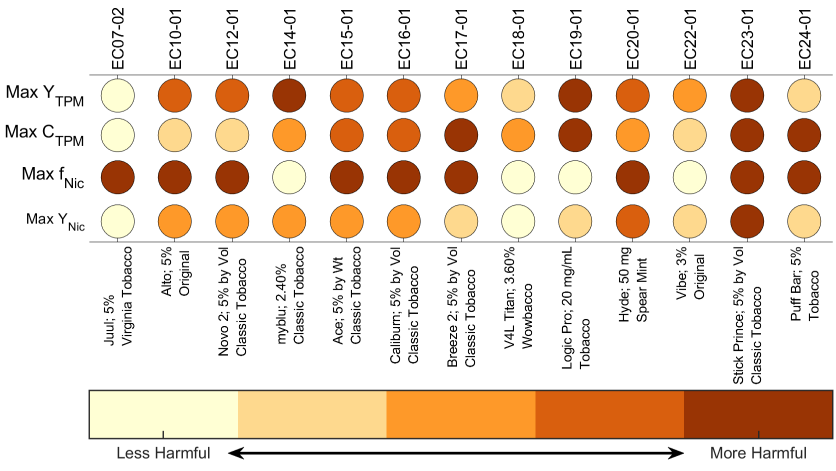
# Interval Plot: Tobacco Product Maximum Emissions Characteristics Comparison



# Tobacco Product Emissions Characteristics

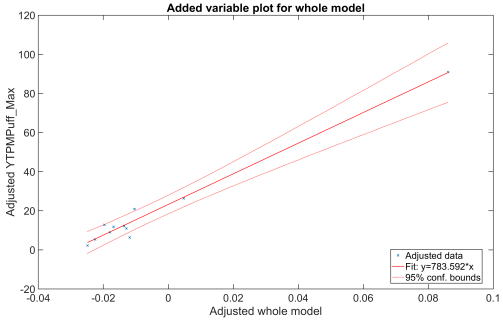
| Product ID Code | Device Manufacturer | Device Model | Consumable Manufacturer | Consumable Labeled Flavor | Max $Y_{TPM}$ [mg/puff] | Max $C_{TPM}$ [mg/mL] | Max $f_{Nic}$ [mg/mg] | Max $Y_{Nic}$ [mg/puff] |
|---|---|---|---|---|---|---|---|---|
| EC07-02 | JUUL LABS | Juul | JUUL LABS | Virginia Tobacco | 2.210 | 0.028 | 0.046 | 0.101 |
| EC10-01 | VUSE | Alto | VUSE | Original | 11.433 | 0.061 | 0.046 | 0.531 |
| EC12-01 | SMOK | Novo 2 | MAD HATTER JUICE | Classic Tobacco | 12.814 | 0.057 | 0.051 | 0.650 |
| EC14-01 | BLU | myblu | BLU | Classic Tobacco | 26.341 | 0.110 | 0.024 | 0.634 |
| EC15-01 | NJOY | Ace | NJOY | Classic Tobacco | 11.790 | 0.190 | 0.056 | 0.663 |
| EC16-01 | UWELL | Caliburn | MAD HATTER JUICE | Classic Tobacco | 12.193 | 0.167 | 0.046 | 0.565 |
| EC17-01 | ASPIRE | Breeze 2 | MAD HATTER JUICE | Classic Tobacco | 10.911 | 0.300 | 0.039 | 0.424 |
| EC18-01 | VAPOR4LIFE | V4L Titan | VAPOR4LIFE | Wowbacco | 6.365 | 0.094 | 0.030 | 0.188 |
| EC19-01 | LOGIC VAPES | Logic Pro | LOGIC VAPES | Tobacco | 20.911 | 0.276 | 0.020 | 0.412 |
| EC20-01 | LOONTECH | Hyde Original | LOONTECH | Spearmint | 16.714 | 0.114 | 0.061 | 1.015 |
| EC22-01 | VUSE | Vibe | VUSE | Original Tobacco | 8.998 | 0.077 | 0.031 | 0.276 |
| EC23-01 | SMOK | Stick Prince | MAD HATTER JUICE | Classic Tobacco | 90.943 | 0.651 | 0.046 | 4.175 |
| EC24-01 | PUFF BAR | Puff Bar | PUFF BAR | Tobacco | 5.343 | 0.288 | 0.049 | 0.260 |

# Maximal emissions screening dashboard for consumer-oriented product comparisons.



**Research Question:** Are there associations between Product Emissions Characteristics (what is delivered to the mouth of a user) and Product Design Characteristics (the design, composition and operation of the tobacco product)?

