



Original investigation

# The Potential That Electronic Nicotine Delivery Systems Can be a Disruptive Technology: Results From a National Survey

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## Abstract

**Introduction:** This study evaluates the reasons for use and acceptance of Electronic Nicotine Delivery Systems (ENDS) among current and former cigarette smokers to assess if ENDS may become a satisfying alternative to cigarettes.

**Methods:** Data are from a national probability sample of 5717 US adults, surveyed June–November 2014. The survey contained questions on awareness, usage, and reasons for use of traditional and novel tobacco products. The analytic sample was current and former smokers who ever used ENDS ( $n = 729$ ) and was divided into four mutually exclusive categories. Among the 585 current smokers, 337 were no longer using ENDS (“E-Cig Rejecters”), and 248 were continuing to use both ENDS and cigarettes (“E-Cig Dual Users”). Among 144 former cigarette smokers, 101 were non-recent users of ENDS (“Quit All Products”), and 43 were continuing to use ENDS exclusively (“Switchers”).

**Results:** Former smokers (the “Switchers”) report finding ENDS a satisfying alternative to regular cigarettes, with only 15.8% (95% confidence interval [CI] 4.4–27.1) rating ENDS as less enjoyable than regular cigarettes. However, greater than fivefold more current smokers did not find them satisfying and stopped using them (77.3%; 95% CI 72.1–82.4 of “E-Cig Rejecters” rated ENDS as less enjoyable). Being less harmful was the most highly rated reason for continuing to use ENDS among “Switchers.” Most (80.9%) “Switchers” reported that ENDS helped them quit cigarettes.

**Conclusion:** Since many current smokers who have tried ENDS reject them as a satisfying alternative to regular cigarettes, ENDS will not replace regular cigarettes unless they improve.

**Implications:** Since about one-half of recent former smokers are trying ENDS with about one-fourth continuing to use them, and many reporting that these products have helped them quit regular cigarettes, the potential impact of ENDS on population quit rates deserves continued surveillance. However, since most current smokers who have tried ENDS reject them as a satisfying alternative to regular cigarettes, the potential of ENDS becoming a disruptive technology replacing regular cigarettes remains uncertain. ENDS need to improve as a satisfying alternative or the attractiveness and appeal of the regular cigarette must be degraded to increase the potential of ENDS replacing regular cigarettes.

## Introduction

Over the last 50 years, progress in tobacco control is estimated to have saved approximately 8 million Americans from premature death caused by smoking; however, over the same period, smoking has caused the deaths of more than 20 million Americans.<sup>1,2</sup> Moreover, each year about an additional 500 000 Americans will die prematurely from a smoking-related illness.<sup>1</sup> Recognizing that this persisting deadly toll is caused primarily by the highly engineered, addictive, and lethal cigarette, the public health community has been debating whether the emerging Electronic Nicotine Delivery Systems (ENDS) could become a disruptive technology that would compete with combusted tobacco products as satisfying and efficient alternative sources of nicotine and thus disrupt the entire tobacco product market.<sup>3-12</sup> Unlike sustaining innovations which improve an existing product, disruptive innovations fundamentally differ from existing technologies, usually by being less complicated, more accessible, and less expensive (eg, "...the Kodak moment when, with the rise of digital processes, photographic film manufacturers were left with an obsolete technology [p. 653]").<sup>12-14</sup> Thus, for the cigarette smoker who is unable or unwilling to discontinue using nicotine, an alternative product which provides "nicotine without the hazards associated with smoking (p. 654)" can be a disruptive innovation if it becomes widely adopted.<sup>12</sup> While the efficiency of nicotine delivery is a key product characteristic in defining ENDS as a potential disruptive innovation,<sup>3,5,12,15-20</sup> research has shown that perceptions about the potential health benefits of ENDS are a primary predictor of use among cigarette smokers.<sup>21-27</sup>

Most of the evidence about ENDS users' reasons for use and satisfaction have focused on differences between ever users and current users and were based on use of earlier or first-generation models of e-cigarettes (ie, from 2010 to 2013).<sup>21-25</sup> However, ENDS products are evolving and improving beyond the initial "cig-alike" designs.<sup>15-20,28</sup> Recently, Finney-Rutten and colleagues reported that the use of ENDS by current smokers in 2014 was motivated by potential health benefits and related to higher intentions to quit or reduce amount smoked.<sup>27</sup> Another recent survey in the United States (May, 2014) by Rass and colleagues reported that among dual users of ENDS and tobacco cigarettes, the primary reasons for using ENDS were harm reduction and smoking cessation.<sup>26</sup> However, neither these studies,<sup>26,27</sup> nor other national surveys of ENDS use,<sup>29-31</sup> have evaluated if recent former smokers in the United States are finding ENDS a satisfying alternative to the regular cigarette.

