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Policy Options to Mitigate Cigarette Filter Litter in California

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This Master's Project

Policy Options to Mitigate Cigarette Filter Litter in California

by

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List of Acronyms

CA CFL-ALR…………………………......California Cigarette Filter Litter to All Litter Ratio
CFL...Cigarette Filter Litter
PS- EPR………………...……Product Stewardship and/or Extended Producer Responsibility
WEEE……………………………………..…...Waste Electrical and Electronic Equipment

Abstract

Approximately 16.2 billion cellulose acetate cigarette filters are littered in California annually. Cigarette filter litter (CFL) creates an annual financial burden of over $1.27 billion for California; 67% of these costs involve abatement efforts, 26% involve damages to the tourism industry, 4% involve damages created by fires, and 3% involve damages to the fishing industry. CFL also poses unquantifiable damages to human and environmental health in the form of ingestion, toxicity, formation into microplastics, and quality of life degradation. These costs and damages warrant the adoption of policy measures in order to mitigate CFL. Cigarette taxes and fees raise government revenue, but they are politically challenging due to California Proposition 26. Charges and price floors are not subject to Proposition 26 but do not raise government revenue. Locational smoking bans encourage anti-smoking cultural norms and may decrease consumption, although indoor smoking bans may increase littering and outdoor smoking bans are poorly enforced. Raising the minimum cigarette purchasing age should reduce consumption but may take years to reach effectiveness. The enforcement of littering fines is a feasible option to decrease CFL generation. California could mandate that a product stewardship organization be funded by relevant stakeholders to provide and maintain a system that recovers CFL, or the state could implement a CFL deposit-refund model. Both of these options contain operational and administrative risks and are recommended to be piloted in Hawaii before consideration at the scale of California. A product ban on filtered cigarettes would mitigate certain environmental risks but may not mitigate toxic contamination. Recent tobacco control regulation in California suggests that the most effective and feasible strategy to mitigate the negative externalities created by cigarette consumption and its generation of litter may be a combination of regulatory and market-based policy instruments.

Acknowledgements

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I. Introduction

Cigarette filter litter (CFL) is defined as one or multiple cigarette filters—commonly referred to as "butts"—that are intentionally discarded in a public environment after consumption. CFL is a massive environmental and economic problem that needs to be mitigated in order to ensure human and environmental health. Globally, approximately 6.3 trillion cigarettes are consumed annually and approximately 83% of these cigarettes contain filters (Novotny & Zhao 1999). In the U.S., between 97% and 99% of cigarettes sold contain filters (Novotny et al. 2009, U.S. Department of Health and Human Services 2014). 95% of cigarette filters are made out of the plastic cellulose acetate (Register 2000). In 2008, 690,000 metric tons (773,000 U.S. tons) of cellulose acetate were globally manufactured for cigarette filters (Puls et al. 2011). One piece of CFL—with no remnant tobacco—weighs .006 ounces and has the volume of .5 mL (Register 2000). In the U.S. alone, 1.35 trillion filtered cigarettes were manufactured in 2007 (Novotny et al. 2009), yet only 360 billion cigarettes were consumed domestically during the same year (U.S. Department of Agriculture 2007); this latter figure decreased to 292.8 billion in 2011 (Table 1, Center for Disease Control 2012).

Table 1. Estimations of generation, weight, and volume of CFL
Assumes a 65% littering rate (Curtis et al. 2016, Schultz et al. 2013, Register 2000).

Scale	Cigarettes Consumed	Filter Weight (U.S. tons)	Filter Volume (m^3)	# Litter	# Landfill
World	6,300,000,000,000	1,181,250	3,150,000	4,843,125,000,000	1,456,875,000,000
U.S.A.	292,800,000,000	54,900	146,400	190,320,000,000	102,480,000,000
California	24,900,000,000	4,669	12,450	16,185,000,000	8,715,000,000

Cigarette filters were originally intended to keep loose tobacco out of smokers' mouths, but then filters were developed as a marketing tool in the 1950's and 1960's when information about the negative health effects of smoking first become publicized (Harris 2011, Novotny et al. 2009, Smith & Novotny 2011, Novotny & Slaughter 2014, Register 2000). In 1950, only 0.54% of cigarettes in the U.S. market had filters (Figure 1, Hoffman & Hoffman 1997). By 1990, about two-thirds of cigarettes had filters with increased ventilation holes that the tobacco industry labelled as "low tar"; although these filters reduced tar delivery as measured by the U.S. Federal Trade Commission protocol, they did not reflect reduced risks of disease or premature mortality in smokers (U.S. Department of Health and Human Services 2014). Advertised benefits of cigarette filters have been misleading, fraudulent, and defective in terms of protecting human health (Novotny & Slaughter 2014). Cigarette filters are often defective, releasing small fragments of cellulose acetate when smoked (Pauly et al. 2002). Investigations substantiating defective filters have been concealed by the tobacco industry, which has been negligent in not performing toxicological examinations to assess the human health risks posed by defective filters (Pauly et al. 2002).

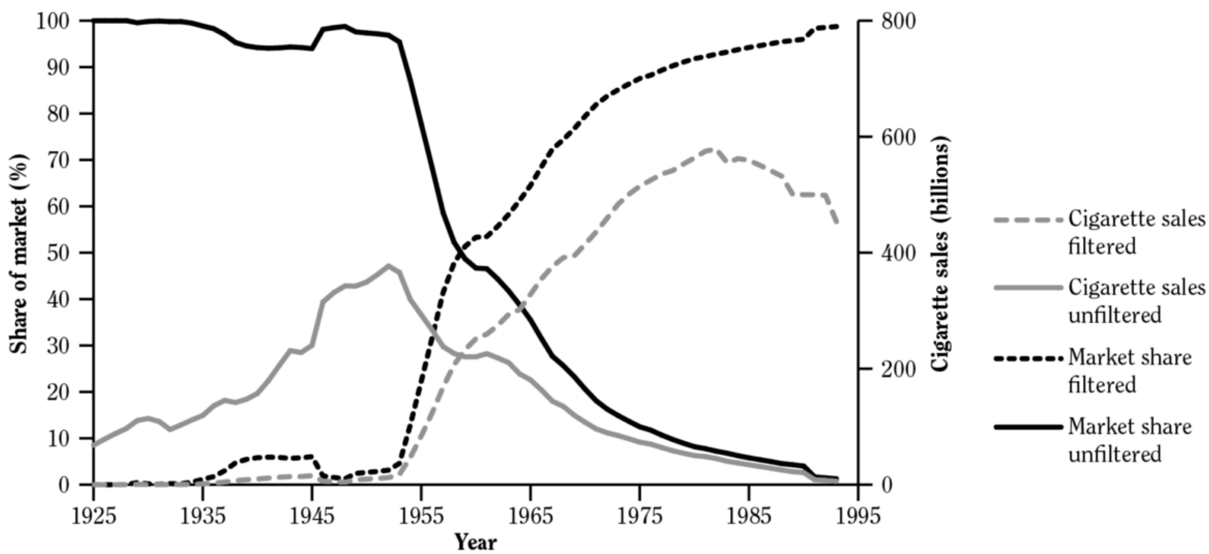


Figure 1. U.S. market share and total annual sales of cigarettes 1925-1993
Filtered and unfiltered cigarettes (U.S. Department of Health and Human Services 2014). In 1950, 0.54% of cigarettes had filters (Hoffman & Hoffman 1997). Today, between 97% and 99% of cigarettes contain filters (Novotny et al. 2009, U.S. Department of Health and Human Services 2014).

CFL is a visible representation of what should be a political alliance between environmental and public health advocates (Smith & McDaniel 2011). CFL is the most common type of litter found on Earth by count (Javadian et al. 2015). Although monitoring CFL in the environment is difficult because it can easily be transported by wind and rain into street drains, streams, rivers, and the ocean (Novotny et al. 2009), it is estimated that between 4.5 and 4.95 trillion cigarettes are discarded as litter annually on a global scale (Moerman & Potts 2011, Novotny & Slaughter 2014). It is possible that CFL accounts for 38% of all U.S. roadside litter, implying that there are over 19.3 billion pieces of CFL in the U.S. (Keep America Beautiful & Mid Atlantic Solid Waste Solutions 2009). An annual international coastal cleanup effort recovered over 2.1 million pieces of CFL around the world in one day in 2012, accounting for

19% of all litter items observed (Table 2, Ocean Conservancy 2012). I have analyzed the International Coastal Cleanup data and concluded that CFL comprises 36.3% of all observed litter in California by count; here, this figure is referred to as the "California CFL compared to all litter ratio", abbreviated as "CA CFL-ALR" (
Table **3**). In this report, I utilize the CA CFL-ALR in order to make certain calculations.

Table 2. Litter characterization of the 2012 International Coastal Cleanup
Over 560,000 volunteers collected this data in 91 countries (Ocean Conservancy 2012).

Rank	Debris item	Number of debris items	Percentage of total debris items
1	Cigarettes/cigarette filters	2,117,931	19 %
2	Food wrappers/containers	1,140,222	10 %
3	Beverage bottles (plastic)	1,065,171	10 %
4	Bags (plastic)	1,019,902	9 %
5	Caps, lids	958,893	9 %
6	Cups, plates, forks, knives, spoons	692,767	6 %
7	Straws, stirrers	611,048	6 %
8	Beverage bottles (glass)	521,730	5 %
9	Beverage cans	339,875	3 %
10	Bags (paper)	298,332	3 %
	Top 10 total debris items collected	8,765,871	80 %
	Total debris items collected worldwide	10,957,338	100 %

Table 3. Calculation of the "CA CFL-ALR"
The ratio of CFL compared to all observed litter in California during the annual International Coastal Cleanup. Data provided by Ocean Conservancy (2016).

Year	# CFL	% Total Litter	Weighted Average	Weighted % Litter
2008	340,221	37.62%	127,991	5.71%
2009	394,920	37.33%	147,424	6.57%
2010	335,320	37.84%	126,885	5.66%
2011	305,697	35.78%	109,378	4.88%
2012	217,423	35.23%	76,598	3.42%
2013	208,028	37.19%	77,366	3.45%
2014	294,099	34.05%	100,141	4.46%
2015	147,207	33.1%	48,711	2.17%
	2,242,915			**36.31%**

It is difficult to estimate the percentage of cigarettes that are discarded as litter due to human behavior. In the U.S., a 65% CFL public littering rate was observed amongst 9,757 subjects. Here, the 65% littering rate is accepted as a reliable figure because of its large sample size as well as geographic relevancy, although it should be noted as conservative compared to the other findings. A 77% CFL littering rate has been observed for 219 smoking subjects in an urban New Zealand environment (Patel et al. 2012). The aforementioned global production figures—combined with the estimated global littering rates—suggest that between 71% and 82.5% (average = 76.9%) of filters are littered globally (Appendix 1). A "two-thirds" CFL littering rate was found by the non-profit organization Litter Free Planet and cited throughout some literature (Novotny & Slaughter 2014, Javadian et al. 2015), although the finding is not properly cited itself (Litter Free Planet 2012).

One particularly problematic and uncertain aspect of CFL is its degradability. Cellulose acetate is synthesized when cellulose—which is a natural polymer found in wood—is acetylated with acetic anhydride to produce cellulose acetate strands (Harris 2011). Titanium dioxide is added to the strands as a whitening agent, and triacetin binds the strands together to form a filter (Harris 2011). Although cellulose is readily biodegraded by organisms that utilize cellulase enzymes, due to the additional acetyl groups, cellulose acetate requires the presence of esterases (hydrolase enzymes) in order to initiate biodegradation. Partial deacetylation can occur either by enzymes or by partial chemical hydrolysis, and then the polymer's cellulose structure can be readily biodegraded (Puls et al. 2011).

Although there is a consensus that CFL is photodegradable (Puls et al. 2011), there has been an arena of debate in the scientific literature regarding its persistence in a natural environment (Novotny 2009, Puls et al. 2011). This includes a disagreement over the definition of biodegradation. Biodegradation can be defined as the microbial-initiated conversion of a substrate in a biologically active environment into carbon dioxide, methane, cell wall material, and/or other biological products (Puls et al. 2011). Another perspective is that all materials biodegrade given a certain time frame and therefore the definition of biodegradation must include a rate function, such as weight loss over time (Puls et al. 2001). More about CFL degradation will be discussed in the microplastics section as well as the sustainable alternatives section; for now, it can safely be assumed that CFL persists as litter after it has been discarded.

Given the scale and ubiquity of CFL, a body of peer-reviewed scientific literature has emerged over the last decade that specifically addresses environmental and economic impacts of CFL and then evaluates policy options for its mitigation (Novotny et al. 2009, Ariza & Leatherman 2011, Barnes 2011, Schneider et al. 2011, Smith & McDaniel 2011, Novotny & Slaughter 2014, Curtis et al. 2016). However, certain academic avenues have not been pursued, including: 1) a comprehensive integration of these studies; 2) an evaluation of damages incurred by CFL within an actual scope of assessment, and; 3) a feasibility assessment of policy options to mitigate CFL within a particular jurisdiction. This paper aims to address these areas of interest and carry forward previous research in order to realistically implement policy that effectively mitigates CFL in the State of California.

California was chosen for many reasons. Firstly, it was deemed to be a challenging but reasonable scale in terms of ascertaining relevant data. Secondly, it has historically been one of the first U.S. states to pass innovative environmental policies—specifically policies that mitigate litter—such as the state plastic bag ban and the microbeads ban. Thirdly, I live in San Francisco, California, and I have both an interest in my place of residence as well more access to local informational resources. California is an interesting case study because its observed CFL-ALR is 17% higher than the national average even though its adult smoking prevalence and its per capita consumption of cigarettes are respectively 35% and 43% lower than the rest of the U.S. (Figure 2 and Figure 3, Appendices 2, 3, and 4). Approximately 24.9 billion cigarettes are consumed in California every year, and assuming a 65% littering rate, it is estimated that 16.2 billion pieces of CFL are annually littered in the state (Table 1). In effect, the generation of CFL in California equates to a weight over 6 million pounds and a volume over 8,000 cubic meters in material (Table 1).

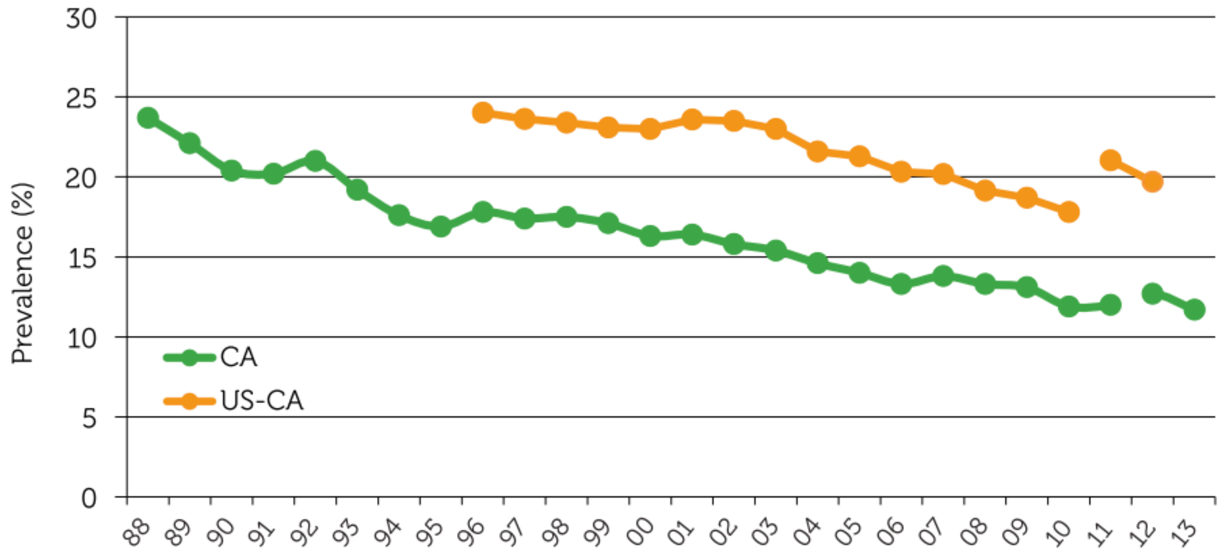
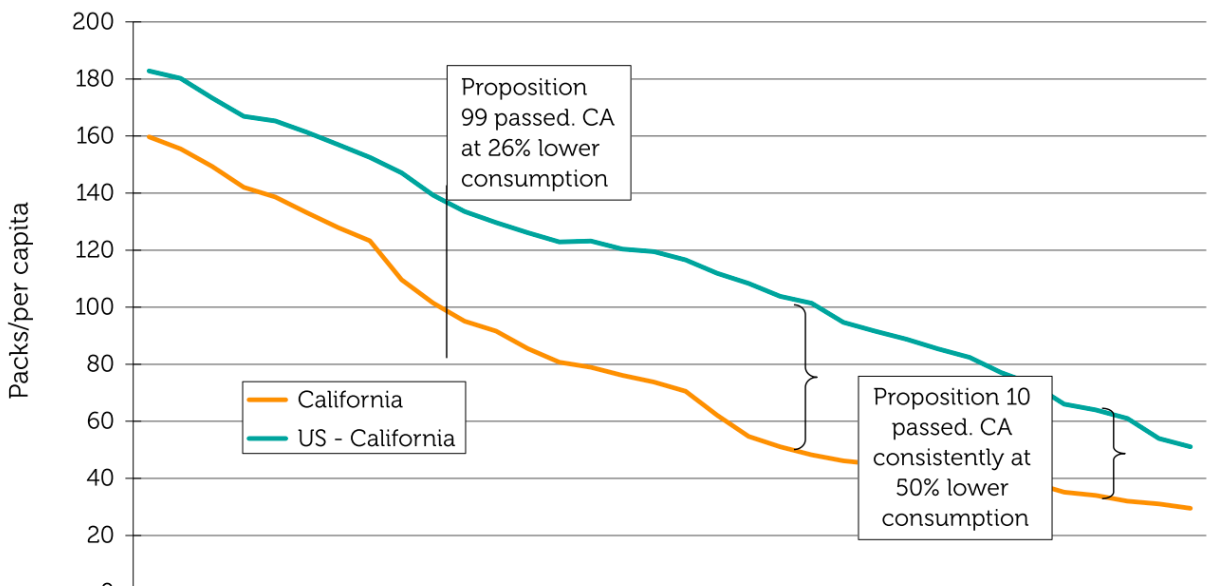


Figure 2. Adult smoking prevalence, 1988 – 2013
Adult smoking has been declining steadily since 1988. California has had a lower smoking prevalence compared to the rest of the U.S. (California Tobacco Control Program 2013).