# Effect of Product Design Characteristics on Max $\hat{Y}_{TPM}(Puff)$




| Estimated Coefficients: | Estimate | SE | tStat | pValue |
|---|---|---|---|---|
| (Intercept) | 23.229 | 28.23 | 0.8228 | 0.457 |
| MaxAF | 0.2516 | 0.1078 | 2.335 | 0.0798 |
| MaxAD | -1.7727 | 1.355 | -1.3082 | 0.261 |
| $R_{Coil}$ | -2.5472 | 5.000 | -0.5094 | 0.637 |
| Max $P_{Nom}$ | 1.4806 | 0.1667 | 8.882 | 0.000888 |
| $f_{Nic}$ Unpuffed | -783.4 | 319.4 | -2.453 | 0.0702 |
| PG Fraction | 17.098 | 15.16 | 1.128 | 0.322 |

Number of observations: 11

Error degrees of freedom: 4

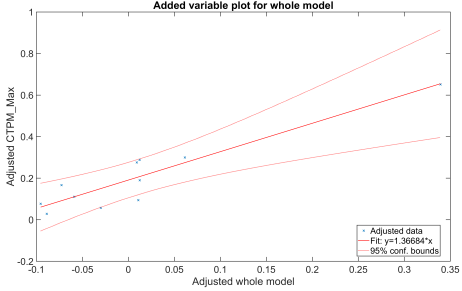
Root Mean Squared Error: 5.62

R-squared: 0.98, Adjusted R-Squared: 0.95

F-statistic vs. constant model: 31.8, p-value = 0.00246

Conclusion: Coil Power is significantly associated ($p < 0.001$) with Max $\hat{Y}_{TPM}(Puff)$.
Conclusion: E-Liquid Nicotine Concentration is marginally associated ($p \approx 0.07$) with Max$\hat{Y}_{TPM}(Puff)$.
Conclusion: Max AF is marginally associated ($p \approx 0.08$) with Max $\hat{Y}_{TPM}(Puff)$.

# Effect of Product Design Characteristics on Max $\hat{C}_{TPM}$




| Estimated Coefficients: | Estimate | SE | tStat | pValue |
|---|---|---|---|---|
| (Intercept) | 0.191 | 0.51052 | 0.37413 | 0.7273 |
| MaxAF | -0.0014389 | 0.0019487 | -0.73839 | 0.50126 |
| MaxAD | -0.01002 | 0.024504 | -0.40893 | 0.70354 |
| $R_{Coil}$ | -0.012922 | 0.090422 | -0.1429 | 0.89328 |
| Max $P_{Nom}$ | 0.0099909 | 0.0030143 | 3.3145 | 0.02953 |
| $f_{Nic}$ Unpuffed | -1.3392 | 5.7751 | -0.2319 | 0.828 |
| PG Fraction | 0.27256 | 0.2741 | 0.99439 | 0.37632 |

Number of observations: 11

Error degrees of freedom: 4

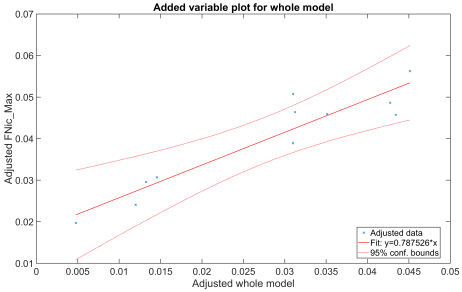
Root Mean Squared Error: 0.102

R-squared: 0.868, Adjusted R-Squared: 0.669

F-statistic vs. constant model: 4.37, p-value = 0.0874

Conclusion: Coil Power is significantly associated ($p < 0.03$) with Max $\hat{C}_{TPM}$..

# Effect of Product Design Characteristics on Max $\hat{f}_{Nic}(Puff)$




| Estimated Coefficients: | Estimate | SE | tStat | pValue |
|---|---|---|---|---|
| (Intercept) | 0.017905 | 0.032952 | 0.54335 | 0.61575 |
| MaxAF | 2.2308e-05 | 0.00012578 | 0.17736 | 0.86784 |
| MaxAD | -0.00033789 | 0.0015816 | -0.21363 | 0.84128 |
| $R_{Coil}$ | -0.0047046 | 0.0058364 | -0.80609 | 0.46539 |
| Max $P_{Nom}$ | -0.0002499 | 0.00019456 | -1.2844 | 0.26834 |
| $f_{Nic}$ Unpuffed | 0.78746 | 0.37276 | 2.1125 | 0.1022 |
| PG Fraction | 0.0087818 | 0.017692 | 0.49637 | 0.64567 |

Number of observations: 11

Error degrees of freedom: 4

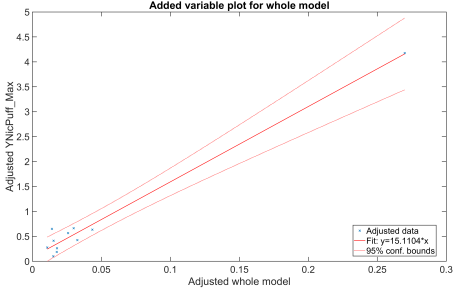
Root Mean Squared Error: 0.00656

R-squared: 0.879, Adjusted R-Squared: 0.698

F-statistic vs. constant model: 4.85, p-value = 0.0741

Conclusion: E-Liquid Nicotine Concentration is marginally associated ($p \approx 0.1$) with Max $\hat{f}_{Nic}$.