Preliminary findings from the nationally representative US National Health Interview Survey (NHIS) of 36 697 civilian adults aged 18 and over living in US households in 2014 reported that almost half of current smokers had ever used ENDS (ie, ever tried, even just one time), with 15.9% currently using ENDS (ie, at least once during the past 30 days), and 22% of recent former smokers (quit within the past year) currently using ENDS.<sup>32-34</sup> Additionally, NHIS estimates of current smoking prevalence have shown recent declines.<sup>35</sup> These declining smoking rates plus the high rates of ENDS use among recent former smokers are consistent with a potential emerging pattern of tobacco product market disruption. However, the NHIS does not include data on attitudes and reasons for use of ENDS needed to evaluate if the recent former smokers are finding ENDS a satisfying alternative to the regular cigarette.

Our 2014 Tobacco Products and Risk Perception Survey observed rates of ENDS similar to the 2014 NHIS reported rates; 51.1% of current smokers reported ever using ENDS, with 20.7% currently using ENDS, and 25.9% of recent former smokers (quit within the

past year) using ENDS.<sup>34</sup> Since the probability sample used in the Tobacco Products and Risk Perception Survey provides representative estimates of non-institutionalized US adults and includes more detailed data on use of ENDS, we examined attitudes and reasons for use of ENDS among four groups of recent former and current smokers to assess the potential that ENDS could become a disruptive technology that replaces combusted tobacco products in the United States.<sup>3,6,8,9,12</sup>

## Methods

### Procedure and Sample

This study used data from the 2014 Tobacco Products and Risk Perceptions Survey conducted June–November, 2014 by the Georgia State University (GSU) Tobacco Center of Regulatory Science (TCORS). This survey is an annual, cross-sectional survey of a probability sample drawn from Gfk's KnowledgePanel, an online web panel designed to be representative of non-institutionalized US adults; the survey sample includes a representative oversample of pre-identified cigarette smokers selected with probabilities proportional to size (PPS) after application of the panel demographic post-stratification weight. Overall, we invited 7991 KnowledgePanel members to participate in the survey: 7061 members for the general population sample, of which 74.3% completed the screener survey and qualified for the main survey; and 930 members for the smoker augment sample, of which 697 completed the screener and 599 (74.9%) qualified for the main survey by confirming their current smoking status. Thus, from the 7991 KnowledgePanel members invited to participate in the survey, we obtained a sample of 5833 qualified participants who completed the survey. After excluding 116 cases for refusing to answer more than one-half of the survey questions, the final sample was 5717 cases, yielding a final stage completion rate of 74.4% and a qualification rate of 98.2%. The sample of interest for the present study consisted of 729 current and former smokers whom reported ever use of ENDS. This study was approved by the GSU Institutional Review Board.<sup>34</sup> More details on the survey sample, weights, and missing data are provided in the [Supplementary Material](#).

## Measures

### Cigarette Smoking Status

Smoking status was assessed using two items, "have you smoked at least 100 cigarettes in your lifetime" and "when was the last time you smoked a cigarette, even one or two puffs?" Respondents that reported not having smoked at least 100 cigarettes in their lives were classified as "never-smokers." Of the remaining respondents, those who reported as having smoked at least 100 cigarettes and reported currently smoking cigarettes "every day" or "some days" were classified as "current smokers" and those who responded "not at all" were classified as "former smokers." Former smokers who reported current use of any other combustible tobacco product (eg, little cigars or cigarillos, large cigars, and/or hookah) were excluded from the analysis.

### Use of ENDS

Awareness and use of ENDS were assessed by asking respondents if they had heard of the product before taking the survey and, if so, whether they had ever tried the product, even just one time. Prior to the questions assessing awareness and use of these products, respondents were shown descriptions and images of ENDS. The description for ENDS used the descriptor "e-cigarette" to broadly include ENDS

products. Those respondents who indicated they had tried one or more of the products were asked whether they had used each of the products at least once during the past 30 days. Respondents reporting past 30-day use were considered current users.

Weaver et al.<sup>34</sup> previously reported the patterns of use of ENDS and other traditional tobacco products in this 2014 online sample of 5717 US adults. Among the overall weighted sample, 16.6% (95% confidence interval [CI]: 15.6–17.6, unweighted  $n = 1349$ ) were current cigarette smokers and 27.6% (95% CI: 26.3–28.8, unweighted  $n = 1554$ ) were former cigarette smokers. Among the current smokers, 51.1% (unweighted  $n = 585$ ) reported ever use of ENDS, and 20.7% (unweighted  $n = 248$ ) reported use of ENDS in the past 30 days. Among the former smokers, 13.1% (unweighted  $n = 164$ ) reported ever use of ENDS, and 3.8% (unweighted  $n = 52$ ) reported use of ENDS in the past 30 days. Twenty of these 164 former cigarette smokers were excluded from the analysis due to missing data ( $n = 5$ ) or due to current use of any combustible tobacco product (eg, little cigars or cigarillos, hookahs, or large cigars;  $n = 15$ ), yielding a sample of 144, among whom 101 were non-recent users of ENDS and 43 were continuing to use ENDS exclusively.