	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97
California	160	156	149	142	139	133	128	123	110	102	95	92	86	81	79	76	74
US - California	183	180	173	167	165	161	157	153	147	139	134	130	126	123	123	120	120

	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14
California	71	62	55	51	48	46	45	45	44	41	41	38	35	34	32	31	30
US - California	117	112	108	104	101	95	92	89	85	82	77	73	66	64	61	54	51

Figure 3. Per capita cigarette consumption, 1980-2013
Consumption has consistently decreased in both California and the U.S. (not including California) since 1980. Californians have generally smoked about 20 packs less per capita than the rest of the U.S. This decrease is correlated with state cigarette taxes, denoted by the passage of Propositions 99 and 10 (California Tobacco Control Program 2013).

Statement of Purpose

My three main research questions are: 1) what are the quantifiable financial costs that CFL creates for California? 2) what are the environmental impacts of CFL imposed upon California? 3) What policy mechanisms could most effectively mitigate CFL in California? For all intents and purposes, the first two questions are support the third, as the scope and scale of the issue determine the appropriateness of implementing any particular policy mechanism.

The first section of this report assesses economic and environmental damages that CFL creates for California. I will assess the financial burden that CFL has historically cost the state by evaluating abatement costs, fire damages, and damages done to the fishing industry and coastal tourism sector. Due to inherent complexity and/or unavailable data, other costs will be qualitatively assessed, including damages caused by child and domestic pet ingestion as well as damages to the human "quality of life". Then, I will qualitatively assess other negative externalities—such as toxicity, animal ingestion, and degradation into microplastics—caused by the unabated CFL that enters natural ecosystems. Taken together, the economic and environmental damages caused by CFL to the State of California will justify the adoption of policy mechanisms designed for its mitigation.

The second major section evaluates policy instruments that could most effectively mitigate CFL in California. First, the theory behind each option will be explained in brief. Then, relevant examples of each policy mechanism as applied to various cases and places will be offered and analyzed in terms of effectiveness. Finally, each policy option will be assessed for feasibility in the State of California. Major factors that will be considered include demographic data, economic factors, social behaviors, legislative history, established infrastructure, and the current political climate. The most feasible policy option(s) will be recommended for adoption to California policy makers. When relevant, I will review and assess certain bodies of past research as it pertains to this purpose.

Note that this report does not address two related topics: 1) the negative externalities created in the upstream production of cellulose acetate filtered cigarettes; 2) the liability that CFL creates for landfills when discarded "properly". The cellulose acetate filtered cigarette manufacturing process requires fossil fuels as an input, and it produces solid, liquid, and airborne wastes (Novotny & Zhao 1999). This waste is not litter so it is not assessed here, but it is acknowledged here. Meanwhile, even when CFL is not littered, it may create environmental risks by producing toxic leachate in landfills. The scope of the cigarette filter problem extends beyond litter; however, this report focuses on litter only. More about CFL toxicity will be discussed in the environmental damages section as well as the product ban section.

II. Financial Costs

This section attempts to quantify the financial costs that CFL has created for various stakeholders in California. Until now, no studies have accounted for how CFL-related costs—such as harm to businesses, tourism, ecosystems, and human health—amount in a particular jurisdiction (Schneider 2011). I calculate cost using different methodologies, almost always synthesizing scientific literature, government data, and/or consulting reports. These costs reflect what entities have historically been spending to abate or remediate damages, not necessarily what should be spent to truly mitigate CFL damages. Various methodologies are utilized depending on the available data. Whenever more specific data could be found, an attempt was made to incorporate those findings into a given methodology in order to ensure accuracy. Sometimes I used multiple methodologies to calculate the same cost; when this happened, the average of each calculation was used here provided that each result fell within the same order of magnitude (which was always the case). Any adjustment for inflation was found using the online consumer price index calculator (U.S. Bureau of Labor Statistics 2016). Some calculations utilize the 36.3% CA CFL-ALR.

The following financial costs will be assessed for the state: 1) abatement costs (the cost to clean up CFL) for various entities; 2) damages to the coastal tourism industry; 3) damages to the fishing industry, and; 4) damages caused by CFL-related fires. Other financial costs include human ingestion and degradation of the quality of life, but because of unavailable data, they are offered here for qualitative assessment. Also, note that there are federally-mandated litter mitigation programs in California that will be discussed towards the end of this report; however, the California taxpayer money funding such programs, which may be substantial, is not assessed here.

Abatement Costs

Litter abatement costs typically include mechanical and manual remediation from public places such as streets, sidewalks, and parks, as well as storm water and sewer treatment systems (Schneider et al. 2011). Here, California CFL abatement costs are quantified for state, county, and city governments, as well as for businesses, volunteer organizations, and educational institutions.

Abatement Costs for Local Governments

My abatement cost methodology for government entities first calculates the costs that these entities spend to abate all litter in California. In order to do so, findings are incorporated from the Keep America Beautiful & Mid Atlantic Solid Waste Solutions (2009) report which surveyed hundreds of entities responsible for litter abatement and then determined per capita litter costs using data analytics techniques. I then multiply these per capita costs by the appropriate California population in order to calculate litter costs at the state, county, and city levels. Finally, these costs are multiplied by the CA CFL-ALR in order to estimate abatement costs for CFL only. I acknowledge that this latter step assumes that the cost to abate CFL is the same as the cost to abate any other form of litter. This may not be true, but the step was necessary in order to extrapolate from general litter reports in order to make a best estimate.

In order to estimate litter abatement costs to state governments, Keep America Beautiful and Mid Atlantic Solid Waste Solutions (2009) assessed 51 survey responses from state government affiliated entities such as departments of transportation, departments of environmental protection, state Adopt-a-Highway programs, and state Keep America Beautiful coordinators. A national annual litter cost of $362.5 million was determined at the state level, yielding a per-capita cost of $1.19. Here, this per capita cost is multiplied by the population of California as well as the CA CFL-ALR to yield an annual cost of $18.8 million to California state government entities (Table 4). This may be a conservative estimate. The California Department of Transportation has estimated that the cost to remediate CFL is $41 million annually, and although this estimation has been cited throughout grey literature (California Legislative Information 2015), the original source could not be located. However, another state government report stated that it spent $63 million in 2013 on the removal of litter and debris on roadways only (McGowen 2015); applying the CA CFL-ALR to this figure yields a CFL cost of $22.9 million for (only) one state department. Averaging the $22.9 million from this latter methodology with the $18.8 million from the previous calculation yields a cost of $19.9 million, and this figure is my (probably conservative) final estimate of costs to California state government entities.

Table 4. Abatement costs for local government entities, methodology 1
Per capita abatement costs for all litter are multiplied by the appropriate population as well as the CA CFL-ALR and the CPI index for 2016 (Keep America Beautiful & Mid Atlantic Waste Solutions 2009, U.S. Census 2012, U.S. Census 2015, U.S. Department of Labor 2016).

Level	State	County	City
Cost Per Capita	1.19	1.06	3.59
Population	39,144,818	39,144,818	37,187,577.10
Litter Cost	$ 46,582,333	$ 41,493,507	$ 133,503,402
CFL Cost	$ 16,914,045	$ 15,066,292	$ 48,475,085
2009-2016 Inflation Adjustment	$ 18,774,590	$ 16,723,585	$ 53,807,345

For county governments, Keep America Beautiful and Mid Atlantic Solid Waste Solutions (2009) received 105 survey responses from county level entities that incur litter costs, such as highway and road departments, public works departments, and solid waste and recycling departments. County responses were stratified by population and extrapolated to determine a $1.06 per capita cost. Here, this per capita cost is multiplied by the California population and the CA CFL-ALR to yield $16.7 million in CFL abatement costs to county governments in California (Table 4).

For city jurisdictions, Keep America Beautiful and Mid Atlantic Solid Waste Solutions (2009) received survey responses from 108 litter-burdened city entities, such as departments of public works, sanitation, landscaping, and streets. The result was a national cost of $797.3 million, equating to a $3.59 per capita cost for residents in U.S. cities. When adjusted for CFL composition and California city population, the resulting cost is $53.8 million for California city-level government entities (Table 4).

The total historic cost that local government entities in California have been spending to abate CFL is calculated to be $90.4 million (Table 5).

Table 5. The total cost to abate CFL for government entities in California
A summary of my findings, largely calculated using data from Keep America Beautiful & Mid Atlantic Solid Waste Solutions (2009).

Entity	Cost
State Government	$ 19,894,673
County Government	$ 16,723,585
City Government	$ 53,807,345
Total	$ 90,425,602

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Abatement Costs for Businesses

Businesses may be spending an order of magnitude greater than governments towards remediating CFL, although survey results indicate that business owners are not aware of these costs (Keep America Beautiful & Mid Atlantic Solid Waste Solutions 2009). Using the previous methodology, Keep America Beautiful & Mid Atlantic Solid Waste Solutions (2009) surveyed 111 businesses through a random sample and concluded that the average annual cost of litter mitigation per-employee is $79.48. Accounting for the number of employees in California, this translates to a $429.3 million cost after accounting for the CA CFL-ALR and inflation (U.S. Bureau of Labor Statistics 2015, Appendix 5).

I use another methodology to estimate business abatement costs by incorporating data from a litter audit in Florida which found that the average business spends $2,435 annually to abate litter (State University System of Florida, 1999). Incorporating a 33% CFL-total litter composition ratio in Florida yields an annual cost of $808 for businesses to abate CFL; multiplying this cost by the number of businesses in California and adjusting for inflation yields a cost of California business CFL abatement of approximately $1 billion (U.S. Census Bureau 2015, Appendix 6).

The average of these two methodologies yields a historic CFL abatement cost to California businesses of $719.6 million.

Abatement Costs for Volunteer Organizations and Educational Institutions

The methodology used here for calculating CFL abatement costs incurred by volunteer organizations and educational institutions incorporates findings from the Keep

America Beautiful & Mid Atlantic Solid Waste Solutions (2009) report. It is different from the previous methodologies because it deduces the national costs incurred by these entities to the scale of California; this is because certain data were unavailable such as the per capita cost or the size of the relevant population.

For volunteer organizations, Keep America Beautiful & Mid Atlantic Solid Waste Solutions (2009) estimated the value of volunteer time by averaging the minimum wage and the national value of volunteer time; then it extrapolated a national cost to the 4.6 million volunteers in such organizations as Adopt-a-Highway, the Ocean Conservancy, Keep America Beautiful affiliates, and other non-affiliated volunteer groups. The result is $677.6 million in time and $92 million in office costs, educational materials, and media. A per capita assessment of volunteer costs is not provided, so here California costs are adjusted by dividing the U.S. population by that of California. The California volunteer cost to abate litter is then adjusted with the CA CFL-ALR and 2016 inflation to yield a cost of volunteer efforts to abate CFL in California of $38.1 million (Appendix 7).

For educational institutions, Keep America Beautiful & Mid Atlantic Solid Waste Solutions (2009) collected survey data from 19 school districts and 18 colleges and universities using surveys of maintenance, facilities, and janitorial departments. The result was a national litter abatement cost of $240.6 million, resulting in a per capita cost of $3.63. I could not locate the population of post-secondary level students in California, so I used the same previous deductive methodology to calculate the cost of CFL abatement to California educational institutions; the result is $11.9 million (Appendix 8). This estimation is complicated by California state law prohibiting minors from purchasing cigarettes.

Total Abatement Costs

It is estimated that business, government, volunteer, and educational entities have historically been spending $860 million to abate CFL in California (Table 6).

Table 6. The historic annual cost to abate CFL for entities in California
A summary of my various abatement cost calculations.

Entity	Cost	% of Abatement	% of Total Cost
State Government	$ 19,894,673	2.3%	1.56%
County Government	$ 16,723,585	1.9%	1.31%
City Government	$ 53,807,345	6.3%	4.21%
Businesses	$ 719,620,523	83.7%	56.33%
Volunteer Organizations	$ 38,079,614	4.4%	2.98%
Educational Institutions	$ 11,904,827	1.4%	0.93%
Total	**$ 860,030,565**		67.33%

Discussion: Keep America Beautiful

The two Keep America Beautiful studies mentioned in this report (Keep America Beautiful & Mid Atlantic Solid Waste Solutions 2009, Keep America Beautiful & Action Network 2009) were both sponsored by Philip Morris USA, a corporation that manufactures and distributes cigarettes and includes the brands Marlboro, Virginia Slims, Benson & Hedges, Parliament, as well as 13 others. Keep America Beautiful was developed as a marketing tool in order to control the possibility of problematic alliances between tobacco control groups and environmentalists, as well as to shift the burden of responsibility of handling CFL away from manufacturers and onto consumers, government agencies, and non-profit organizations (Smith & McDaniel 2010). By reporting with statistical significance that most smokers litter and that cigarette receptacles are effective for CFL mitigation, Big Tobacco can argue that the industry is not accountable for the negative externalities created by its products (Smith & Novotny 2010). Although the Keep America Beautiful campaign may have conducted the self-reported largest and most thorough national litter study to date (Rath et al. 2012) with certain intentions, its findings have provided a wealth of valuable data that can be used to make a variety of arguments. The Keep America Beautiful studies have sound methodologies with large sample sizes, and their findings are not wrong; it is true that smokers litter (as has been seen) and that the provision of infrastructure reduces litter (as will be seen). Nonetheless, these observations do not exempt cigarette manufacturers from responsibility, as will be discussed later in the extended producer responsibility and product stewardship sections.

Discussion: Adopt-a-Highway

States have many options to reduce litter, and the Adopt-a-Highway program is a promotional campaign funded by local and state governments to encourage volunteers to remediate highway litter in exchange for some form of advertising (Waterfront Partnership of Baltimore & Abell Foundation 2011). The program Sponsor-a-Highway is similar except that the organization pays professional contracts due to safety concerns (Waterfront Partnership of Baltimore & Abell Foundation 2011). Adopt-a-Highway programs are relatively costly and have limited reach, covering 35% of state maintained highways at best (Waterfront Partnership of Baltimore & Abell Foundation 2011). Adopt-a-Highway sites average between 9% and 15% less litter than non-adopted highways; it is possible that people litter more when they know that a remediation system is in place (Waterfront Partnership of Baltimore & Abell Foundation 2011). Paid programs involve similar problems, and litter areas tend to return to pre-cleaning conditions within 7 to 31 weeks (Waterfront Partnership of Baltimore & Abell Foundation 2011). This data suggests that litter prevention is more effective than remediation.

In contrast, states such as Hawaii and Washington have implemented comprehensive litter control programs that combine education, public awareness, anti-litter legislation, beautification programs, and litter law enforcement to prevent litter. Funding local programs alone is not sufficient for success, and a state-level program manager is recommended to monitor and direct anti-litter efforts; such programs have reduced litter by about 75% (Waterfront Partnership of Baltimore & Abell Foundation 2011). However, these comprehensive litter control programs required constant funding to cover costs—approximately $0.23 per item recovered—and make take as many as 8 to 15 years to take full effect (Waterfront Partnership of Baltimore & Abell Foundation 2011.

Damages to the Coastal Tourism Industry

CFL can damage the tourism industry by creating aesthetic intangible costs that diminish the public's perception of the image and reputation of an area, leading to decreased tourism numbers and revenue (Ten Brink et al. 2009, Mouat et al. 2012). California's coastal economy includes such sectors as construction, living resources, minerals, ship and boat rental, tourism and recreation, and transportation (Kildow & Colgran 2005). Litter also causes losses to tourism by degrading habitats and killing wildlife (Kier Associates 2013). The state's wildlife viewing sector is estimated to have a non-market value on the order of tens or even hundreds of millions of dollars (Pendleton 2006). Adjusted for 2016 inflation, California's coastal tourism and recreation sector is $31 billion (Kildow & Colgran 2005). Ten Brink et al. (2009) reported that the Swedish tourism industry was negatively impacted between 1-5% by the accumulation of litter, particularly along beaches, due to a loss of economic opportunities caused by aesthetic perception and possible health concerns. To estimate the cost that CFL damages California coastal tourism, I have multiplied the average (3%) of this latter finding by the CA CFL-ALR and the value of the California tourism economy to yield an annual cost of $336 million (Appendix 9).

Damages to the Fishing Industry

Damages to the California fishing industry are estimated by multiplying the value of California fishing catches by an estimated contamination rate of fishing catches due to maritime litter. Then, this figure is adjusted for the CA CFL-ALR as well as inflation. In 2001, the California fishing economy employed over 1,300 people, included wages of $68.8 million, and created a gross state product of $177.5 million, including $100,000,000 in the value of catches (Kildow & Colgran 2005). Marine litter could cost the fishing industry as much as 5% of total revenue (Mouat et al. 2010). In two separate cases, contamination rates of fishing catches caused by marine litter have been reported at 69% and 82% (Ten Brink et al. 2009, Mouat et al. 2010). The average of these contamination rates (75.5%) is multiplied by the value of California fishing catches to estimate costs of damages caused by marine litter. This figure is then adjusted for the CFL-litter ratio as well as 2016 inflation to yield an annual cost to California fishing catches caused by CFL contamination of $36.7 million (Appendix 10). It should be noted that the "living resources" category of California's coastal economy—which includes the fishing industry and the aquaculture industry as subsets—was estimated to be $726 million in 2001 (Kildow & Colgran 2005). Data regarding marine litter costs to aquaculture is lacking; although Mouat et al. (2010) suggested that marine litter does not damage controlled aquaculture systems as much as it damages fishing catches, the aquaculture industry is about twice the size of the fishing industry in California.