# Effect of Product Design Characteristics on Max $\hat{Y}_{Nic}(Puff)$




| Estimated Coefficients: | Estimate | SE | tStat | pValue |
|---|---|---|---|---|
| (Intercept) | 0.082103 | 1.3125 | 0.062552 | 0.95312 |
| MaxAF | 0.0090964 | 0.00501 | 1.8157 | 0.1436 |
| MaxAD | -0.062473 | 0.063 | -0.99164 | 0.3775 |
| $R_{Coil}$ | -0.02223 | 0.23248 | -0.095622 | 0.92842 |
| Max $P_{Nom}$ | 0.06775 | 0.0077498 | 8.7422 | 0.00094341 |
| $f_{Nic}$ Unpuffed | -15.094 | 14.848 | -1.0166 | 0.36684 |
| PG Fraction | 0.69682 | 0.70471 | 0.98881 | 0.37873 |

Number of observations: 11

Error degrees of freedom: 4

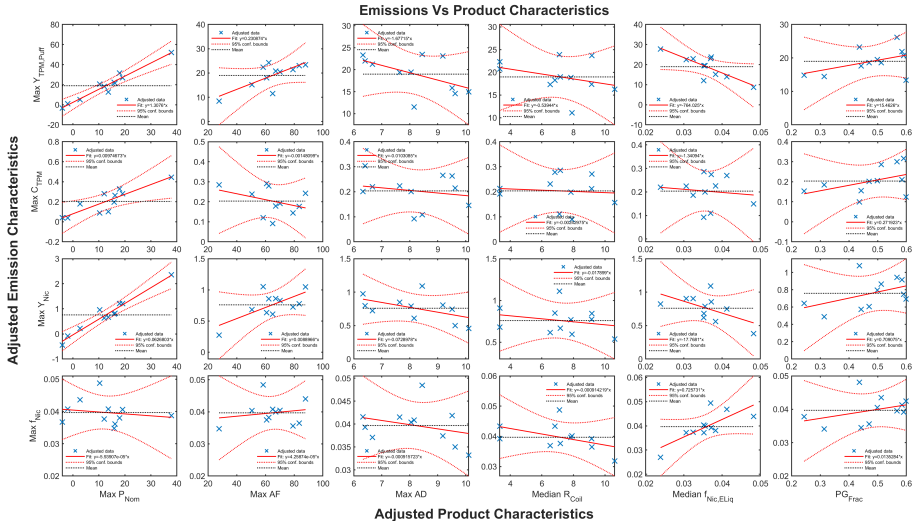
Root Mean Squared Error: 0.261

R-squared: 0.979, Adjusted R-Squared: 0.948

F-statistic vs. constant model: 31.6, p-value = 0.00249

Conclusion: Coil Power is significantly associated ($p < 0.001$) with Max $\hat{Y}_{Nic}(Puff)$.

# Identifying Influential Product Design Characteristics for ENDS Regulation



**Regulatory Recommendations:**

- The product emission characteristics of Max $\hat{Y}_{TPM}$, Max $\hat{C}_{TPM}$, Max $\hat{Y}_{Nic}$ and Max $\hat{Y}_{HPHC}$ should be regulated.
- The product design characteristic of maximum achievable power dissipated in the coil, Max $P_{Coil}$, should be regulated.

# Product User Behavior Characteristics

## What is needed: An essential gap

| Device Manufacturer | Device Model | Consumable Manufacturer | Consumable Labeled Flavor | Range $q_{Puff}$ [mL/s ] | Range $d_{Puff}$ [s] | Range $v_{Puff}$ [mL] | Range $N_{PD}$ [puff/day] | Range $N_{PS}$ [puff/sess] | Range $N_{SD}$ [sess/day] | Session Duration [s] | Session Period [s] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JUUL LABS | Juul | JUUL LABS | Virginia Tobacco | | | | | | | | |
| VUSE | Alto | VUSE | Original | | | | | | | | |
| SMOK | Novo 2 | MAD HATTER | Classic Tobacco | | | | | | | | |
| BLU | myblu | BLU | Classic Tobacco | | | | | | | | |
| NJOY | Ace | NJOY | Classic Tobacco | | | | | | | | |
| UWELL | Caliburn | MAD HATTER | Classic Tobacco | | | | | | | | |
| ASPIRE | Breeze 2 | MAD HATTER | Classic Tobacco | | | | | | | | |
| VAPOR4LIFE | V4L Titan | VAPOR4LIFE | Wowbacco | | | | | | | | |
| LOGIC VAPES | Logic Pro | LOGIC VAPES | Tobacco | | | | | | | | |
| LOONTECH | Hyde Original | LOONTECH | Spearmint | | | | | | | | |
| VUSE | Vibe | VUSE | Original Tobacco | | | | | | | | |
| SMOK | Stick Prince | MAD HATTER | Classic Tobacco | | | | | | | | |
| PUFF BAR | Puff Bar | PUFF BAR | Tobacco | | | | | | | | |