### ENDS and Smoker User-Groups

The selected sample (unweighted  $n = 729$ ) of current and former smokers reporting ever use of ENDS were classified into four mutually exclusive groups based on their current use of ENDS: E-Cig Rejecters, E-Cig Dual Users, Quit All Products, and Switchers. Current cigarette smokers who had ever used ENDS but who were no longer using them were classified as E-Cig Rejecters ( $n = 337$ ). E-Cig Dual Users ( $n = 248$ ) were current cigarette smokers who were also currently using ENDS. “Quit All Products” ( $n = 101$ ) were defined as former smokers who had tried ENDS but no longer using them or any combustible tobacco product. Switchers ( $n = 43$ ) were former smokers who reported use of ENDS in the past 30 days but reported no current use of any other combustible tobacco product (eg, little cigars or cigarillos, hookahs, or large cigars). [Supplementary Table S1](#) provides a summary of these four mutually-exclusive groups.

### Attitudes, Affect, and Reasons for Use of ENDS

Respondents were asked a series of questions about their attitudes toward ENDS, reasons for use, and perceptions of how ENDS compared with smoking regular cigarettes. To measure affect toward ENDS, respondents were asked: “If you were to use an e-cigarette, would it make your feel...?” Similarly, they were asked: “How tense or relaxed would using an e-cigarette make you feel?” Current and former smokers who had ever used ENDS were asked: “How would you compare the experience of using e-cigarettes to smoking regular cigarettes?” (Responses included: “E-cigarettes are more enjoyable,” “About the same,” or “E-cigarettes are less enjoyable”).

To assess reasons for using ENDS, respondents were asked: “For each reason listed, please indicate how important it is to you in your use of e-cigarettes.”

Reasons were presented in random order:

1. I could use them in places where regular cigarette smoking isn't allowed
2. E-cigarettes are less harmful to me than regular cigarettes
3. E-cigarettes are less harmful to those around me than regular cigarettes
4. E-cigarettes could help me quit smoking regular cigarettes
5. E-cigarettes could help me reduce the number of regular cigarettes I smoke

6. Using an e-cigarette feels like smoking a regular cigarette
7. E-cigarettes are more acceptable than regular cigarettes
8. To satisfy my curiosity
9. They come in flavors I like
10. People who are important to me use e-cigarettes

### ENDS and Quitting Regular Cigarettes

Former smokers who had ever tried ENDS were asked: “Did using e-cigarettes help you quit smoking regular cigarettes?” (Responses included: “Yes,” “No,” and “I don't know”) and “How likely are you to go back to smoking regular cigarettes in the future, now that you've used e-cigarettes?” (Responses included: 1 = “Very unlikely” to 5 = “Very likely”). All respondents were also asked: “In your opinion, are cigarette smokers who also use e-cigarettes more likely to quit smoking regular cigarettes, less likely to quit, or equally likely to quit smoking regular cigarettes.”

### Respondent Characteristics

Demographic and other respondent characteristics data were obtained from profile surveys administered by GfK to all KnowledgePanel panelists. Respondent characteristics included self-reported sex, age, race/ethnicity, educational attainment, annual household income, US Census region, perceived health status, sexual orientation, and presence of a child (under 18 years) in the home.

### Statistical Analysis

We used SAS 9.4 to obtain design-based (weighted) point estimates and 95% CIs. Bivariate associations among variables were tested using Rao-Scott  $\chi^2$  tests,<sup>36</sup> and between group differences were tested using multinomial logistic regression, or weighted  $F$  or  $t$ -tests. Prior to conducting these analyses, we assessed the extent and ignorability of missing data for “ever use” and past 30-day use questions for the tobacco products. On the bases of these checks, respondents with missing data were excluded from further analyses under the data supported assumption that missingness is ignorable and completely at random (See Weaver et al.<sup>34</sup> [Supplementary Material](#) for an expanded summary of the missing data.).

### Results

[Table 1](#) reports the population demographics of the selected sample ( $n = 729$ ) of current and former smokers reporting ever use of ENDS and the four mutually exclusive groups based on their current use of ENDS: E-Cig Rejecters, E-Cig Dual Users, Quit All Products, and Switchers. In multinomial logistic regression analyses, the four groups were similar in sociodemographic distributions for sex, age, race/ethnicity, household income, perceived health status, sexual orientation, and presence of children under 18 in the home, although E-Cig Rejecters and E-Cig Dual Users were less likely than Switchers to have a college degree ( $P = .002$  and  $P = .044$ , respectively). E-Cig Rejecters also were less likely than Switchers to live in the West region of the United States ( $P = .0235$ ). Weighted frequencies by population demographics are provided in [Supplementary Table S2](#).