Fire Damages

CFL creates fire risks (Patel et al. 2012, Rath et al. 2012, Markowitz 2013, National Fire Protection Association 2013). Here, the annual damages caused by these fires will be quantified in the following order: 1) direct property damages; 2) indirect costs associated with fire mitigation; 3) cost of civilian death, and; 4) cost of civilian injury. Taken together, these damages will approximate how much CFL-caused fires have historically cost California.

In order to estimate direct property damages caused by CFL, I synthesize census data with data provided by the National Fire Protection Association. Between 2007 and 2011, on yearly average, U.S. fire departments responded to 90,000 fires that were caused by smoking materials (Hall 2013). Most of these fires were caused by unextinguished filters igniting upholstery or bedding within a building (Hall 2013); as per the definition of litter, these costs are excluded for the purposes of this report. The 21% of cigarette-related fires began by the ignition of vegetation caused by CFL are assessed here (Hall 2013). The Hall (2013) report included data regarding the national average number of fires, civilian deaths, civil injuries, and value of direct property damage caused by cigarette-related fires. When adjusted for the percentage of fires caused by littered filters, as well as the California population, CFL in California is calculated to produce the following fire damages: 1) 3,792 fires; 2) 3 civilian deaths; 3) 9 civilian injuries; and 4) $3.8 million in direct property damage (Appendix 2). This is probably a conservative estimate because the climate of California creates more fire risks than the national average, especially given that the provided national data overlapped with the state's historic drought (Herring 2015).

In order to estimate indirect costs associated with CFL-related fires, I utilize empirical data to calculate a ratio of indirect damages compared to direct damages historically incurred by fires. Indirect costs associated with fires include: 1) business interruption; 2) temporary shelter costs; 3) funds for public fire departments; 4) the cost of the provision of fire protection within buildings, 5) insurance costs; and 6) medical costs (Markowitz 2013). In 2009, fires caused $15.4 billion in direct property damage and $149.6 billion in indirect property damage (Karter 2010). In effect, it is inferred that indirect damages have historically incurred about 9.7 more costs than those incurred by direct damages. It has been calculated that the direct costs caused by CFL-related fires in California are \$3.8 million. Multiplying this figure by the 9.7 indirect-to-direct cost ratio yields about \$37.3 million in annual indirect costs caused by CFL-related fires in California (Appendix 12).

In order to quantify the costs of civilian injury and death caused by CFL-related fires, I incorporate data from a study that has estimated costs of occupational injury and death. Adjusted for inflation, the average cost of an occupational death is calculated to be \$955,000, and the average occupational injury is estimated to be \$18,000 (Leigh et al. 1997, Appendix 13). Given the estimated average number of deaths and injuries caused caused by CFL-related fires in California, annual financial costs to the state are estimated to be \$3.1 million and \$167,000 respectively (Appendix 13).

The total annual costs caused by CFL-related fires in California is estimated to be \$44.4 million (Table 7).

Table 7. Total annual CFL-related fire damages in California
A summary of my fire damage cost calculations.

Category	Amount
Direct Property Damage	\$ 3,835,211
Indirect Costs	\$ 37,256,336
Death	\$ 3,116,733
Injury	\$ 167,300
Total	**\$ 44,375,581**

Human and Domestic Animal Ingestion

CFL has created costs for human beings that are difficult to quantify due to unavailable data. For example, between 2006 and 2008, there were 10,573 reported cases in the U.S. of children (aged <6 years) ingesting CFL (Connolly et al. 2010). It is not reported how many of these cases involved trips to hospitals; these would be real, but difficult to quantify costs. Nicotine found in CFL may cause vomiting and neurological toxicity in human infants and animals (Novotny et al. 2009). In another study, of the 679 cases of CFL ingestion reported, 357 included health effect data (Appleton 2011). Of these, 69% had no effect, 28% had a minor effect, and 2% had a moderate effect such as nausea or vomiting.

Psychological trauma put on the families associated with child CFL ingestion could be included as a qualitative cost. Between 2005 and 2010, 848 cases of CFL ingestion by domestic pets (94% canine) have been reported (Novotny et al. 2011). This data point suggests costs in the form of veterinarian visits and psychological trauma, although this is difficult to quantify especially given the possible number of unreported cases.

Quality of Life

Another real but intangible cost caused by CFL is a negative effect on the "quality of life", meaning the subjective well being of individuals and societies. Litter can impact the quality of life by reducing recreational opportunities, aesthetic values, and non-use values (Cheshire et al. 2009). The perception of litter in the residential environment negatively affects the quality of life (State University System of Florida 1999, Healton et al. 2011). A San Francisco survey determined that CFL is the primary reason given by pedestrians when determining street and sidewalk cleanliness (Figure 4); 48% of those surveyed described CFL as an "extremely important" factor when judging cleanliness (Figure 5). Keep America Beautiful & Mid Atlantic Solid Waste Solutions (2009) surveyed homeowners, business development officials, real estate agents, and property appraisers and concluded that the presence of litter in a community could reduce the value of a property by as much as 7%; however, due to the methodology used to determine this figure, no extrapolations to California are made here.

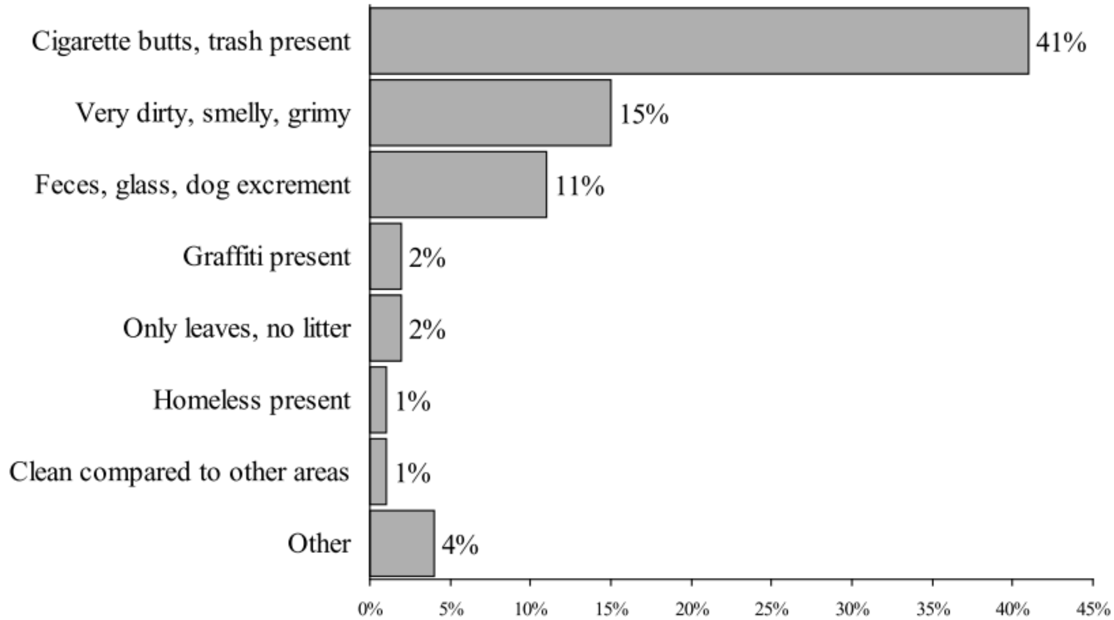


Figure 4. Pedestrian reasons for a low cleanliness rating in San Francisco (Fairbank, Maslin, Maulin, Metz & Associates 2011).

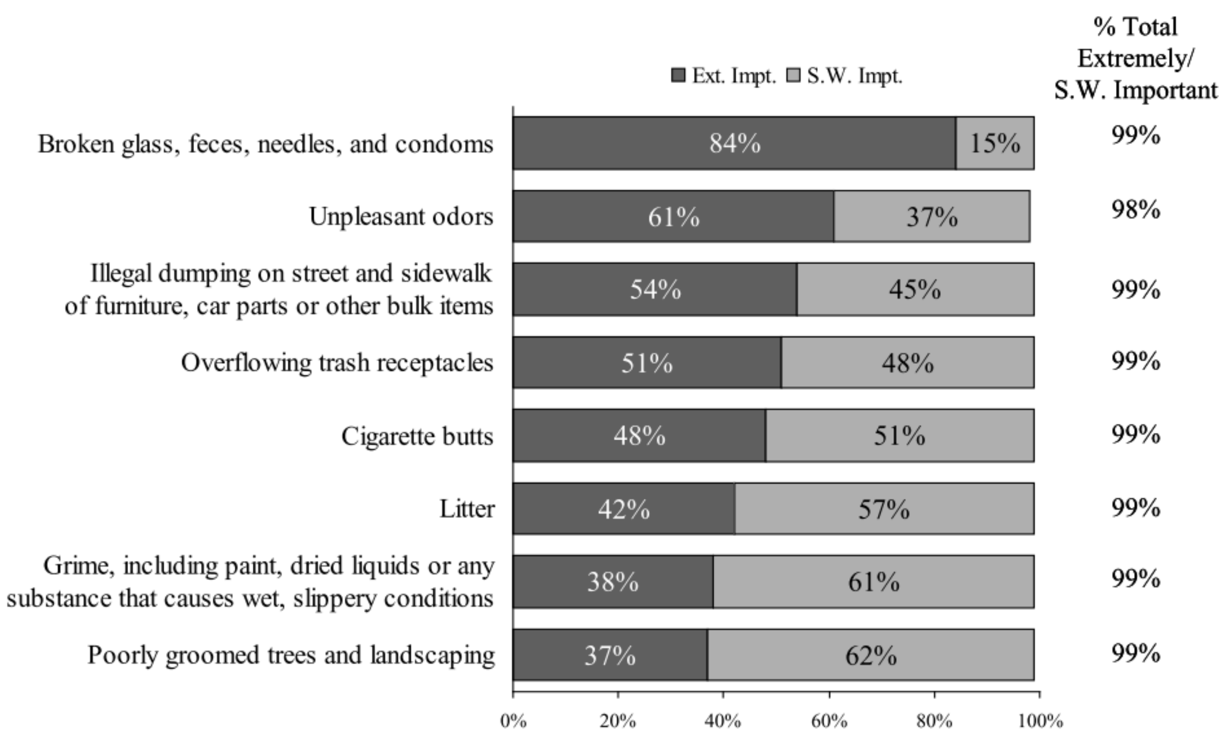


Figure 5. Factors determining lower street and sidewalk cleanliness in San Francisco (Fairbank, Maslin, Maulin, Metz & Associates 2011).

Additionally, the "broken windows theory" suggests that a small sign of disorder in a given neighborhood—including litter, graffiti, and vandalism—can serve as a catalyst for future offenses (Harcourt & Ludwig 2006). It is well-documented that littering behavior increases in a littered setting compared to a clean setting (Bator et al. 2011, Finnie 1973, Geller et al. 1977, Krauss et al. 1978). The presence of litter can increase further littering behavior and may even increase theft in certain situations (Keizer et al. 2008). The perception of high street-level litter and graffiti is correlated with feelings of anxiety and depression (Ellaway et al. 2009). Depression and anxiety have been correlated with other health outcomes, including high smoking rates (Ellaway et al. 2009), thus suggesting a possible feedback loop between smoking and litter. According to the broken windows theory, CFL may have residual negative impacts on the human quality of life. Although these damages are difficult to quantify, clinicians and policy makers are increasingly recognizing the importance of measuring the quality of life in order to inform decisions (Guyatt et al. 1993).

Total Financial Costs

The total annual financial costs that have been historically incurred by various entities in California due to CFL is calculated to be $1.277 billion (Table 8).

Table 8. Total annual financial costs to California
A summary of my financial cost calculations.

Category	Cost	% of Total
Abatement	$ 860,030,565	67%
Tourism	$ 336,279,161	26%
Fishing Catches	$ 36,738,934	3%
Fires	$ 44,375,581	3%
Total	**$ 1,277,424,241**	

Discussion: The California Tobacco Control Program

The California Tobacco Control Program is funded mostly by the California Department of Public Health and has the purpose to dissuade Californians from smoking using outreach and advocacy (California Tobacco Control Program 2016). In the fiscal year 2011-2012, the program was appropriated $70 million, $20 million of which was funded by the California Department of Education (Figure 6). The question is raised: should this money, funded by the California taxpayer, be included when determining costs associated with CFL damages to state? After all, the program effectively reduces CFL generation whenever cigarette consumption is reduced; eliminating the program would increase the generation of CFL. One could make the argument that (at least a portion of) the $70 million should be included in the state's CFL cost determination. However, for the purposes of this assessment, the state's anti-smoking outreach program budget is not included, using the logic that CFL mitigation is a residual effect unassociated with the program's intended purpose. This cost exclusion adds an element of conservation to my total cost estimate. If the California Tobacco Control Program were to incorporate into its mission statement a concern regarding the environmental and human health hazards created by CFL, however, then this cost should certainly be included in a cost analysis.

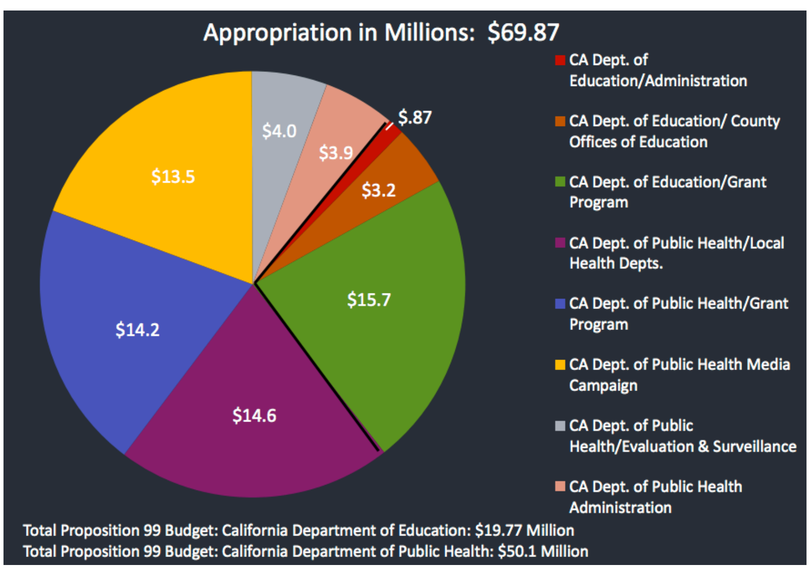


Figure 6. California Tobacco Control Program budget, fiscal year 2011-2012 (California Tobacco Control Program 2016).

Discussion: Kier Associates

In 2013, Kier Associates, a fisheries and watershed consulting agency, was contracted by the Natural Resources Defense Council to conduct a study that quantified annual costs to mitigate litter spent by California "communities", meaning cities, counties, and municipal agencies. This study will be analyzed here in brief for a comparative analysis. The bottom line reported was $428 million (Kier Associates 2013). If the CA CFL-ALR were applied to this figure, the cost incurred by cigarettes to the state would be $155 million (Appendix 14) which is substantially lower than my estimate. The scope of the Kier Associates study focused on damages to waterways, and it compiled data from 95 communities to assess costs associated with storm water capture, storm drain cleaning and maintenance, waterway and beach abatement, other manual abatement, and education. It appears that the study assessed neither costs incurred upon state level entities nor business abatement costs. In the report, the per capita cost categories that fall under the responsibility of a department of public works—street sweeping and manual abatement—translate to about $5 million for the population of San Francisco, whereas in reality the city's budget for such programs is $34.7 million, almost an order of magnitude higher (Appendix 15). Additionally, costs that were acknowledged but not quantified were damages to tourism, damages to the fishing industry, and damages to maritime vessels. Taken together, these factors may explain why the Kier Associates (2013) California litter cost estimates are lower than my own.

III. Environmental Damages

This section assesses environmental risks caused by CFL through a review and synthesis of scientific literature and government reports. CFL creates possible pathways for hazardous effects on human health through direct exposure, bioaccumulation in the food chain, and volatization and polarization into toxic compounds (Figure 7). Here, toxicity, ingestion, and degradation into microplastics will be assessed. Then, an explanation of the precautionary principle will contextualize these findings and suggests the importance of CFL mitigation through policy implementation.

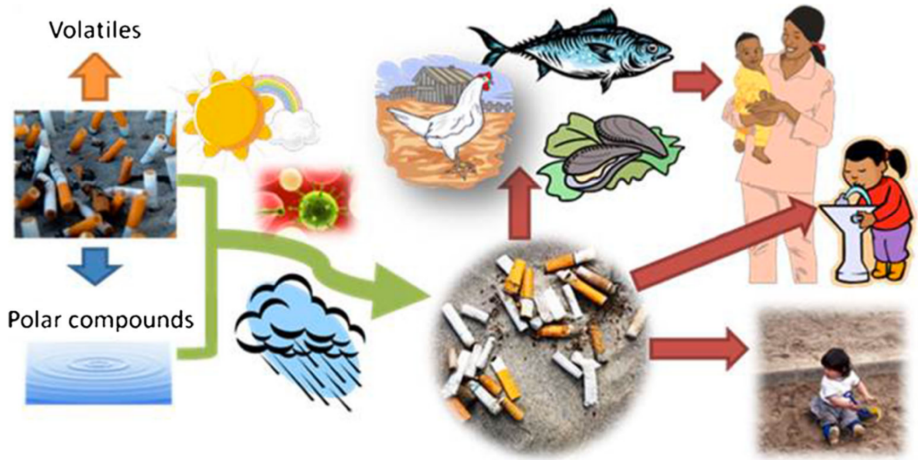


Figure 7. Possible pathways for human health risks caused by CFL
CFL can directly affect human and animal health, bioaccumulate up food chains, and volatize and polarize into various media (Novotny & Slaughter 2014).

Toxicity

When cigarettes are smoked, toxic substances are absorbed into cellulose acetate filters. A combusted cigarette releases between 4,000 and 7,000 airborne chemical compounds, including at least 69 known human carcinogens such as carbon monoxide, hydrogen cyanide, nitrogen oxides, heavy metals, polycyclic aromatic hydrocarbons, ammonia, acetaldehyde, formaldehyde, benzene, argon, pyridines, ethyl phenol, and acetone (U.S. Department of Health and Human Services 2010, Curtis et al. 2016). Indeed, one piece of CFL may contaminate up to 1,000 liters of water above the predicted no-effect concentration (Roder Green et al. 2014). CFL has been observed to create an environmental loading of heavy metals including Cd, Cr, Cu, Pb, and PAH's, as well as Ar and nicotine (Moriwaki et al. 2009). Another study found CFL to be a point source for metal contamination—including Al, Ba, Cr, Cu, Fe, Pb, Mn, Ni, Sr, Tr, and Zn—thus increasing the risk of acute harm to local organisms (Moerman & Potts 2011). With that said, CFL as a whole is a non-point source of pollution, meaning that it can not be attributed to a single identifiable source and that its impacts occur diffusely over a wide area (EPA Victoria 2012).

The research involving CFL's impact on organisms has been recent and will now be presented in chronological order. CFL leachate has been shown to significantly increase acute toxicity for cladoceran, a small crustacean (Register 2000, Micevska et al. 2005).

Certain species of plants may grow higher and have longer roots than those those exposed to CFL, suggesting that there may be a connection between CFL and the depletion of soil nutrients (Dahlberg et al. 2006). LC_{50} values have been calculated with exposure to CFL leachate for two species of fish—the marine topsmelt (*Atherinops affinis*) and the freshwater fathead minnow (*Pimephales promelas*)—the LC_{50} values were found to be approximately one cigarette filter per liter (Slaughter et al. 2011). Notably, it was found that unsmoked cigarette filters (with no tobacco) increased toxicity; LC_{50} values were determined to be 5.1 and 13.5 filters per liter respectively for each species (Figure 8 and Figure 9, Slaughter et al. 2011). CFL has been observed to attract female Asian tiger mosquitos (*Aedes albopictus*) and then lethally affect its progeny (Dieng et al. 2013). Different concentrations of CFL leachate have been observed to alter the heart rate, development, behavior, and mortality of Japanese rice fish (*Oryzias* latipes) embryos (Lee & Lee 2014). Significant lethal and sub-lethal effects of CFL leachate have been reported for three species of tidepool snails (Booth et al. 2015). House finches (*Carpodacus mexicanus)* using CFL to line their nests were found to have a *positive* correlation with hatching success, fledging success, and chick immune response because the CFL acted as a pesticide; however, genotoxicity in the blood cells also increased with the proportion of CFL in the nests, suggesting that the CFL's negative impacts may outweigh its benefits (Suarez-Rodriguez & Garcia 2015). Taken together, this body of literature suggests that CFL could qualify as household hazardous waste as defined by the U.S. EPA because it exhibits toxicity, meaning harm or death when ingested or absorbed (Novotny & Zhao 1999). More about toxicity will be discussed in the product ban section.

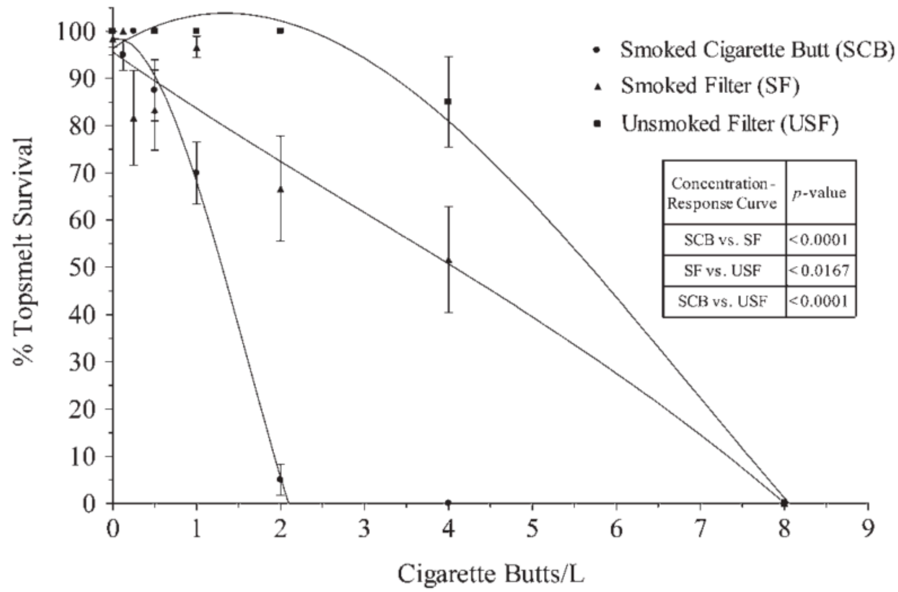


Figure 8. Concentration-response curve for topsmelt
LC_{50} values for the fathead minnow from smoked cigarette butts (filter + tobacco), smoked cigarette filters (no tobacco) and unsmoked cigarette filters (no tobacco). Error bars represent one SE of the mean. Dose-response curves are significantly different (p<.05) (Slaughter et al. 2011).

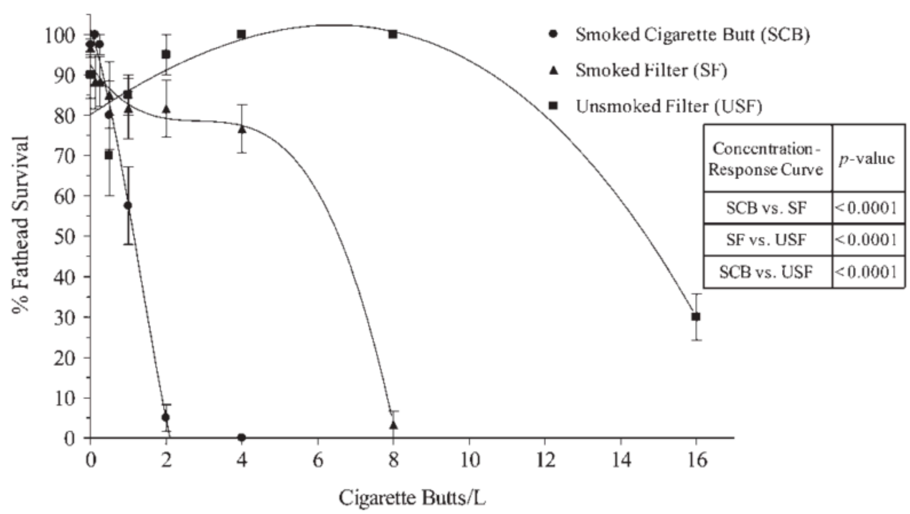


Figure 9. Concentration-response curve for fathead minnow
LC_{50} values for the fathead minnow from smoked cigarette butts (filter + tobacco), smoked cigarette filters (no tobacco) and unsmoked cigarette filters (no tobacco). Error bars represent one SE of the mean. Dose-response curves are significantly different (p<.05) (Slaughter et al. 2011).

Ingestion

Ingestion is inherently difficult to monitor, and so are its effects. For example, consider a fish that ingests CFL and experiences sub-lethal effects; then the weakened fish is eaten by a larger fish. How should that sub-lethal effect be qualified, or even known known in the first place? Linking mortality unequivocally to ingested debris is difficult (Moore 2008) so it is important to conceptualize how non-lethal impediments caused by ingestion could lead to fatal consequences. Plastic ingestion can block gastric enzyme secretion, diminish feeding stimulus, lower steroid hormone levels, delay ovulation, and cause reproductive failure, reduce food uptake, and cause internal injury and death due to the blockage of the intestinal tract (Derraik 2002). The ingestion of plastic materials has been documented in 267 species, including 111 species of seabirds, 26 species of marine mammals, and 6 species of sea turtles (Moore 2008, Sheavly & Register 2007). The extent to which cellulose acetate filters contribute to this problem is undocumented, and it may be valuable for future research to audit and database animal plastic ingestion.

Ingestion would not be such an environmental hazard if CFL was biodegradable. Puls et al. (2011) conducted an extensive literature review regarding the biodegradability of cellulose acetate and stated that some of the initial assessments of the biodegradability of cellulose acetate in the 1970's reached incorrect conclusions because the deacetylation process was not recognized, and the review went as far to state that cellulose acetate is "generally recognized as a biodegradable polymer within the scientific community". This contradicts more recent literature that directly or indirectly referenced Hon (1977) to state outright that cigarette filters are non-biodegradable (Smith & McDaniel 2011, Smith & Novotny 2011, Marah & Novotny 2011). One report has stated that CFL may take many decades to degrade (Dahlberg 2006), while others have argued that although cellulose acetate is technically biodegradable, it is resistant to degradation and can persist for over 18 months even under optimal biodegradation conditions (Novotny & Zhao 1999, Ach 1993). Another recent study found that CFL has a low degradation rate, losing only 38% of its mass after two years (Bonanomi et al. 2015). Notwithstanding, the problem remains that even when a filter degrades into smaller fragments, the result may simply transfer the risk to a similar but smaller scale.

Formation of Microplastics

The exact definition of microplastics has varied across the scientific literature, but it is generally accepted that microplastics are less than 5mm in diameter (Andrady 2011). In contrast to primary microplastics that are directly manufactured—such as microbeads—secondary microplastics are derived from the breakdown of larger macroplastics (Thompson et al. 2009). The disintegration of CFL is impeded by a highly entangled network of approximately 12,000 fibers—each about 20 μm in diameter—which are fused together by plasticizers (Novotny et al. 2009) but over time, cellulose acetate photodegrades into smaller molecule fragments, reducing the the average molecular weight of the plastic polymer and weakening the material (Andrady 2011). Weathering processes degrade plastics and transport the microparticles to water sources (Andrady 2011). Fragmented plastic, even when invisible to the human eye, can undergo further degradation through microbial-mediated biodegradation whereby the carbon is converted into $C0_2$ and incorporated into marine biomass (Andrady 2011). Environmental degradation of plastics can also occur thermally and through hydrolysis (Andrady 2011).

Microplastics create environmental risks including ingestion, toxic leachate, and the disassociation of extraneous pollutants adhered to the microplastics (Cole et al. 2011). The available pathways for the transport of microplastics are complex (Figure 10). Microplastics introduce toxins to the base of the marine food chain, leading to bioaccumulation (Teuten et al. d2009). Ivar Do Sul & Costa (2013) performed a survey of 101 peer-reviewed reports and found that all of the studied marine organism groups are at an eminent risk of interacting with microplastics. The potential for CFL to degrade into secondary microplastics creates environmental risks that are complex, wide scale, microscopic, and difficult to monitor.

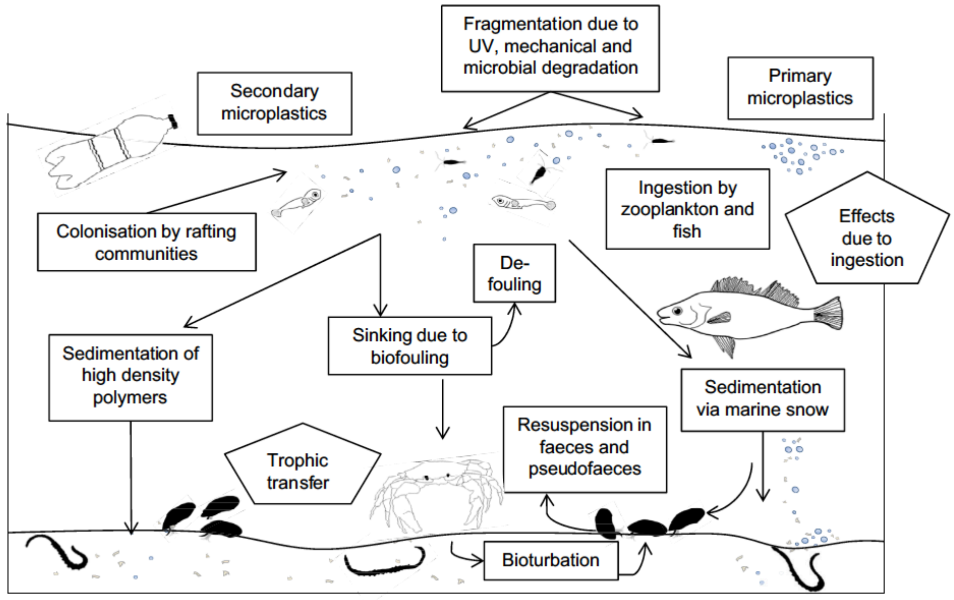


Figure 10. Potential pathways for the transport of microplastics.
These pathways are inherently complex and difficult to monitor (Wright et al. 2013).

The Precautionary Principle

Future CFL mitigation policy action should be warranted due to a recognition of the precautionary principle. The precautionary principle serves as a framework for environmental policy decision making involving uncertain risks, such as complex and poorly understood systems (Kriebel et al. 2001). The principle seeks to address negative externalities by: 1) taking preventative action in the face of uncertainty; 2) shifting the burden of proof to the proponents of a potentially harmful product; 3) exploring alternatives to potentially harmful actions; and 4) increasing public education in decision making (Kriebel et al. 2001). Table 9 presents a qualitative comparison between the precautionary principle and the assimilative principles—which has been the traditional framework for U.S. policy decision making—as they pertain to marine litter (Williams 1996).

Table 9. Assimilative and precautionary principle policy approaches
The two principles are compared and contrasted for addressing marine litter. U.S. governments have traditionally implemented policy under the assimilative capacity approach, although more recently the precautionary principle has been utilized as a guiding framework (Williams 1994).

Assimilative capacity approach	Precautionary approach
<u>Assumptions</u> Contamination of the marine environment is acceptable up to the point of serious or irreversible harm. The ocean has a definable capacity to absorb and assimilate contaminants without harming the biota of marine ecosystems Even with scientific uncertainty regarding the effects of pollutants, it is possible, by risk analysis, to determine safe and unsafe levels of particular contaminants entering the marine environment.	<u>Assumptions</u> Contamination of the marine environment is to be avoided. The variety and complexity of the contaminants and the variety and complexity of the biological species and interactions, make it impossible to accurately predict the effects of specific levels of contamination. Because of the scientific uncertainties, it is not possible to define safe and unsafe levels of contamination, and acceptable levels derived from incomplete information are not protective.
<u>Elements</u> Risk assessment leading to acceptable levels of input of contaminants. Action after proof of damage. Burden of proof upon those questioning a polluting activity. Implementation through discharge limits, usually based on water concentrations rather than total input.	<u>Elements</u> Prevention of contaminants entering the marine environment. Use of scientific information to prioritize reduction efforts. Action before damage and before conclusive scientific proof. Burden of demonstration upon those proposing the activity. Implementation through clean production methods (reducing contamination at the source).
<u>Consequences</u> After decades of implementation, marine pollution and degradation of coastal marine ecosystems has continued to increase.	<u>Conclusions</u> Pollution will decrease if sources of contamination are reduced; coastal marine ecosystems will begin to recover if reductions continue.

Although the U.S. became bound to utilize the precautionary principle on the federal level when it signed and ratified the Rio Declaration, the framework has not been widely adopted because of the influence of commercial interests in the political process (Tickner et al. 2007). New York, New Jersey, and Massachusetts have utilized the precautionary principle in order to regulate cleaning products at schools, pest management products, and 900 industrial chemicals, respectively (Bowling 2008, Tickner et al. 2007). In 2003, San Francisco became the first local government in the U.S. to incorporate the precautionary principle into the city's environmental code; the code frames and develops health and environmental policies (Tickner et al. 2007). Utilizing the precautionary principle, in 2007 California passed legislation that banned the manufacture, distribution, and sale of children's toys containing toxic chemicals including phthalates and bisphenol-A (Tickner et al. 2007).

A need to incorporate the precautionary principle as a means to mitigate CFL has been suggested several times throughout the literature (Barnes 2011, Novotny & Slaughter 2014, Javadian et al. 2015). The damages caused by CFL are difficult to measure as they involve complex and uncertain risks including the following factors: 1) large quantities of generation on a global scale; 2) wide geographic dispersion in a variety of ecosystems; 3) physical characteristics, such as small size, buoyancy, and potential to degrade into microplastics; 4) unknown toxic effects of both cellulose acetate and the combusted chemicals in a cigarette that may be transmitted through ingestion and leachate, and; 5) unknown interactions with other ecological risks such as climate change (Williams 1996). The precautionary principle strongly suggests that policy makers prevent the generation of CFL. The following section explores the available policy options that California has to do so.

IV. Policy Evaluation

Now that damages have been assessed, this section evaluates a variety of policy options that California has to mitigate the negative impacts caused by CFL. First, the general theory is explained of how and why policy mechanisms can address litter. Governments have implemented a variety of policy mechanisms in order to mitigate the damages caused by litter (Derraik 2002, McIlgorm et al. 2011, Oosterhuis et al. 2014). These policy options generally fall into one of two categories: market-based instruments and regulatory policies. Market-based instruments alter prices in a given market as a means to achieve a certain goal; this category includes taxes, fees, charges, and price floors. Regulatory instruments require or prohibit certain activities, products, or behaviors; this category includes locational smoking bans, minimum purchasing age requirements, littering fines, extended producer responsibility and product stewardship programs, and product bans.

For each policy option, I will generally follow the same assessment format: 1) the theoretical purpose of each policy tool; 2) relevant cases and places; 3) the effectiveness of previous implementation, and; 4) feasibility for implementation in California. Effectiveness may involve multiple metrics such as CFL remediation, a reduction in cigarette consumption, and/or economic efficiency. Feasibility in California involves various factors including demography, economy, culture, infrastructure, geography, and political climate. Finally, I will recommend the best policy option(s) for California environmental policy decision makers.

Litter Mitigation Policy Theory

This section explains the general concept as to why and how there are policies designed to mitigate CFL in the first place. Litter is a negative externality; market prices for litter-producing products do not reflect the burden that the product places on various people and entities (Schneider et al. 2011). Environmental economic theory suggests that CFL is as a "public bad", meaning a negative externality that is both non-excludable and non-rival (Oosterhuis et al. 2014). Non-excludability refers to the concept that everyone is somewhat affected by the negative impacts of CFL; non-rivalry refers to the concept that the damages imposed by CFL on an entity do not reduce the damages imposed upon another (Oosterhuis et al. 2014). Those responsible for creating these negative externalities, whether the cigarette manufacturer or the littering consumer, do not incur the full costs of their actions (Oosterhuis et al. 2014). There is a missing market for CFL in the environment, meaning that those contributing to CFL and those that demand to reduce it do not meet to negotiate solutions to the problem—and even if there were, high transaction costs would make this market inefficient (Oosterhuis et al. 2014).