[Figure 1](#) displays the mean rating of importance for each of the 10 reasons for using ENDS across the four groups. Details on statistical testing of these ratings across the four groups are provided in [Supplementary Table S3](#). Switchers rated ENDS “were less harmful to me than regular cigarettes” and “could help me quit smoking regular cigarettes” as highly important reasons for using ENDS, with ratings significantly higher than the E-Cig Rejecters and the Quit All products

Table 1. Respondent Characteristics Among Current and Former Smokers Who Have Ever Used ENDS

Respondent characteristics	Total (current and former smokers who have ever used ENDS) (N = 729)		E-Cig Rejecters (Current Smoker and Non-recent ENDS User) (n = 337)		E-Cig Dual Users (Current Smoker and Recent ENDS User) (n = 248)		Quit All Products (former smoker and non-recent ENDS user) (n = 101)		Switchers (former smoker and recent ENDS user) (n = 43)		Adjusted odds ratio switchers (ref) VS.	
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	E-Cig Rejecters	E-Cig Dual Users	Quit All Products	
Sex												
Male	50.7 (46.5–54.9)	50.3 (44.2–56.4)	51.3 (44.0–58.6)	48.7 (38.5–59.0)	55.6 (39.4–71.9)	Ref	Ref	1.5 (0.7–3.2)				
Female	49.3 (45.1–53.5)	49.7 (43.6–55.8)	48.7 (41.4–56.0)	51.3 (41.0–61.5)	44.4 (28.1–60.6)							
Age (y)												
18–34	33.2 (29.1–37.2)	29.0 (23.2–34.8)	36.9 (29.5–44.3)	36.9 (26.9–46.9)	32.0 (15.7–48.2)	Ref	Ref	Ref				
35–54	40.1 (36.0–44.2)	43.2 (37.1–49.2)	37.3 (30.2–44.3)	38.6 (28.5–48.8)	38.4 (22.8–53.9)							
>55	26.7 (23.3–30.2)	27.8 (22.6–33.0)	25.8 (20.1–31.6)	24.5 (16.1–32.9)	29.7 (15.2–44.2)							
Race/ethnicity												
White, NH	72.5 (68.5–76.5)	74.2 (68.5–79.9)	67.0 (59.6–74.3)	77.1 (67.5–86.6)	73.1 (56.7–89.5)	Ref	Ref	Ref				
Others	27.5 (23.5–31.5)	25.8 (20.1–31.5)	33.0 (25.7–40.4)	22.9 (13.4–32.5)	26.9 (10.5–43.3)							
Education												
HS or less	48.5 (44.3–52.6)	54.0 (48.0–60.0)	51.3 (44.1–58.6)	35.9 (25.9–45.9)	39.6 (23.1–56.1)	Ref	Ref	Ref				
Some college	36.8 (32.8–40.7)	35.0 (29.5–40.6)	33.0 (26.4–39.6)	47.0 (36.8–57.3)	34.3 (18.5–50.1)							
>College degree	14.8 (12.0–17.5)	10.9 (7.4–14.5)	15.7 (10.8–20.5)	17.0 (9.8–24.3)	26.1 (13.4–38.7)							
Household income												
<30K	33.9 (29.9–37.9)	37.3 (31.3–43.3)	36.5 (29.3–43.8)	24.1 (15.1–33.0)	30.1 (14.2–46.1)	Ref	Ref	Ref				
30K–60K	29.6 (25.9–33.3)	30.3 (24.8–35.9)	31.1 (24.5–37.8)	28.4 (19.2–37.6)	22.9 (10.1–35.7)							
>60K	36.5 (32.5–40.5)	32.4 (26.7–38.0)	32.3 (25.6–39.0)	47.5 (37.2–57.8)	47.0 (30.7–63.3)							
US region												
Northeast	17.3 (14.1–20.6)	21.0 (15.8–26.1)	14.7 (8.9–20.5)	15.2 (8.0–22.5)	13.0 (2.9–23.1)	Ref	Ref	Ref				
Midwest	22.6 (19.3–25.9)	23.4 (18.6–28.1)	20.8 (15.0–26.5)	24.6 (16.2–33.0)	20.6 (8.0–33.2)							
South	36.7 (32.7–40.7)	37.1 (31.2–43.0)	39.6 (32.5–46.7)	35.2 (25.1–45.3)	27.1 (13.0–41.3)							
West	23.4 (19.7–27.1)	18.6 (13.4–23.7)	25.0 (18.7–31.2)	25.0 (16.0–34.0)	39.2 (22.7–55.7)							
Perceived health status												
Excellent/very good	34.5 (30.4–38.5)	31.2 (25.4–37.0)	36.8 (29.4–44.2)	39.2 (28.8–49.6)	31.7 (16.5–46.9)	Ref	Ref	Ref				
Good	42.0 (37.9–46.2)	43.3 (37.3–49.4)	38.7 (31.6–45.8)	46.2 (35.7–56.7)	37.0 (20.7–53.4)							
Fair/poor	23.5 (19.8–27.2)	25.5 (19.9–31.1)	24.5 (18.1–30.9)	14.6 (7.0–22.3)	31.2 (14.5–48.0)							
Sexual orientation												
Heterosexual	91.2 (88.9–93.5)	92.7 (89.7–95.6)	91.8 (88.4–95.3)	86.6 (79.3–93.9)	93.1 (85.0–100.0)	Ref	Ref	Ref				
Non-heterosexual	8.8 (6.5–11.1)	7.3 (4.4–10.3)	8.2 (4.7–11.6)	13.4 (6.1–20.7)	6.9 (0.0–15.0)							
Presence of children under 18 in the household												
Yes	32.0 (28.0–36.0)	30.5 (24.6–36.4)	34.9 (27.7–42.1)	30.7 (21.3–40.2)	32.3 (16.9–47.7)	Ref	Ref	Ref				
No	68.0 (64.0–72.0)	69.5 (63.6–75.4)	65.1 (57.9–72.3)	69.3 (59.8–78.7)	67.7 (52.3–83.1)							