Even though governments have already determined that citizens have the theoretical property right to an un-littered environment—as implied by the passage of anti-litter laws—there is still a burden on the damaged parties to make things right because these laws have poor enforcement, according to Maggie Winslow, professor of environmental economics at the University of San Francisco (M. Winslow, personal communication, March 11, 2016). Opponents to government regulation on litter might invoke the Coase theorem, an economic theory which argues that government regulation of negative externality-producing activities is unnecessary because affected parties will negotiate an efficient outcome amongst themselves over time (Keohane & Olmstead 2007, Guhl & Hughes 2006). However, the

Coase theorem only holds true when transaction costs between parties are negligible. Transaction costs become surmountable between two parties involved in an environmental conflict of interest when certain phenomena occur, such as: 1) a large number of firms or individuals contribute to the problem; 2) information about damages is not widespread; and 3) firms or individuals act strategically in bargaining situations (Keohane & Olmstead 2007). Policy instruments are put in place in order to account for these missing criteria in certain markets and create a more efficient economy.

Determining the effectiveness of a policy depends on what goals are desired by policy makers. Here, the overarching metric for effectiveness is the reduction of CFL in the environment. However, the goal could be the reduction of a particular risk, such as removing plastic or toxic substances from the environment or reducing the financial costs that CFL places on society. In any case, policy makers should strive to achieve a certain goal in the most cost-effective means possible (Walls 2006). Cost-effectiveness can theoretically be measured by comparing the marginal costs and benefits for mitigating a certain extent of litter (Keohane & Olmstead 2007), assuming that the data is available. Policy mechanisms can be designed to reach certain goals by influencing different stages of the targeted material's product life-cycle (Figure 11). Multiple policy instruments may be needed to accomplish certain goals because one instrument may not efficiently do so (Walls 2006).

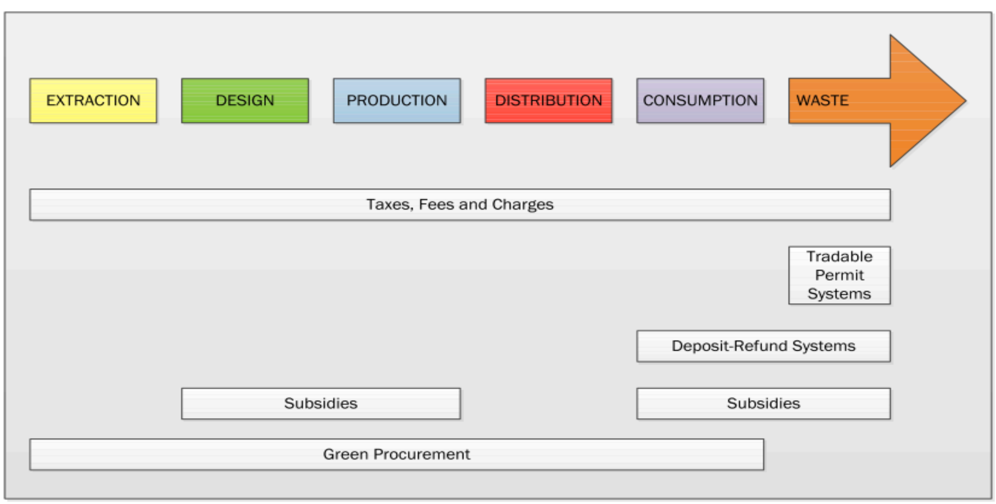


Figure 11. Policy instruments throughout the value chain
The boxes represent stages of a product's life cycle. Policies can affect different stages of the value chain. The term "green procurement" is similar in concept to "design for environment" to be discussed in the product stewardship section (Hogg et al. 2011).

Market-Based Instruments

Theory

Market-based instruments—sometimes referred to as "market-based economic instruments" or "economic instruments"—comprise a category of policy options that addresses inherent market flaws by creating a price signal, meaning a change in the cost or price of a market good or service, or by creating a new market with allowable trading systems (Ten Brink et al. 2009). This category includes taxes, charges, fees, fines, liability and compensation schemes, subsidies, price floors, incentives, and tradable permit schemes (Keohane & Olmstead 2007, Ten Brink et al. 2009). Depending on which of these instruments is implemented, a market-based instrument can change behavior, such as reducing production or consumption, and/or raise revenue for a governing agency. When the goal is to raise an amount of revenue that reflects the cost of the negative externality, the policy is sometimes said to reflect the "polluter pays principle" or "full cost recovery" (Ten Brink et al. 2009). As a policy tool, market-based instruments generally require less resources than regulatory instruments because the desired behavioral changes should naturally occur through market forces if the instruments are implemented correctly (Keohane & Olmstead 2007). Although it is widely acknowledged that market-based instruments tend to be more economically efficient than regulatory instruments, market-based instruments may require supporting regulations or targets in order to function properly (Hogg et al. 2011). Increasing the price of cigarettes is an evidence-based tobacco control strategy that can produce substantial long-term improvements in health by reducing consumption (Ribisl et al. 2010). Also, jurisdictions with policies that raise the price of cigarettes are correlated with having fewer fires (Markowitz 2013). Here, I assess the feasibility and potential effectiveness of market-based instruments as applied to CFL mitigation in California.

Tax

Theory

A tax is a market-based instrument that places a surcharge on a product or activity whereby the surcharge is remitted to a governing agency in a fund to be used for general public benefits; there does not need to be a direct relation between the tax paid and the benefit that a taxpayer receives (Smith & McDaniel 2011, Hogg et al. 2011). Taxes can be levied at different points in the value chain, and the collected tax revenue can be allocated in different ways. The goal of a tax can be two-fold: it can both reduce consumption of a harmful product as well as raise revenue for the government (David 2011, Ten Brink et al. 2009). If the goal is to maximize revenue for the government, an optimal tax incorporates the concept that consumers purchase less of a given product when its price is higher; this is known as Pareto-efficiency (Guhl & Hughes 2006). Empirical studies indicate that historic tax rates imposed on cigarettes are often far below the level of maximizing tax income (David 2011).

Determining an effective tax is influenced by the willingness for a customer to pay for a product once its price is increased; this concept, known as demand elasticity, will now be discussed. Economists calculate demand elasticity for consumer goods in order to assess market conditions and predict how a market-based instrument could raise government revenue (Keohane & Olmstead 2007). Elasticity can be calculated through empirical studies when the price of a commodity changes. Generally, a commodity with an elasticity above the absolute value of 1 is said to be elastic, while a commodity with an elasticity below 1 is considered to be inelastic (Keohane & Olmstead 2007). Next, I will assess the effectiveness of prior taxes on cigarettes in terms of reduced consumption and revenue procurement.

Examples

For human health reasons, cigarettes have been taxed in various jurisdictions. In 1995, the U.S. federal excise tax on cigarettes was $0.24 per pack; in 2009, the tax was raised to $1.01 per pack. During the same period, the average state excise tax increased from $.33 to $1.20 (U.S. Department of Health and Human Services 2009). The federal tax is allocated to the Children's Health Insurance Program in order to address human health issues (Jamison et al. 2009).

In California, ballot initiative proposition 99 was passed in 1998, placing a $0.25 tax on every pack of cigarettes sold; the tax fund partially supported tobacco control programs throughout the state (California Department of Public Health & California Tobacco Control Program 2015). Statewide per capita cigarette consumption declined significantly afterwards (California Department of Public Health & California Tobacco Control Program 2015).

Currently, the California tax on cigarettes is $0.0435 per unit ($0.87 per pack), which ranks the state as number 32 in the nation (Figure 12); for comparison, New York has a $4.35 tax per pack (U.S. Department of Health and Human Services 2009). Of this $0.87, the revenue is allocated as such (Table 10): 1) $0.50 is allocated to the California Children and Families Trust Fund, which develops programs that encourage proper childhood development; 2) $0.25 is allocated into the Cigarette and Tobacco Products Surtax Fund, which may use the revenue to develop tobacco-related health education programs disease research, medical and hospital care for low-income residents, and programs for fire prevention, environmental conservation, and the enhancement of state and local parks and recreation; 3) $0.10 is allocated into the Cigarette Tax Fund, and; 4) $0.02 is allocated to the Breast Cancer Fund (California State Board of Equalization 2015). The Cigarette and Tobacco Products Surtax Fund is allocated towards fire prevention, environmental conservation, and the enhancement of parks.

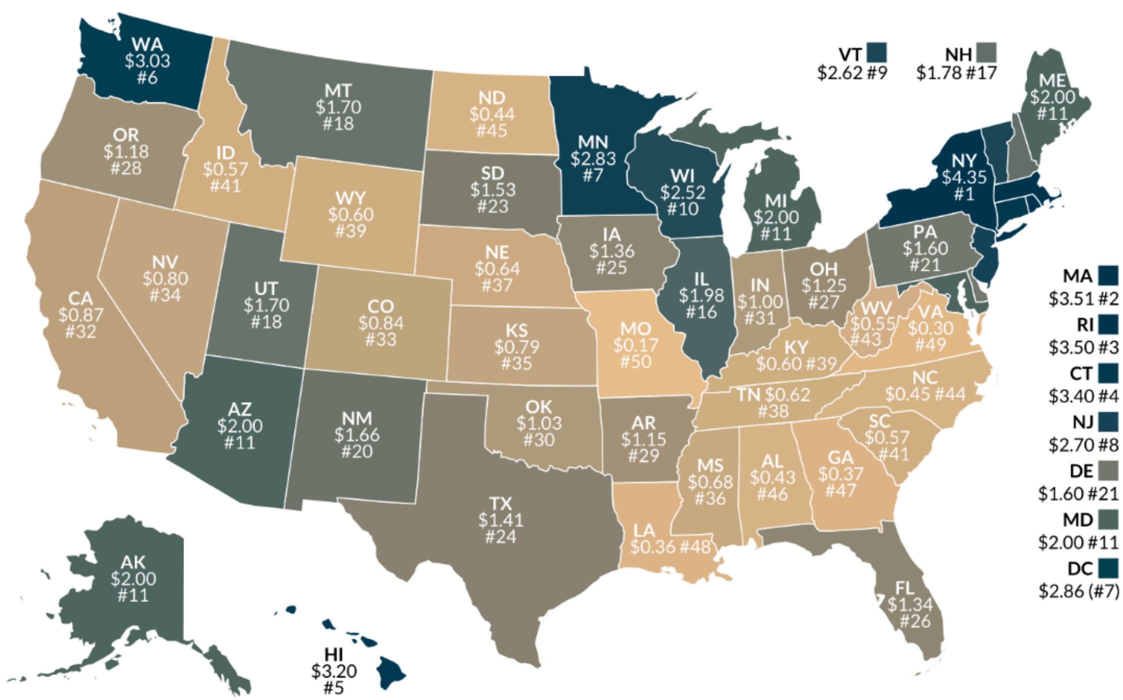


Figure 12. 2014 State Cigarette Excise Tax Rates
Per pack of 20 cigarettes. Local taxes are not included (Emmanuel & Borean 2014).

Table 10. Allocation of California State Cigarette Tax
(California Board of Equalization 2015).

Amount Allocated	Program Name	Program Uses
$ 0.50	California Children and Families Trust Fund	Childhood development, including professional and parental education and training
$ 0.10	Cigarette Tax Fund	General fund
$ 0.02	Breast Cancer Fund	Breast cancer research
$ 0.25	Cigarette and Tobacco Products Surtax Fund	1. Tobacco-related health and education programs and disease research 2. Medical and hospital and treatment care prevention; 2) environmental conservation; protection, restoration, enhancement, and
$ 0.87	Total	

Logistically, California distributors pay the $0.87 tax by purchasing cigarette tax stamps from the State Board of Equalization, and the distributors are required to affix the stamp to each pack before distribution; importantly, distributors pass the tax on to their customers, effectively rendering a higher retail selling price (California State Board of Equalization 2015). There are also fixed and annual cigarette licensing fees placed on registered retailers, wholesalers, distributors, manufacturers, and importers (California State Board of Equalization 2015).

Effectiveness

In terms of revenue raising, California cigarette excise taxes annually have generated as much as $786 million in state revenue and $350 million in local revenue (California Legislative Information 2015). The California Cigarette and Tobacco Products Surtax Fund is notable because it addresses environmental damages. The actual allocation of the fund is unknown, but if an equal allocation is assumed across its three categories (education and research, medical care, and environmental damages), then the current California environmental mitigation fund is calculated to be $103.7 million; this covers 8.1% the financial costs previously calculated in this report (Appendix 16).

A reduction in the consumption of cigarettes leads to a reduction in CFL. Understanding demand elasticity for cigarettes can therefore suggest how CFL generation changes. Performing a literature review, Chaloupka & Warner (2000) found that estimates of cigarette elasticity demand using individual level data generally range from -0.20 to -0.70 for various age groups, meaning that if cigarette prices were increased by 10%, there would be a decrease in global consumption between 2-7%, or roughly 42 million smokers (Table 11). Although the demand curve is non-linear, it is generally purported that a 10% increase in price will be accompanied by a decrease in consumption between 2.5-5% (Chaloupka & Warner 2000). Tauras (2006) examined the impact of cigarette prices and smoke-free air laws on adult cigarette demand, but unlike previous studies, he allowed for the possibility that general sentiment toward making the laws in the first place may have confounded results, concluding that the true elasticity is -0.126. Ahmad & Franz (2008) determined that a 40% tax-induced price increase would reduce smoking prevalence from 21% in 2004 to 15.2% in 2015.

Table 11. Potential global impact of 10% increase in price of cigarettes
Non-price measures include advertising and promotion bans, consumer information, clean air laws, and warning labels on cigarette packs. From Chaloupka & Warner (2000).

	Change in No of smokers (millions)		Change in No of deaths (millions)	
Countries	Price increases	Non-price measures	Price increases	Non-price measures
Low or middle income	–38	–19	–9	–4
High income	–4	–4	–1	–1
Worldwide	–42	–23	–10	–5

There are drawbacks to tax mechanisms. Tax revenue can be missed due to smuggling and black markets for cigarettes. Increasing tax rates on cigarettes has been shown to increase international and interstate smuggling (Stehr 2005, Ahmad & Franz 2008). The presence of smuggling complicates accurate determinations of cigarette demand elasticity—and effectively the generation of tax revenue—because the consumption of smuggled cigarettes is unaccounted for and untaxed (Ahmad 2005, Stehr 2005). In addition, cigarette taxes have been accused of being regressive in nature, meaning that they impact a disproportionate number of lower-income individuals (David 2011, California Legislative Information 2016).

Smuggling currently accounts for 8% of cigarette consumption in the U.S. (Ahmad & Franz 2008, Chaloupka & Warner 2013), and perhaps 32.7% of the cigarettes consumed in California were smuggled in 2012 (Henchman & Drenkard 2014). In response to smuggling, enforcement efforts and penalties can be increased, although these activities place a burden on government resources (Ahmad & Franz 2008). The 2003 California Cigarette and Tobacco Product Licensing Act (Assembly Bill 71) requires that any seller of cigarettes must be registered with the California State Board of Equalization (Horton 2014). Every year, the Board of Equalization conducts 10,000 inspections to ensure compliance; in fiscal year 2004-2005, 869 inspections showed counterfeit stamps (Horton 2014). This number decreased to 13 in fiscal year 2012-2013; although cigarette and tobacco tax evasion still amounted to $214 million during this time, the program has been viewed as successful (Horton 2014).

Feasibility

The largest obstacles to increasing cigarette taxes in California are political. In 2012, the California ballot initiative Proposition 29 sought to raise the state tax to $1.87—and despite polling showing 2:1 support in favor for the initiative—tobacco companies spent $46.3 million to the opposition campaign, and the initiative was narrowly defeated (California Department of Public Health & California Tobacco Control Program 2015). In 2015, a poll conducted by the California Wellness Foundation found that 50% of 1,555 registered California voters would strongly support raising the state tobacco tax by $2.00 and that 17% would somewhat favor such legislation (Seipel & Calefati 2015).

An significant political barrier to furthering California cigarette taxes is Proposition 26. The 2009 passage of the San Francisco Cigarette Abatement Ordinance (discussed in the next section) initiated a strong political reaction from Big Tobacco (Freiberg 2013, Tobacco Control Legal Consortium 2014). In 2010, Big Tobacco led a front group called "Stop Hidden Taxes", which—together with the alcohol and oil industries—lobbied for the successful passage of the statewide ballot initiative Proposition 26 (Freiberg 2013). Under Proposition 26, any proposed fee within the state is categorized as a tax and must receive a supermajority vote (>66%) from the state legislature in order to take effect (California Taxpayer Association 2011, Tobacco Control Legal Consortium 2014). Prior to Proposition 26, such a fee required a simple majority vote (>50%). A supermajority is very difficult to obtain for any political measure—let alone a policy that involves any degree of controversy—according to Robert Haley, Zero Waste Program Manager at the San Francisco Department of the Environment (R. Haley, personal communication, April 12, 2016).

If it weren't for state politics, an increase in the California cigarette tax would be a feasible and straightforward way to reduce cigarette consumption and CFL generation. The logistics and processes are already in place; it would only be a matter of increasing the current tax. More about California cigarette taxes will be discussed in the recent California legislative activity section.

Fee

Theory

A fee is a market-based instrument that places a surcharge on a given commodity whereby the fund generated is allocated to programs that are designed to mitigate negative externalities caused by the taxed commodity (Smith & McDaniel 2011, Tobacco Control Legal Consortium 2013). So, a fee is conceptually very similar to a tax except that fee revenue can't be allocated to a general fund. A fee should be designed to reasonably correspond to the public cost of addressing the waste problem and administering the fee program (Tobacco Control Legal Consortium 2013). Fees can be levied at different points in the value chain e.g. manufacture, distribution, wholesale, retail, and consumption (Oosterhuis et al. 2014).

Examples

There have been various accounts of fees placed on products that are frequently littered. In 2002, Ireland instituted a $0.17 levy on plastic bags whereby the revenues generated are remitted to the Department of the Environment, Heritage, and Local Government (Convery et al. 2007). The policy has reported great success with low administrative costs and a 90% plastic bag consumption decrease by 2007 (Convery et al. 2007, Oosterhuis et al. 2014,

Table **12**, Figure 13). In 1994, Denmark placed a plastic bag tax of 22 krones (U.S. $3.30) per kilogram on retailers, which cut plastic bag usage by 66% by 1999 (He 2012). In 2012, Denmark had the lowest per capital consumption rate (4 bags) and litter rate (0.5%) of plastic bags compared to the rest of Europe (Kasidoni et al. 2015).

Table 12. Fees and charges, consumption, and litter in 6 locations
Trends show a consistent decrease in both consumption and litter. Data from Hogg et al. (2011), He (2012), and San Francisco Department of Environment (2016).

Year	Location	Surcharge (U.S. Equivalent)	Consumption Trend	Impact on Litter
2002	Ireland	Initially 17¢, then 25¢	Per capita decrease from 328 bags to 30 bags in 2007	Plastic bag litter reduced from 5% to 0.25% from 2001 to 2010
2002	Italy	Initialy 15¢, then 23¢	Decrease from 1.3 billion to 20 million from 2001 to 2003	N/A
2003	South Africa	5¢	Approximate 50% reduction	N/A
2007	Belgium	1 - 10¢ per bag (weight dependent)	80% reduction in sales between 2003 and 2009	N/A
2007	San Francisco	10¢ charge on paper, compostable, recycled-content bags + plastic bag ban	N/A	All bag litter reduced from 4.4 to 4.2% in 2009. Plastic bag litter reduced from 2.49% to 2.05%
2008	China	3¢ - 8¢ (retailer decides)	49% reduction (40 billion bags)	N/A

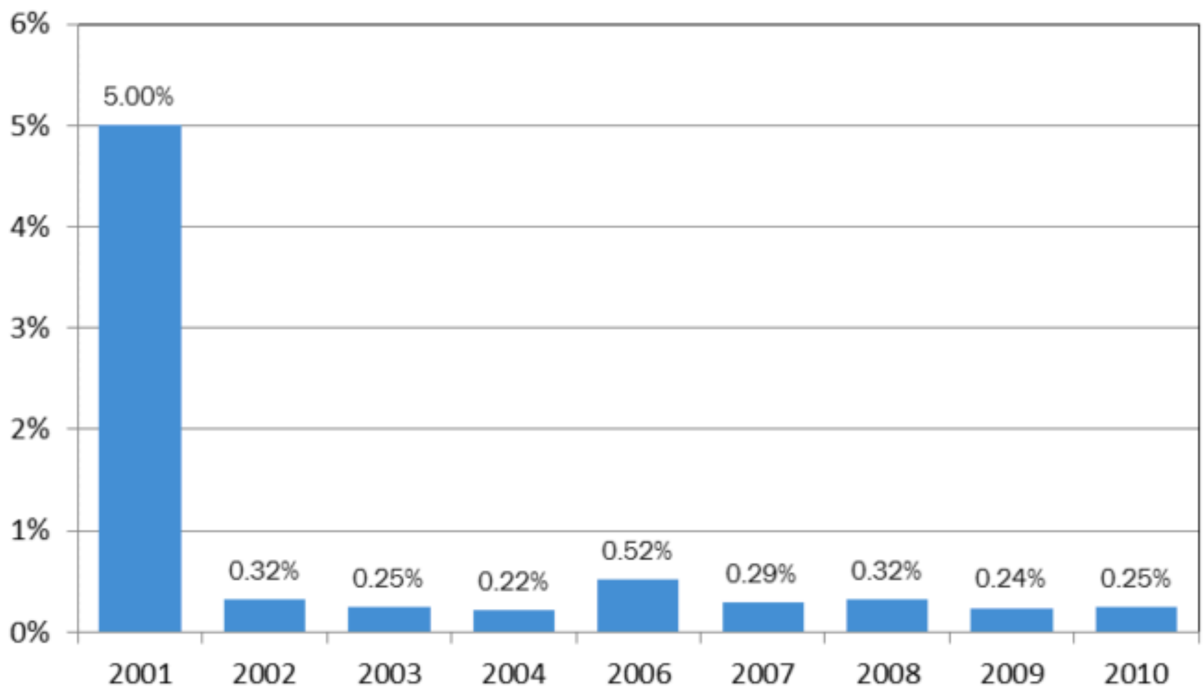


Figure 13. Plastic bags as a percentage of Ireland's national litter composition
Ireland implemented a plastic bag charge in 2002, which led to a 90% decrease in plastic bags as litter (Hogg et al. 2011).

In California, statewide fees exist for commonly improperly discarded consumer products; examples include the Electronic Waste Recycling Fee on electronics (1995) and the Tire Recycling Act (1996), which currently imposes a $1.75 fee upon the purchase of a new tire and uses the fee revenues to fund programs that promote recycling and other alternatives to stockpiling and landfilling tires (CA State Board of Equalization 2016). New Jersey implemented a Litter Control Fee in 2002 that applies to manufacturers, wholesalers, distributors, and retailers of 15 categories of litter-generating products whereby the revenue funds litter cleanups and municipal recycling programs (Waterfront Partnership of Baltimore & Abell Foundation 2011). The effectiveness of the New Jersey fee is debatable; litter rates in the state are close to the national average, and urban litter rates are 41% higher than the national average (Waterfront Partnership of Baltimore & Abell Foundation 2011).

In 2009, San Francisco implemented the Cigarette Litter Abatement Fee Ordinance. The ordinance required that every pack of cigarettes sold within the city includes a $0.20 fee to be imposed on the consumer at the point of sale (Schneider et al. 2011). The revenue created by the fee is remitted to the San Francisco Office of Treasurer and Tax Collector, which allocates the majority of the fund to the San Francisco Department of Pubic Works for litter abatement—commonly referred to as manual and mechanical street sweeping—while the rest of the fund is allocated to the Treasury Office for administrative costs.

It is important to recognize that the fee was designed and calculated to cover only the costs that the Department of Public Works had previously been spending on CFL abatement (Schneider et al. 2009, Schneider et al. 2011). The other financial costs associated with CFL, as previously discussed, were not included in this calculation (Schneider et al. 2011). The fee was calculated using the following methodology: in 2009, the San Francisco Department of Public Works had a budget of $25 million for the category "Street Environmental Services" which includes street sweeping, the placement and maintenance of litter receptacles, and graffiti abatement (Schneider et al. 2011, San Francisco Department of Public Works 2016). The San Francisco Department of Environment hired a consulting agency that performed a litter audit and determined that CFL comprised 22.5% of all litter (Schneider et al. 2011). Street sweeping costs for CFL were determined to be $5.6 million by assuming that the cost to abate CFL is about the same as the cost to abate an average mix of litter (as I have done). An additional $1.4 million was added in order to account for administrative costs to handle the abatement program—as well as an anti-littering campaign developed by the city—yielding a total cost of $7 million (Schneider et al. 2009). Schneider et al. (2011) analyzed data from the U.S. Economic Census, the Center for Disease Control, and the 2007 California Health Interview Survey to determine that the annual per capita number of cigarette packs consumed is about 31.8 in both California and San Francisco. Assuming that half of cigarettes are purchased outside of the city, it was estimated that 30.6 million packs are consumed in San Francisco annually (Schneider et al. 2011). Dividing the $7 million cost by the number of packs consumed yielded a per-pack fee of $0.22, and this was used to justify the $0.20 fee mandated by local ordinance (Schneider et al. 2011).

On January 1, 2016, the San Francisco Office of the Controller doubled the fee to $0.40 (Cisneros 2015). Doubling the fee to $0.40 was justified by an analysis of the 2014 litter audit conducted by the same consulting agency in 2009 (HDR 2014, Sabatini 2015). Using the same litter audit methodology, it was reported that—between 2009 and 2014—the ratio of CFL (compared to all litter) increased from 24.5% to 53% despite the fact that the volume of CFL actually decreased 24% from 2,683 to 2,057 observations (HDR 2014). This is explained by the dramatic 68% decrease of all litter observed from 10,970 to 3,881 pieces (Table 13, HDR 2014). The fee increase was also influenced by the fact that the Department of Public Works increased its budget for street environmental services from $25 million in 2009 to over $37 million in 2015 (Table 15, San Francisco Department of Public Works 2016); again, the methodology used to calculate the fee multiplied the budget by the CFL composition ratio. Based on these factors, the City Controller announced that a true fee to effectively cover CFL street sweeping costs would be $0.84 per pack but that the Controller's Office decided to limit the fee to $0.40 in order to reduce market volatility (Sabatini 2015).

Table 13. Characterization of San Francisco 2009 and 2014 litter audits
Although the volume of tobacco-related litter decreased during this time, its relative composition increased from 22% to 53% (HDR 2014).

Year	Total Litter	Non-Tobacco	Tobacco	% Tobacco
2009	12,123	9,399	2,724	22%
2014	3,881	1,817	2,064	53%
Decrease	68%	81%	24%	

Effectiveness

Between 2010 and 2015, the the San Francisco Cigarette Litter Abatement Fee generated an annual average of $2.9 million (SD = $462,000) for the San Francisco Department of Public Works "Neighborhood Corridor Manual Cleaning Program", according to Shelly Ericksen, the Chair of the Hold on to Your Butt campaign, an anti-CFL advocacy volunteer effort supported by the San Francisco chapter of the non-profit SurfRider Foundation (S. Ericksen, personal communication, November 19, 2015, Table 14). This figure is significantly less than the $5.6 million that the fee was designed to collect for the Department of Public Works. Perhaps the implementation of the fee led to an increase in cigarette purchasing outside of San Francisco, although this is merely speculation. The street environmental services budget for the San Francisco Department of Public Works increased from $25 million in 2009 to an average of $35.9 million (SD = $2.2 million) between fiscal years 2012 and 2015, thereby suggesting an average CFL abatement cost of $8.1 million (SD = $500,000); this approximation assumes the 22.5% CFL-Litter ratio from 2009 and not the increase in the ratio found in the 2014 litter audit (Table 15). This implies an even larger differential between the desired revenue and the actual revenue raised.

Table 14. San Francisco abatement fee revenue, 2010-2015
This is the revenue allocated by the San Francisco Department of Public Works towards its Neighborhood Corridor Manual Cleaning Program. Information provided by S. Ericksen (personal communication, November 19, 2015).

Year	Amount
2010	$ 3,814,970
2011	$ 2,468,579
2012	$ 2,840,522
2013	$ 2,878,825
2014	$ 2,780,188
2015	$ 2,721,230
Average	$ 2,917,386
Standard Deviation	$ 462,986

Table 15. San Francisco Department of Public Works budget for street sweeping
As the budget increases, so should the San Francisco Cigarette Abatement Fee, according to the fee's original calculation methodology. The CFL costs column assumes the 22.5% CFL-ALR originally observed; the 2014 San Francisco litter audit observed a 53% ratio, which should also increase the abatement fee amount (Department of Public Works 2016, HDR 2014).

Fiscal Year	Street Environmental Services	CFL Costs (Assuming 22.5% CFL-ALR)
2012-13	$ 33,400,000	$ 7,515,000
2013-14	$ 37,000,000	$ 8,325,000
2014-15	$ 37,400,000	$ 8,415,000

It is important to understand that the fee calculation is derived from what the local government had *previously been spending* on one form of CFL abatement, not necessarily what should be spent for effective abatement. Even though observed CFL decreased from 2009 to 2014, the fee was justifiably doubled because the fee calculation methodology involved historic data and post-hoc logic. Data is unavailable regarding CFL remediation by street sweeping; a back-end litter audit on the materials collected would provide valuable input for future research. For now, suffice it to say that a significant portion CFL is not remediated by street sweeping; between November 2015 and May 8, 2016, San Francisco volunteer organizations collected over 54,000 pieces of CFL at beaches and parks; this is an extremely conservative estimate because most of the clean ups did not account for CFL as a separate material at all (S. Ericksen, personal communication, April 15, 2016, Table 16). If the goal of a fee is to fund projects that mitigate the true costs of CFL, then all financial costs should be included in the fee calculation for a proper cost-benefit analysis. Even so, such a fee would not address all of the unquantifiable environmental damages caused by CFL.

Table 16. CFL collected by San Francisco volunteer organizations in 2016
The SurfRider Foundation beach performs 3 two-hour beach clean ups every month, but CFL is usually not collected as a separate material, so these numbers are likely to be very conservative (Data provided by S. Ericksen, personal communication, April 15, 2016).

Organization	# CFL
SurfRider Foundation	41,204
Shark Stewards	10,583
SF State University	3,100
Total	54,887

With that said, the San Francisco Cigarette Litter Abatement Fee is an innovative policy measure that creates a model from which other CFL abatement fees can be built. The fee places a financial disincentive on the consumer and contributes to a fund designed to mitigate CFL damages, thus creating an element of product stewardship (which will be discussed in detail later).

Feasibility

Devising a proper fee for California fundamentally requires two inputs: the financial costs CFL creates for the state and the number of packs of cigarettes consumed in California. Financial costs to the state of California caused by CFL have been calculated to be $1.227 billion. To determine California cigarette consumption, the Schneider et al. (2011) methodology is used, multiplying the per capita pack of cigarette figure (31.8) to the population of California to yield 1.25 million packs; dividing the CFL-related financial costs to the state by the number of packs consumed yields a California Cigarette abatement fee of $1.03 (Appendix 17). Perhaps a more appropriate statewide fee calculation would only consider abatement costs. Using the same methodology, an appropriate California cigarette abatement fee would be $0.69 (Appendix 18).

One potential challenge with a statewide CFL fee mechanism is the equitable allocation of the revenues across the stakeholders that pay the costs to mitigate CFL. The cost of implementation, or cost efficiency, for allocating scare resources—such as public funds—is an important factor that determines the effectiveness of a market-based instrument (Oosterhuis et al. 2014). From an administrative standpoint, it could be difficult and expensive to determine how to fairly allocative the fund across local governments, businesses, educational institutions, and non-profit organizations.

With that said, fees face similar challenges as taxes in California due to Proposition 26. Under Proposition 26, a policymaker can establish that any levy, charge, or exaction is a fee, rather than a tax, if and only if it abides by the following qualifications: 1) the charge is used to specifically and exclusively benefit the people who pay the charge; 2) the government imposing the charge can establish by a preponderance of the evidence that the charge is reasonable in amount and effect, and; 3) the fee falls under an exception outlined in Proposition 26. A California CFL mitigation fee would benefit a variety of stakeholders—not exclusively the smokers who pay the fee—so such a fee would qualify as a tax under Proposition 26. Also, it would easy for opponents to claim that the government's charge is not reasonable in amount and effect by a preponderance of the evidence because—as has been discussed here—such a calculation is inherently complicated. So, despite the San Francisco abatement fee being grandfathered in, any further attempt at implementing a cigarette fee in California, either locally or statewide, would be politically challenging.

Charge

The terms “tax”, “fee”, and “charge” are often used interchangeably throughout the literature; however, in California, a charge is differentiated from a tax or a fee, and this can make a big difference in terms of political feasibility. Unlike taxes and fees, in California, charges are not remitted to governing agencies but rather kept by retailers (State Board of Equalization 2011, R. Haley, personal communication, April 24, 2016). In effect, although a charge should influence consumption just as a tax or a fee would, a charge does not create revenue for government funds. Charges are not subject to the supermajority vote requirement that Proposition 26 requires of proposed fees in California (R. Haley, personal communication, April 24, 2016). The revenue raised by a charge is not included in the retailer’s gross receipts and is not subject to sales or use tax (State Board of Equalization 2011). Therefore, proposed charges should receive less political pushback from entities representing local business interests. So, charges are tools that can reduce the consumption of products with relative political ease.

Examples and Effectiveness

Most of the plastic bag bans in the U.S. simultaneously place a charge on the allowable alternative bags—such as paper, compostable bags, and recycled content bags—with the intention to further encourage the use of re-usable bags (San Francisco Department of the Environment 2016, Surf Rider Foundation 2016). After San Francisco implemented such a policy in 2007 for supermarkets and retailers, bag litter in the city decreased from 4.4% composition to 4.2% in 2009 (HDR et al. 2009, San Francisco Department of the Environment 2016). In 2014, New Jersey attempted to pass a $0.05 fee/charge mechanism on all disposable bags in certain commercial entities whereby $0.01 would be kept by the retailer and $0.04 would be remitted to the State Department of Environment (National Conference of State Legislatures 2015). Although the bill died in the State Senate, the duality of the payment mechanism is noteworthy as a possible strategy for policy decision making.

Because most of the literature uses the terms “charge” and “fee” interchangeably, there is little available data regarding charges as defined in California. The clarification is identified here to highlight a potentially politically feasible means to introduce a market-based instrument to cigarettes in California—bypassing the requirements of Proposition 26—therefore reducing the consumption of cigarettes and the generation of CFL.

Price Floor

A price floor mandate on the sale of cigarettes is another potential avenue to reduce cigarette consumption without involving Proposition 26. Price floors can be established by legally requiring minimum percentage markups throughout the cigarette distribution chain and/or by prohibiting trade discounts from cigarette manufacturers to wholesalers and retailers (Ribisl et al. 2010). In 2010, 25 U.S. states had minimum price laws for cigarettes (Ribisl et al. 2010). As recently as March 2016, the northern California Sonoma County Board of Supervisors approved an ordinance that would set a $7 price floor on a pack of cigarettes starting in the year 2018 (Hart 2016). Price floors should reduce consumption as per demand elasticity, although literature regarding price floors is lacking; more research should be conducted to determine how price floors affect consumption and revenue generation (Ribisl et al. 2010). More about California price floors will be discussed in the recent California legislative activity section.