CI = confidence interval; ENDS = Electronic Nicotine Delivery Systems; NH = Non-Hispanic. Current users of other combustible products (viz., little cigars or cigarillos, large cigars, and/or hookah) were excluded from “Switchers” and “Quit All Products” groups.

\*  $P < .05$ , \*\*  $P < .01$ .

groups ( $P < .05$ ). Rating that “ENDS were less harmful for others around me than regular cigarettes,” and that the ENDS could help users reduce cigarette consumption also were significantly more important reasons among the Switchers than the Quit All Products ( $P < .05$ ). Similarly, ratings for the reason that ENDS “are more acceptable than regular cigarettes” were significantly higher among the Switchers than the Quit All Products ( $P < .05$ ). Ratings on the importance of the reason “To satisfy my curiosity” overall were somewhat lower and did not differ between the four groups. The ratings between groups were significantly different for “They come in flavors I like” ( $P < .0001$ ) with this reason being rated higher among Switchers than the Quit All Products ( $P = .003$ ). This is consistent with 74% (95% CI: 60.4–88.4) of Switchers indicating that they had ever used ENDS with flavors other than tobacco flavors versus 50.6% (95% CI: 43.3–58.0) of E-Cig Dual Users, 35.2% (95% CI: 29.4–41.1) of E-Cig Rejecters, and 34.7% (95% CI: 24.9–44.4) of Quit All Products (Rao-Scott  $\chi^2 = 28.7, P < .0001$ ).

As displayed in Figure 2, the four groups varied significantly when asked to imagine how they would feel using an ENDS, from *very bad* to *very good* (Rao-Scott  $\chi^2 = 107.06, P < .0001$ ) and from *very tense* to *very relaxed* (Rao-Scott  $\chi^2 = 53.4, P < .0001$ ). Among

Switchers, 66.8% (95% CI: 50.6–82.9) felt good or very good, and 68.7% (95% CI: 52.8–84.6) felt somewhat or very relaxed. Similarly, 50.6% (95% CI: 43.0–58.1) of E-Cig Dual Users felt good or very good, and 60.0% (95% CI: 52.6–67.4) felt somewhat or very relaxed. In comparison, only 27.4% (95% CI: 21.4–33.4) of E-Cig Rejecters and 18.9% (95% CI: 10.2–27.5) of Quit All Products imagined that they would feel somewhat or very good, and 38.4% (95% CI: 31.7–45.1) and 39.9% (95% CI: 28.6–51.1), respectively, imagined that they would feel somewhat or very relaxed using an ENDS.

Figure 3 displays the differences in opinions about “How would you compare the experience of using E-cigarettes to smoking regular cigarettes” among the four groups (Rao-Scott  $\chi^2 = 111.79, P < .0001$ ). Few E-Cig Rejecters, E-Cig Dual Users, and Quit All Products (2.2%, 95% CI: 0.5–3.9; 14.4%, 95% CI: 9.3–19.6; and 19.0%, 95% CI: 10.4–27.7, respectively) reported that ENDS were more enjoyable than regular cigarettes; and 77.3% (95% CI: 72.1–82.4), 52.0% (95% CI: 44.6–59.3), 43.1% (95% CI: 32.9–53.4), respectively, stated that ENDS were less enjoyable. Almost all Switchers reported that ENDS were either more (51.6%, 95% CI: 35.3–67.9) or about as enjoyable (32.7%, 95% CI: 17.7–47.6), and only 15.8%