Regulatory Policy Instruments

Now that the category of market-based instruments has been assessed, this section evaluates the other major policy category that could effectively mitigate CFL—regulatory instruments. Whereas market-based instruments are designed to reach goals by creating market price signals, regulatory instruments take a more direct government approach by requiring certain standards to be met by stakeholders involved with a product, system, or activity that produces negative externalities (Keohane & Olmstead 2007). These stakeholders could be virgin material extractors, product manufacturers, transporters, distributors, retailers, consumers, and/or waste haulers. Regulatory policy is sometimes referred to as "command-and-control" or "prescriptive policy" and it is generally more resource-intensive to administer—compared to market-based instruments—because it involves setting standards, monitoring activities, and enforcing penalties for non-compliance. Here, three subsets of regulatory instruments will be evaluated: consumer behavior regulation, extended producer responsibility / product stewardship, and product prohibition. These options will be assessed using the same format as that of the previous section: theory, examples, effectiveness, and feasibility with California.

Consumer Behavior Regulation

This section discusses policy options that regulate consumer behavior. I will discuss locational smoking bans, minimum purchasing age requirements, and littering fines. These options tend to place burdens on local governments and may be costly to enforce and administer.

Locational Smoking Bans

Theory

Due to the negative effects of secondhand smoke on human health and the quality of life, there have been many behavioral smoking bans in the U.S. since the 1980's (Novotny et al. 2009). Behavioral restrictions are laws designed to prevent certain environmental and human health risks from occurring. If such a regulation is violated, then a penalty is administered to the bad actor(s). Past research has suggested that the adoption of such bans create a change in social norms about smoking and reduce its acceptability (Klein et al. 2006).

Examples

Federal law prohibits smoking within any indoor educational facility or library that has access for children (Holtby et al. 2011). In 1995, California became the first state to ban smoking in all enclosed workplaces; restaurants and bars were exempted until 1998 (California Air Resources Board 2015). Whereas indoor smoking bans have been implemented to protect human health, outdoor smoking bans have generally been implemented to address littering. Maine has prohibited smoking in all state parks and beaches, and various U.S. municipalities have banned smoking in parks and beaches (Barnes 2011). In 2004, the California State Senate attempted to ban smoking on all 64 state parks and beaches, but the bill failed by two votes (Novotny et al. 2009). Then, in 2010, a California law prohibiting smoking in all states and beaches passed both legislative bodies, but it was vetoed by Governor Schwarzenegger, who stated that a more effective approach would be to increase the fines and penalties already established in the littering laws (Barnes 2011). In 2004, California Assembly Bill 846 banned smoking with 20 feet of all public buildings and within all state owned vehicles (Vincent 2003). Smoking is prohibited on the premises of licensed childcare centers, within 25 feet of a playground, as well as within a motor vehicle in which a minor is present (Holtby et al. 2011). On May 4, 2016, California Assembly Bill 7 was signed by Governor Brown, extending the workplace ban to include owner-operated businesses and excluding previous exemptions such as certain bars and gaming clubs (Adler 2016); this will be discussed further in the recent California legislative activity section.

Effectiveness

Compliance with indoor smoking laws has been successful in the U.S., reaching 90% within 3 months in New York City and Boston, and 99% in restaurants in California (Klein et al. 2007). Clean indoor air laws predict lower average daily smoking among adults, although smoke-free air laws generally do not predict smoking prevalence (Tauras 2006). It is possibly problematic that indoor smoking bans may exacerbate CFL prevalence by forcing people to smoke outside; one case study performed in the U.K. found that CFL increased 43% after an indoor smoking ban was introduced (Novotny & Slaughter 2014). Also, jurisdictions with laws regulating indoor smoking are correlated with having a higher number of fires (Markowitz 2013).

Feasibility

Indoor smoking bans have already been successfully implemented in California. It is certainly feasible that California could pass a state or assembly bill that prohibits smoking in all state parks and beaches so long as the governor does not veto it. Like anti-littering penalization, enforcement is a key ingredient for the effectiveness of an outdoor smoking ban. Prohibitions on smoking behavior have been legally challenged on the grounds that smokers have a constitutional right to due process of the law and equal protection; however, these challenges have generally failed because smoking is not a protected right under the U.S. Constitution (Tobacco Control Legal Consortium 2013). Local jurisdictions have the ability to implement stricter smoking behavior regulations, and at least 32 California cities and counties have done so (Novotny et al. 2009). In addition, local communities and landlords also have the right to prohibit on premise smoking (Novotny et al. 2009).

Minimum Age Requirement

Another behavioral regulatory instrument is setting the minimum age at which a person can purchase cigarettes. Because most people begin smoking between the ages of 15 and 17—which is when they are most susceptible to becoming addicted (Institute of Medicine 2015)—the theory of raising the purchasing age is to decrease consumption by preventing smokers from getting addicted at an early age. I was able to locate one piece of grey literature that discussed the effectiveness of raising the smoking age to 21, finding that the adult smoking prevalence decreased 50% over 10 years since the policy was adopted in the town of Needham, Massachusetts (Feferberg 2015). One drawback of this policy mechanism is that it may take many years to take effect. In California, one benefit is that the policy is not subject to Proposition 26.

In January 2016, Hawaii became the first U.S. state to raise the age from 18 to 21 (Feferberg 2015). In June 2016, San Francisco will join more than 100 other U.S. cities in doing the same (Tinker 2016). In fact, by June 9th, the entire state of California's minimum cigarette purchasing age will be raised to 21 due to Governor Browns' signing of Senate Bill 7 on May 4, 2016; this is a very significant development that will be discussed in the recent California legislative activity section.

Littering Fines

Theory

A penalty is a financial disincentive designed to reduce a targeted behavior or activity placed on consumers when a behavior, such as littering, violates a law (Oosterhuis et al. 2014). Policymakers are challenged with setting the appropriate level of a penalty in order to achieve a given target (Oosterhuis 2014). The level can be based on a variety of criteria, including costs of damages produced by the targeted behavior, legal limits or precedents administered elsewhere, and/or an affordability basis (Ten Brink et al. 2009). Penalties vary widely depending on the jurisdiction and the scope of the problem (Ten Brink et al. 2009).

Examples

All U.S. states have anti-litter laws, but penalties differ widely based on the type, amount, and location of litter generated (Schultz & Oleen 2014). In some states, the severity of the littering penalty is determined by weight, whereas in others, volume is the determining factor (Schultz & Oleen 2014). The California penal code states that it is unlawful to litter and that the fine for a first offense must be between $250 and $1,000; second offense penalties must range between $500 and $750, and third (and subsequent) convictions require a fine between $750 and $3,000 (California Legislative Information 2007). Novotny et al. (2009) stated that fines for littering may be as high as $1,000 in some states, and importantly, that fines could be levied by states or municipalities "against cigarette manufacturers based on the amount of cigarette waste found either as litter or as properly disposed waste". Barnes (2011) stated that a reward of 50% of an administered fine can be granted to a person who gives information leading to an arrest and conviction of a littering party. However, I could not locate cases of these two latter assertions in the literature.

Paris has received recent media attention by ramping up its enforcement of administering €68 ($76) litter fines for cigarette filters in particular (The Local 2015). It is reported that 3,900 Paris employees collect 350 (metric) tons of CFL annually (The Local 2015), but supporting data is unavailable, and the effectiveness of the enforcement is unknown. It is interesting to note that Paris installed 30,000 "ashtray bins" to encourage smokers to discard CFL properly (The Local 2015); the provision of this kind of infrastructure will be discussed in the product stewardship section.

Effectiveness

Anti-littering laws are generally poorly enforced (Barnes 2011, Ten Brink et al. 2009, Novotny & Zhao 1999). The California Highway Patrol is responsible for enforcing littering laws on highways throughout the state, but relatively few tickets are administered because the violation must be observed in progress (Gordon 2006). Between 1998 and 2005, the

Washington State Department of Ecology (2007) conducted various focus group studies on littering behavior and determined that the primary motivation that would encourage litterers not to litter would be the realistic threat of being caught and fined. Threats of fines are commonplace in litter prevention programs, but there are few systematic evaluations of their efficacy; threats may even exacerbate littering behavior (Keep America Beautiful & Action Research 2009). Enforcement is essential for an effective implementation of a penalty mechanism (Ten Brink et al. 2009).

Feasibility

Littering fines could very well be an effective and feasible policy tool to mitigate CFL in California. The policy already exists; as previously stated, enforcement is what needs to happen. Various consulting and government reports highly recommend enforcement strategies and offer appropriate mechanisms for penalizing CFL, including making enforcement visible (Department for Environment, Food, and Rural Affairs 2007, New South Wales EPA 2013, Ueda et al. 2011, California Tobacco Control Program 2013). Through civil action, the offense of littering needs to be made a priority to both local council and enforcement officers. Before implementing enforcement mechanisms on littering, municipalities usually make a public announcement about the new law and allow for an arbitrary grace period of enforcement to take effect; some municipalities run awareness-raising media campaigns as well (Ueda et al. 2011). Gordon (2006) suggested increasing anti-litter enforcement by authorizing citizen monitoring, implementing a uniform reporting procedure and reporting hotline, and deputizing citizens in local communities as "trash police".

It is proposed here that the penalty for CFL is exempted from California penal code section 374.4 so that the fine can be lowered. I submit that law enforcement officers generally aim to keep good relations with the citizens whom they serve and that a $250 fine for CFL is excessive. If littering fines were lowered to $50 to $100 (like in Paris), then they would be easier to administer because the fine would match the crime. In the U.K., penalty notices that allow for a degree of flexibility for penalty amounts—including a reduced rate for early payment—have been suggested as an effective anti-litter mechanism (Department for Environment, Food, and Rural Affairs 2007). Once the quantity of administered fines increases, awareness about the issue should motivate smokers to litter less; however, the extent of this behavior change, as well as its timeliness, is uncertain. Although enforcement requires resources, the money generated by CFL fines could generate revenue for local enforcement agencies.

Discussion: Producer Pays Principle

I will transition now from consumer to producer regulation by discussing the polluter pays principle in brief. The polluter pays principle is the regulatory concept that the costs of the pollution (a negative externality) that an entity emits—typically a commercial producer—should be fully incorporated into the market price for goods and services produced by that entity (Oosterhuis 2014). These costs can be internalized through penalization or through litigation. Witkowski (2014) discussed the possibilities of legally challenging cigarette manufacturers to pay for the negative externalities created by CFL, although such legal action is unprecedented; cigarette manufacturers claim to relinquish responsibility for CFL once the product is transferred to the consumer (Curtis et al. 2014). Penalties are placed on producers when regulatory standards determined by the government are violated, such as emission standards, product standards, or ambient environmental quality standards (Keohane & Olmstead 2007, Ten Brink et al. 2009). Penalties do not directly affect market prices; however, the enforcement (or threat) of a penalty may incentivize a commercial polluter to administer resources towards mitigating the polluting behavior, and these resources may indirectly raise market prices. Or, a commercial polluter may choose to continue paying pollution penalties if a cost-benefit analysis deems the behavior profitable; the penalization costs should indirectly raise market prices in this scenario as well (Keohane & Olmstead 2007). The following section discusses options for internalizing negative externalities through regulatory policy aimed at producers and other responsible entities.

Extended Producer Responsibility and Product Stewardship

Theory

Extended Producer Responsibility (EPR) is an environmental policy protection strategy designed to reduce the impact of a consumer product by making a manufacturer legally responsible for the product's entire life-cycle, including its post-consumption life stage (Javadian et al. 2015, Curtis et al. 2014). This is sometimes known as "cradle-to-grave" responsibility (Hunt et al. 1992, Figure 14). EPR regulates toxic and environmentally unsustainable materials materials that pollute and litter the environment (Curtis et al. 2014). By making producers responsible for the economic, physical, and informational handling of consumer goods, the net negative externalities caused by the consumer good are reduced to the public (Curtis et al. 2014). Lindhqvist (2000) identifies the following three core tenants of EPR: 1) an internalization of the costs associated with negative environmental externalities into the retail price of a product; 2) a shift of the economic burden associated with the management of toxicity and other environmental damages towards producers and away from local governments, and; 3) a provision of incentives for producers to adopt more sustainable design throughout a product's life cycle. It should be noted that when an EPR system creates financial responsibility for a producer, price signals may be indirectly created.

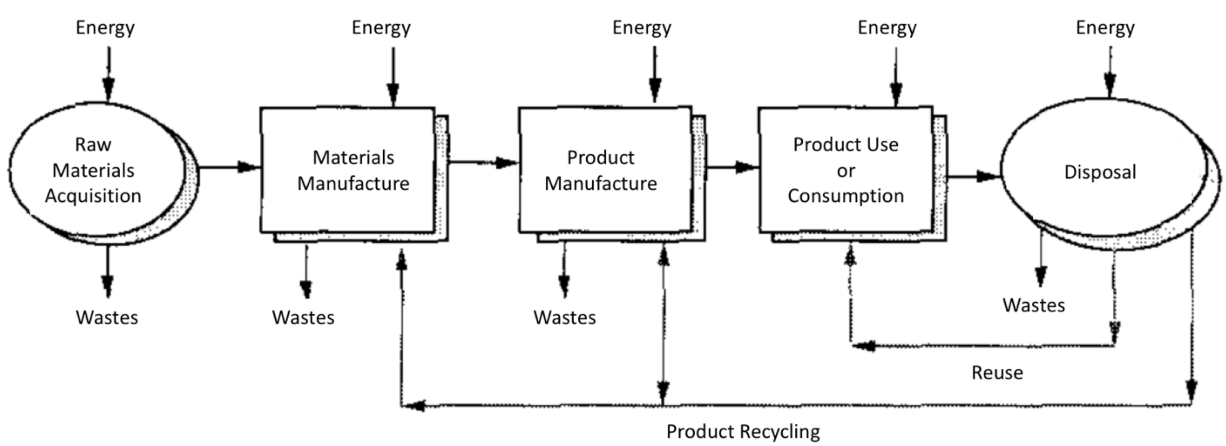


Figure 14. General flow for "cradle-to-grave" materials management
There are various stages in a consumer product's life cycle. Extended producer responsibility attempts to make producers and manufacturers responsible for all stages, particularly the post-consumption disposal stage (Hunt et al. 1992).

Product stewardship is a closely related concept to EPR, the difference being that product stewardship allocates responsibility not just to producers but also to various stakeholders involved in the product's life cycle such as growers, designers, distributors, sellers, disposers, and/or consumers (Curtis et al. 2016). The responsibility is allocated based on the extent to which a particular stakeholder has the ability to create or reduce the negative externalities that a consumer product creates (Curtis et al. 2014).

For the purposes of this study, the general concepts of EPR and product stewardship are similar enough that they will be assessed here in tandem as "EPR-PS"; differentiations will be acknowledged when relevant. EPR-PS has historically been implemented through mandatory and/or voluntary take-back programs whereby manufacturers, importers, distributors, or retailers responsibly recover a product (Oosterhuis et al. 2014). The government typically establishes recycling rate targets for specific materials, and to meet these requirements, industries or businesses may be required to form a separate entity referred to as a producer responsibility organization. EPR-PS are designed to effectively ensure the safe recovery of materials. The application of EPR-PS principles to CFL mitigation policy may create residual public health outcomes by: 1) de-normalizing tobacco use; 2) increasing the price of tobacco products; 3) enacting new tobacco product regulations to make cigarettes less marketable; 4) strengthening anti-litter and outdoor smoking prohibitions, and; 5) creating new alliances with environmental advocacy and tobacco control groups (Curtis et al. 2016). Examples of EPR-PS systems will now be identified and assessed for effectiveness. Then, an EPR-FS system for CFL in California will be assessed for feasibility.

Examples

Due to declining landfill capacity, European nations have generally led the way with EPR-PS legislation (McKerlie et al. 2006). The German Green Dot model is another well-known, successful, noteworthy EPR model; however, the Green Dot model deals with recyclable and/or reusable packaging materials, and it falls outside of the scope of this assessment. The Directive on Waste Electrical and Electronic Equipment (WEEE), however, deals with potentially hazardous materials, and it will be now discussed in brief. In 2003, the European Union member states implemented the WEEE Directive and its accompanying Directive on the Restriction of certain Hazardous Substances. The directive required producers of electronic consumer products to clearly label their products and inform consumers that the product must be handled outside of the landfill waste stream (McKerlie et al. 2006). Consumers were mandated to be able to return WEEE to collection points free of charge, and producers bore all costs for recovery (McKerlie et al. 2006). Producers were also made responsible for taking back “orphaned waste”, meaning obsolete WEEE consumer goods produced before the directive was passed (McKerlie et al. 2006). The legislation also mandated the phase out of certain known toxic ingredients in the production process for electronic consumer goods, such as lead, cadmium, mercury, hexavalent chromium, and certain brominated flame retardants (McKerlie et al. 2006).

In the U.S., EPR-PS systems are more patchwork and less stringent when compared to European efforts. The Product Stewardship Institute is a non-profit organization that works with government, private sector, and non-profit partners to implement systems in the 33 U.S. states where EPR-PS legislation has passed (Curtis et al. 2016). As of October 2010, 32 U.S. states had implemented laws requiring manufacturers to finance the costs of recycling and safe disposal of consumer products such as auto switches, batteries, carpet, cellular phones, electronics, fluorescent lighting, mercury-containing thermostats, paint, and pesticide containers (Barnes 2011). These systems, as well as the WEEE Directive, are more applicable to a proposed model for CFL because of the hazardous nature of the materials that they are designed to recover.

The California Product Stewardship Council is a network of local governments, non-government organizations, businesses, and individuals that advocates for EPR-PS programs (Sanborn 2016). The council currently facilitates such statewide programs involving troublesome materials including batteries, carpet, fluorescent lamps, paint, mattresses, pharmaceuticals, sharps, and thermostats (Sanborn 2016). In 2007, California Assembly Bill 2449 required that large grocery stores and pharmacies have a take-back program for plastic grocery bags and other kinds of plastic film (California Ocean Protection Council 2008). In 2015, San Francisco passed the Safe Drug Disposal Stewardship Ordinance, requiring producers of prescription and/or over-the-counter medicines sold in the city to participate in an approved stewardship program for the collection and disposal of unwanted medicine from residential sources (San Francisco Department of Environment 2016, P. Ojea, personal communication, April 21, 2016). The ordinance has yet to be fully implemented, but due to the size and scope of pharmaceutical consumer products, there could be lessons learned and applied to a CFL EPR-PS program regarding infrastructure, outreach, collection, and creation of the stewardship organization.