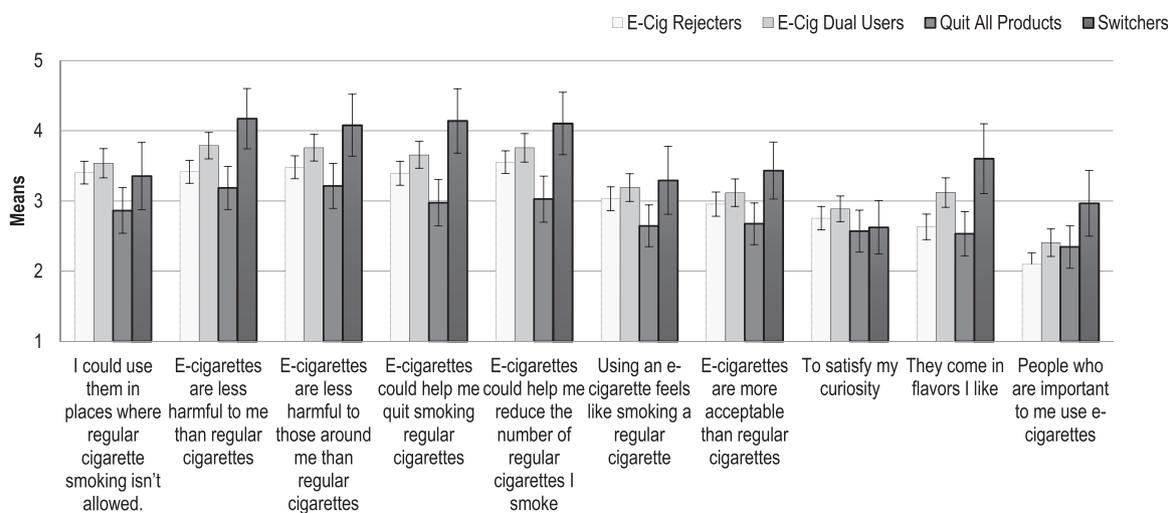


Figure 1. Self-reported reasons for using Electronic Nicotine Delivery System.

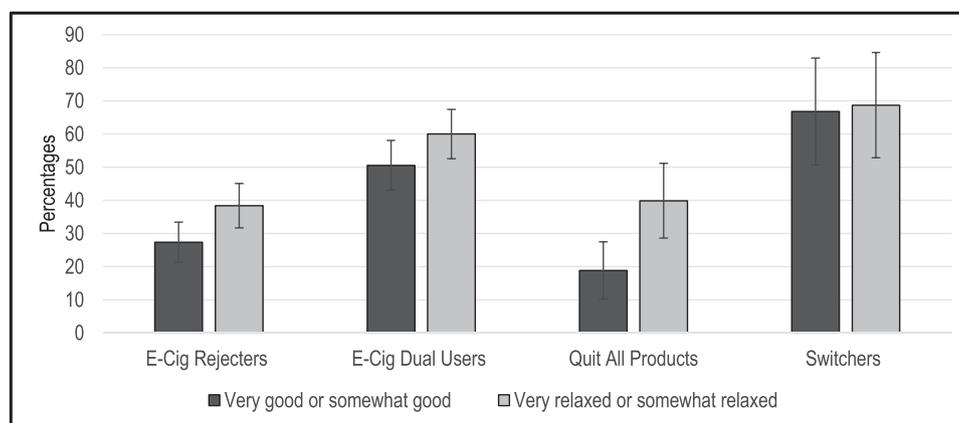
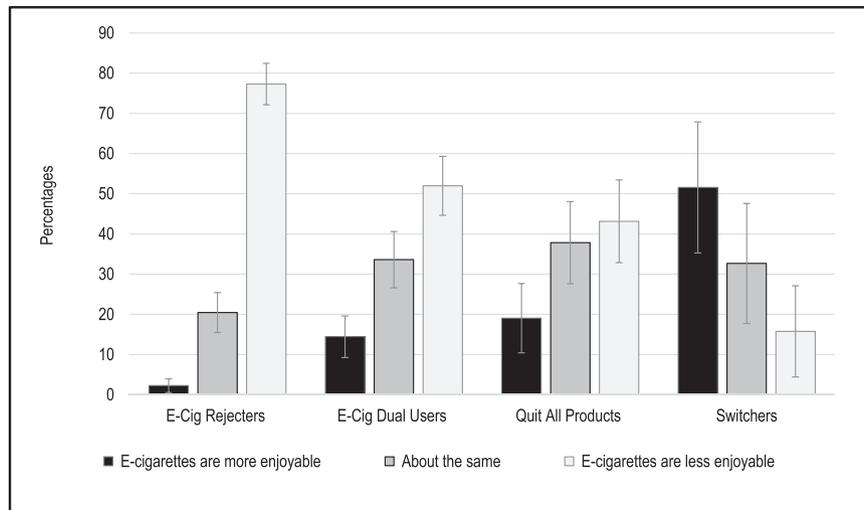


Figure 2. Affect towards using Electronic Nicotine Delivery System. Note. Depicted by the darker shade bars are the percent that reported feeling “very good” or “somewhat good” to the question: “Please imagine how you would feel using an e-cigarette. If you were to use an e-cigarette, would it make you feel...” Depicted by the lighter shade bars are the percent that reported feeling “very relaxed” or “somewhat relaxed” to the question: “How tense or relaxed would using an e-cigarette make you feel.”



**Figure 3.** Self-reported experience of using Electronic Nicotine Delivery System compared to smoking regular cigarettes

(95% CI: 4.4–27.1) rated ENDS as less enjoyable than smoking regular cigarettes.

The selected sample of current and former smokers reporting ever use of ENDS was representative of an estimated 22 472 712 (95% CI: 21 563 133 to 23 382 291) US adults (aged 18+) in 2014. Among this subpopulation of current and former smokers reporting ever use of ENDS, an estimated 9 443 788 (42.0%, 95% CI: 38.0–46.1) were current smokers who were not current ENDS users (E-Cig Rejecters); 6 766 362 (30.0%, 95% CI: 26.4–33.8) were both current smokers and current ENDS users (E-Cig Dual Users); 4 474 978 (19.9%, 95% CI: 16.3–23.5) were former smokers and former ENDS users (Quit All Products); and 1 787 584 (8.0%, 95% CI: 5.5–10.4) were former smokers who were also current ENDS users (Switchers).

Overall, 87.8% (95% CI: 85.0–90.6) endorsed the opinion that cigarette smokers who also use ENDS are equally or more likely to quit smoking regular cigarettes. Among the Switchers, 80.9% (95% CI: 68.3–93.6, weighted  $n = 1\,396\,753$ ) reported that using ENDS helped them quit smoking regular cigarettes, whereas only 25.4% (95% CI: 16.0–34.8, weighted  $n = 1\,037\,727$ ) of the Quit All Products reported this. Among these approximately 1 million Quit All Products former smokers, an estimated 460 000 quit smoking regular cigarettes within the past year (Supplementary Table S5 provides more detailed data on self-reported time since smoking last cigarette among Quit All Product and Switchers groups). Among the approximately 1.4 million Switchers who reported that using ENDS helped them quit smoking regular cigarettes, an estimated about 920 000 quit within the past year. Although this cross-sectional survey did not have extensive questions on their smoking cessation process, these data suggest that about 2.4 million former smokers perceived that the use of ENDS may have helped in quitting use of regular cigarettes, with about 1.4 (460K + 920K) million having quit in the past year. No former smokers who had used ENDS but then had quit all nicotine products (Quit All Products) rated the likelihood of going back to smoking regular cigarettes as somewhat or very likely. Among the Switchers, 2.0% (95% CI: 0.0–6.1) rated relapse back to regular smoking as very likely, and 5.2% (95% CI: 0.0–12.4) rated it as somewhat likely.

Supplementary Table S4 provides more detailed data on which ENDS device types were used most often by the sample. A high

proportion of E-Cig Rejecters and Quit All Products groups reported primarily using “electronic cigarettes” (89.5%, 95% CI: 85.5–93.6; 87.0%, 95% CI: 79.7–94.2; respectively), whereas E-Cig Dual Users and Switchers were less likely to report primarily using “electronic cigarettes,” and reported greater use of a “tank system containing e-liquid” (11.8%, 95% CI: 6.7–17.0 and 35.3%, 95% CI: 19.6–51.0, respectively). Among E-Cig Dual Users “vape pens” (9.9%, 95% CI: 5.5–14.3) were also reported.

## Discussion

ENDS need to improve as a satisfying alternative or the attractiveness and appeal of the regular cigarette must be degraded to increase the potential of ENDS developing into a disruptive technology that most smokers may adopt in place of the cigarette.<sup>3,5-7,9</sup> About one-fourth of recent former smokers (the Switchers) reported finding ENDS a satisfying alternative to regular cigarettes (almost 85% rating ENDS as equally or more enjoyable than cigarettes). However, more than fivefold more current smokers (1 787 584 ÷ 9 443 788 = 5.28) did not find them satisfying and stopped using them (“E-Cig Rejecters”). Consistent with other recent research,<sup>26,27</sup> we found that 6.8 million “E-Cig Dual Users” had more mixed perceptions about how satisfying ENDS were and continued to smoke regular cigarettes along with using ENDS.

These varying patterns of acceptance and rejection of ENDS as a satisfying alternative to regular cigarettes provide some insights into factors about ENDS that will be most important in evaluating their potential to develop into truly disruptive innovations beyond efficiency in nicotine delivery (ie, documented health benefits, public acceptability, and flavors).<sup>3,5-7,10,12,22-27,37</sup> Evidence from the United Kingdom have emphasized the need for “clear information on the relative harm of cigarettes and e-cigarettes” especially among smokers trying to quit who are seeking a less harmful source of nicotine.<sup>4,17,38-42</sup> The comparative costs of ENDS versus regular cigarettes also could be very important in wider adoption of ENDS as an alternative.<sup>27,43,44</sup> Additionally, the E-Cig Dual Users and Switchers were more likely to use ENDS products other than the basic E-cigarette, suggesting that continuing product innovation could increase users’ satisfaction (Supplementary Table S4).

To encourage a potentially positive pattern of ENDS replacing cigarettes, it can be argued that efforts are needed from the public health community to reduce the appeal and attractiveness of the cigarette and other combusted tobacco products; namely, decreasing the product, promotion, placement, and price advantage of these more lethal combusted tobacco products.<sup>1,45</sup> The passage of the 2009 Family Smoking Prevention and Tobacco Control Act (Tobacco Control Act) provides the FDA with authority to regulate cigarettes and smokeless tobacco, including the authority to adopt product standards, such as reducing nicotine levels<sup>1,37,46–48</sup> or requiring the smoke to have a higher pH<sup>46</sup>; and graphic warning labels to reduce the “promotional” appeal.<sup>1,49–51</sup> Educational campaigns<sup>1,52,53</sup> and sales restrictions using “time-place-manner” local authority,<sup>1,54–56</sup> plain packaging,<sup>57</sup> raising the minimum age of legal access to 21<sup>58,59</sup> and raising the average retail “price” of combusted tobacco products have also been recommended.<sup>1,43,44,60</sup>

A range of potential regulatory options for ENDS have been reviewed<sup>10,17,42,55,61–67</sup>; however, ENDS include a wide variety of electronic cigarettes (disposable and rechargeable) and tank-style systems that can be modified, thus forming a very heterogeneous group of products<sup>4,5,15</sup> that make the evaluation of safety and potential harm and benefit difficult to evaluate.<sup>5,10,17,61,68</sup> Although the 2009 Tobacco Control Act did not originally cover ENDS<sup>69</sup>; once the proposed deeming rule is finalized, the FDA may have the authority to regulate ENDS, creating premarket approval requirements and product standards appropriate for the protection of public health. How the population health standard in the 2009 Tobacco Control Act will be implemented in regulating ENDS as a disruptive technology has been widely debated.<sup>3–5,8–10,42,61,63,70–72</sup> A positive impact on adult cessation rates would be important,<sup>73,74</sup> but the overall impact on population health would also consider the impact of ENDS on initiation among youth and young adult never smokers.<sup>62,73,75,76</sup> Our 2014 data estimate that about 2.4 million US adults were helped in quitting regular cigarettes by using ENDS, with 1.4 million of these former smokers quitting in 2014. However, we cannot assess how many of these former smokers would have quit without using e-cigarettes nor how many “dual users” may have been delayed from quitting cigarettes. Hence, the impact (if any) of these 2.4 million former smokers on national quit rates cannot be determined by this study.

### Limitations

This study has multiple limitations. First, the use of the internet panel may raise concerns about sample representativeness, especially if the panel has been used in prior tobacco research. Mitigating this concern, however, is internal research by GfK that suggests minimal panel conditioning from participation in prior tobacco research.<sup>77</sup> Second, the data are based upon self-report, and biochemical verification of cigarette smoking and use of other products could not be conducted. While the validity of self-reported cigarette smoking has been confirmed,<sup>1,78</sup> the accuracy of self-report of other products, particularly novel products, has not been evaluated and remains uncertain. Third, the rapidly changing nature of ENDS makes accurate questionnaire descriptions and terminology difficult to define. Fourth, the 2014 Tobacco Products and Risk Perception Survey had limited assessments of smoking cessation behaviors among ENDS users. Fifth, the cross-sectional design of this study makes it very difficult to assess the actual impact on population quit rates of these self-reports of using ENDS to quit or how much dual use may be delaying smoking cessation.

### Conclusion

The potential of ENDS to have positive impacts on population health remains uncertain.<sup>1,41,42,61,62,73–75,79,80</sup> Since about one-half of recent former smokers are trying ENDS with about one-fourth continuing to use them, and many report that these products have helped them quit regular cigarettes, the potential impact of ENDS on population quit rates deserves continued surveillance. However, since most current smokers who have tried ENDS reject them as a satisfying alternative to regular cigarettes, the potential of ENDS becoming a disruptive technology replacing regular cigarettes remains uncertain. If the level of acceptance of ENDS among some recent former smokers (almost 85% of the Switchers rating ENDS as equally or more enjoyable than cigarettes) could be achieved among all current smokers who are trying ENDS, the potential of ENDS becoming a disruptive technology replacing regular cigarettes would dramatically increase. This outcome could become more likely if the ENDS products continue to improve or the attractiveness and appeal of regular cigarettes is degraded.

### Supplementary Material

Supplementary Material and Tables S1–S5 can be found online at <http://www.ntr.oxfordjournals.org>

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