Effectiveness

EPR-PS systems create significant potential economic benefits for local governments and taxpayers by diverting and recovering hazardous waste materials with financial support from responsible entities (Wagner 2013). In Vancouver, EPR-PS systems have been estimated to annually divert 165,000 tons of materials from collection and disposal systems to product stewardship management systems, translating to at least $22 million in savings to local governments in addition to reduced environmental liability and regulatory risks (McKerlie et al. 2006). Through conducting waste composition studies, EPR-PS systems have been found to significantly decrease the presence of hazardous waste materials as well as recyclable material such as metal, glass, and plastic containers (McKerlie et al. 2006).

The WEEE and Restriction of Hazardous Substances Directives is credited to have had an immediate global impact on the product design of electronics, particularly by phasing out lead solder and polybrominated diphenyl ethers (McKerlie et al. 2006). However, due to the continued increase in the global production of electronic consumer products, the disposal of WEEE products has been estimated to have increased between 16-28% between 2002 and 2007 (Ongondo et al. 2010). Recycling mandates are not ordinarily designed to curb usage (Smith & McDaniel 2011); this is a potential argument against EPR-PS legislation for CFL. In Germany, the program has been estimated to responsively recover 50-63% of targeted materials (Ongondo et al. 2010). A major global concern is the environmental impacts caused by WEEE entering landfills (Ongondo et al. 2010). In the U.S., it is estimated the over 102.5 billion toxic cigarette filters are annually discarded "properly" into the landfill stream (Table 1); based on this volume, cigarette filters deserve attention considering their potentially toxic effects on landfills.

Feasibility

There is enough groundwork to implement an EPR-PS model for CFL. Barnes (2011) argued that an effective CFL EPR-PS system should follow the 2011 Maine Product Stewardship Law; this would require the tobacco industry to institutionalize a stewardship organization that submits a plan to the government as to how CFL would be responsibly recovered. Curtis et al. (2016) developed a guiding framework to institutionalize an EPR-PS system in order to mitigate CFL. Its core provisions draw upon the Oregon PaintCare law which requires paint manufacturers to finance and operate a system for retrieving, transporting, and processing leftover paint. In effect, a stewardship organization, funded by the cigarette industry, would submit to the government various accountability measures such as plan approvals and amendments, goals and performance standards for material recovery, education and outreach programs, annual reports, annual stakeholder meetings, and privacy considerations (Curtis et al. 2016). The main benefit of such a system would be to recover CFL and therefore mitigate its presence in the environment. A residual benefit could be substantial data collection regarding CFL generation. Although a CFL EPR-PS model could be resource-intensive to develop—particularly in terms of up front governmental administrative costs—over time, the idea is that relevant stakeholders will fund the program.

In December 2015, the California Department of Public Health funded a project that developed specific language written as an ordinance designed to legally codify such a program; nuances of the ordinance are clarified in detail, and the authors encourage California jurisdictions to incorporate the model ordinance into their respective legal codes (ChangeLab Solutions 2015). This "Model California Ordinance Regulating Tobacco Waste" would make it illegal for any cigarette brand to be sold in a jurisdiction unless the manufacturer or distributor created or joined a product stewardship program. Cigarette manufacturers would be required to submit a plan that includes how CFL is collected, how the program would reduce CFL, and how the collected CFL would be disposed. The jurisdiction could set performance measures. Manufacturers would be required to perform outreach efforts regarding how to properly dispose of CFL. Manufacturers would be responsible for covering all costs associated with collecting, transporting, and disposing the CFL as well as the costs incurred by the jurisdiction in implementation and enforcement. A manufacturer could opt out of the program by paying an in-lieu fee to the local jurisdiction. The jurisdiction would calculate the amount of the fee by considering both the total costs incurred by the government to mitigate CFL as well as the percentage of market share that a particular cigarette brand has in the jurisdiction. The methodologies used earlier to calculate CFL abatement costs for government entities could be a useful tool for determining appropriate in-lieu fees.

Alternatively, if CFL were recognized as a household hazardous waste, then it would be legally required to a have a responsible recovery system in place. The U.S. EPA defines household hazardous waste as having a chemical nature that can poison, corrode, explode, or ignite easily when handled improperly while also having the potential to be generated in a residence (U.S. EPA 2016). It is important to note that "household hazardous waste" is a separate category from "hazardous waste"—which refers to byproducts from manufacturing and/or production processes—and the two are treated very differently for regulatory processes (California Department of Toxic Substances Control 2016). In 1986, California Assembly Bill 1809 required local government agencies to identify programs for household hazardous waste. The California public resources code (section 47000-47004) mandates that the state should assist the efforts of local governments and other agencies to provide responsible disposal systems for household hazardous waste. In California, it is illegal to dispose of household hazardous waste in the landfill, down the drain, or by abandonment (California Department of Toxic Substances Control 2016). Assembly Bill 1809 established guidelines and state policies for local governments to provide community services for household hazardous wastes, authorized cities and counties to increase fees or rates charged for services that responsibly recover the materials, and required public education concerning household hazardous substances (CalRecycle 1997). Assembly Bill 888 (1989) required local agencies to implement household hazardous collection, recycling, and disposal programs (CalRecycle 1997). The major drawback to this approach, however, is that once a material is recognized as a household hazardous waste, its disposal becomes heavily regulated; legally, volunteer organizations would not be permitted to abate CFL if it were considered as household hazardous waste, according to Maggie Johnson, Residential Toxics Reduction Coordinator for the San Francisco Department of the Environment (M. Johnson, personal communication, May 12, 2016).

Discussion: Outreach and Consumer Education

If an EPR-PS system were implemented for CFL, one potentially problematic point of contention could be the extent to which producers should fund and/or perform consumer outreach about the negative externalities created by CFL. Barnes (2011) stated that the unique issues surrounding the disposal of cigarette filters would require the stewardship organization to include extensive consumer education about the environmental hazards of CFL as well as better enforced penalties for improper disposal. Essentially, the issue boils down to the extent to which consumers are responsible for creating CFL.

Proponents of CFL EPR-PS systems have reported how the tobacco industry has funded studies designed to prove that smokers litter in order to avoid producer responsibility (Novotny et al. 2009, Smith & McDaniel 2010, Smith & Novotny 2010). This was discussed earlier in the Keep America Beautiful discussion section. In spite of this observation, or perhaps because of it, these proponents have tended to ignore consumers' littering behaviors and attitudes as a significant contributing factor to the problem. Although Curtis et al. (2016) admitted that enforcement of a CFL EPR-PS system may be challenging due to smokers' lack of adherence to litter laws, the authors did not acknowledge consumers as a responsible entity in the EPR-PS schematic. Rather, the authors suggested that consumers should be induced to comply through better anti-litter law enforcement. Here, I submit that smokers do litter and should accordingly be given a degree of financial responsibility in an equitable EPR-PS system. Walls (2006) makes the case that the advanced recycling fee mechanism—whereby a tax is assessed on product sales and remitted to an entity that responsibly recovers the product—qualifies as an EPR mechanism. Such a fee can be assessed upstream on producers and effectively be incorporated into the product retail price or it could be assessed downstream on consumers at the point of sale as a separate line item (Walls 2006). The latter option is similar to the fee market-based instrument discussed earlier, and it allows for an allocation mechanism for equitable financial responsibility in an EPR-PS model.

To what extent will outreach and education influence littering behavior? The evidence is mixed regarding smokers' knowledge and attitudes about the environmental impacts of CFL. Some smokers believe that certain brands of cigarettes, such as Camel, contain cotton, biodegradable filters (Smith & Novotny 2011). Rath et al. (2012) cited two surveys which reported that a majority of smokers perceive CFL as biodegradable and one survey that reported the opposite finding. It must be noted that the definition of biodegradability is not clarified. Even those considered to be well-informed on the subject matter have varying perceptions about CFL's impacts. Javadian et al. (2015) surveyed 350 members of the Framework Convention Alliance which included mainly non-governmental tobacco control advocacy groups that support the Framework Convention on Tobacco

Control. 73% considered CFL to not be biodegradable. When asked who should be responsible for the remediation of CFL, 72% responded “smokers”, 62% responded “cities/communities”, and 77% responded “the tobacco industry”. Rather et al. (2012) concluded that most of the smokers who litter do consider CFL to be litter, and the authors suggested—as originally submitted by Dr. Thomas Novotny, the primary CFL research scientist in the field—that the term “litter” does not properly convey the toxic, damaging nature of cigarette filters and that the term “waste” may be more appropriate.

Witkowski (2014) held that although cigarette manufacturers are not littering themselves, it is reasonably foreseeable that the smoker is likely to do so; even if the manufacturers made the argument in court that the smokers’ littering behavior were an intervening action—thus eliminating proximate cause responsibility for the manufacturer—such a lack of control of this behavioral misuse is not an absolute bar to liability for the manufacturer. Interestingly, Witkowski (2014) assessed the possibilities of litigation in the form of a public nuisance offense; in this case, a government could sue the cigarette manufacturing industry in order to hold producers liable for the damages incurred by CFL. This possibility would validate the polluter pays principle. I recommend that future research investigates such legal strategies.

Discussion: Infrastructure

The availability and convenience of collection infrastructure is a key factor in determining the effectiveness of an EPR-PS system (Wagner 2013). EPR-PS frameworks require participation from consumers, who must segregate the material and transport it to a specifically designated collection site (Wagner 2013). EPR-PS generally requires the creation of a separate and often parallel convenient collection system for a targeted material—as is the case for Connecticut and Maine state law—although the definition of convenience is not defined (Wagner 2013). Wagner (2013) performed a thorough and comprehensive analysis of EPR-PS collection systems and concluded that the key factors influencing consumer convenience are: 1) knowledge of the collection system; 2) proximity to a collection site; 3) available times to drop off materials; 4) the desirability of the collection site, and; 5) the ease of the drop off process. Here, the feasibility of CFL infrastructure will be discussed.

Various studies have suggested how both the availability and proximity of waste receptacles are correlated with lower littering rates (Finnie 1973, Geller et al. 1979, Meeker 1997). Littering rates typically decrease as the provision of proper receptacles increases (Cope et al. 1993, Geller et al. 1979, Geller et al. 1982). These studies have also found that brightly decorated receptacles significantly reduce litter. As discussed earlier, some proponents of EPR-PS have discredited Keep America Beautiful studies that have shown the importance of infrastructure for recovering CFL, claiming that the results are used to shift responsibility away from cigarette manufacturers and towards local governments, which are typically responsible for the provision of waste receptacles (Barnes 2011). However, the Keep America Beautiful findings are not wrong; people litter less when more receptacles are provided. The real question for policy makers is: how should the permitting, installation, and maintenance of such infrastructure be equitably funded in a CFL EPR-PS system?

Regardless of how the responsibility is allocated, any CFL waste collection system should be cost effective and practical. Thankfully, recent technologies, systems, and companies have developed that can streamline an EPR-PS system for CFL. TerraCycle is an American business that utilizes innovative technologies in order to recycle notoriously difficult-to-recycle items; the company currently recycles cigarette filters into plastic pellets to make industrial products like shipping pallets (Yi 2014). To date, TerraCycle has designed and installed over 300 CFL receptacles in 13 North American cities (TerraCycle 2016). In November 2013, the City of Vancouver, Canada, installed 100 CFL receptacles purchased from TerraCycle for $12,000 and by June 12, the city had collected 200 pounds, or approximately 5,300 pieces of CFL (City of Vancouver 2014, Appendix 19). The receptacles were serviced by a non-profit recycling organization that works with disadvantaged people from the neighborhood (Meisner 2013). Kreisman (2014) estimated that the efficacy of this pilot program was between 3% to 6%, although the definition of "efficacy" was not clarified.

Sidewalk Buttler has installed 100 CFL receptacles in Portland, Maine, collecting over 400,000 butts in one year, according to the company's owner, Mike Roylos (M. Roylos, personal communication, April 7, 2016). The maintenance of the Sidewalk Buttler receptacles is streamlined using a mobile application that monitors the fullness and frequency of service for each receptacle using geo-location (M. Roylos, personal communication, April 7, 2016). This data collection model can suggest where to best strategically place receptacles.

It could also be used to develop a mobile application to show smokers where CFL receptacles are located on a digital map.

Another bottom-up approach to streamline CFL infrastructure could utilize data provided by the mobile application Litterati, which builds geo-spatial “litter profiles” and a digital database of litter based on user photographs and material-specific tags, according to the company’s founder and owner, Jeff Kirschner (J. Kirschner, personal communication, April 8, 2016). The Litterati database currently contains over 202,000 data entries, of which approximately 16.6% are CFL (Appendix 3). Litterati could be used to geo-locate high impact CFL areas, and infrastructure could be placed there accordingly.

Another approach could utilize data provided by Marah & Novotny (2011), who developed top-down model to predict high impact CFL areas using Geographic Information System software. The researchers utilized census data of business such as bars, convenience stores, cafes, and gas stations to predict where CFL is most likely to occur (Figure 15). Then the model was tested with litter collection audits, and the average number of CFL found in the high-predicted areas (38.1, SD = 19.9) was found to be statistically significant when compared to that of the low-predicted areas (4.8, SD = 5.9). The authors concluded that CFL was highly correlated with businesses that sell cigarettes. This finding raises the question: to what extent should sellers be responsible for implementing a CFL EPR-PS system?

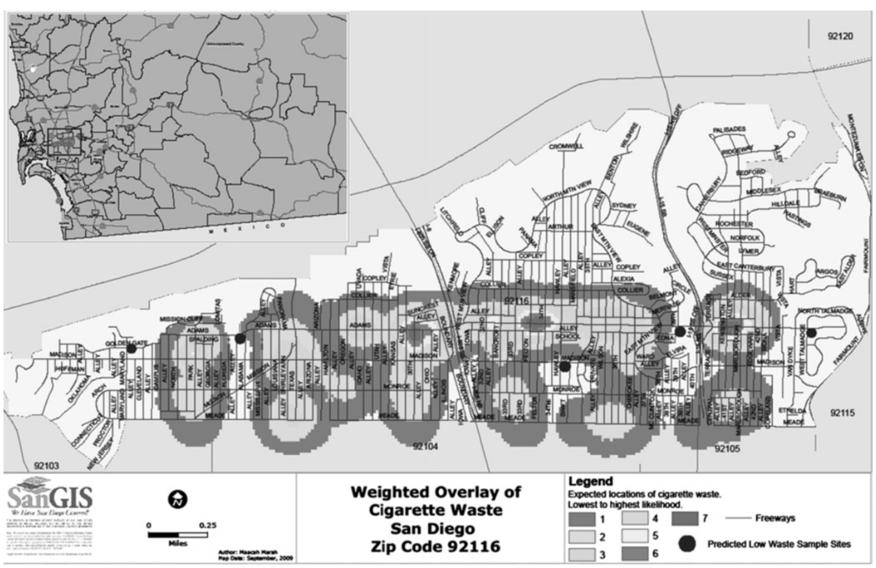


Figure 15. G.I.S. model designed to predict CFL in San Diego
This model utilizes census data to predict high impact CFL areas. When matched with a litter audit, its predictability was found to be statistically significant (Marah & Novotny 2011).

Novotny & Zhao (1999) recommended that worksites and public buildings be encouraged or required to supply CFL receptacles, and indeed some jurisdictions mandate the provision of CFL receptacles in local code. The San Francisco Public Works Code, article 5.1 (section 173) explicitly states that any person, firm, corporation, or property owner operating a place of employment must provide and maintain "sufficient ashtrays or other receptacles for the disposal of cigarettes, cigars, and other similar combustible products used by employees and patrons who smoke" adjacent to the place of employment (American Legal 2015). The design, capacity, location, and number of ashtrays and receptacles are prescribed by the Director of Public Works. Interestingly, this law is not limited to businesses that sell cigarettes. Although there is no data available on the matter, there is a consensus that this law is poorly enforced (S. Ericksen, personal communication, March 25, 2016). If an EPR-PS system for CFL were implemented, enforcement of the law that mandates the provision of CFL receptacles is imperative—regardless of how responsibility is allocated to businesses, producers, and/or governments for the provision.

Design for Environment

Theory

"Design for environment" is a tenant of EPR-PS that is conceptually distinct from the systems discussed so far. The design for environment concept suggests that if a consumer product creates negative externalities throughout its lifecycle, then producers should research an alternative, more sustainable design for the product (Wagner 2013). In other words, policies should incentivize producers to incorporate environmental considerations into the design of their products (Walls 2006). The application of sustainable i.e. biodegradable design to cigarette filters has been mentioned as a possible option to mitigate CFL (Novotny & Zhao 1999, Novotny et al. 2009). Such a practice could be mandated by law, and this policy option will now be assessed.

Examples

In the 1990's, the tobacco industry formed the "Cigarette Butt Degradability Task Force" through its international research organization, CORESTA (Novotny et al. 2009). Its goal was to develop a biodegradable filter for marketing purposes in order to prepare for the industry being regulated for filter biodegradability standards (Novotny et al. 2009, Smith & Novotny 2011). The task force admitted that CFL degradation could take "many months or even years, depending on environmental conditions" and so it sought to develop an accelerated test to provide consistent results (Cigarette Butt Degradability Task Force 2000). However, the effort failed and the task force disbanded due to an inadequate level of interest (Cigarette Butt Degradability Task Force 2000).

There is a company in the U.K. called Green Butts that has developed a cigarette filter made out of cotton, hemp, flax, and an all-natural starch binder that degrades between 2 and 6 weeks, meaning that its residual tensile strength is reduced by 90% or more (Donahue 2014). It does not appear that Green Butts has taken its product to market.

Effectiveness

The effectiveness of a biodegradable filter is questionable at best in terms of reaching policy goals. Although the negative externality of plastic litter would be reduced, it is unlikely that designing biodegradable filters would mitigate the risks associated with chemicals absorbed into the filter from cigarette combustion (Curtis et al. 2014). Curtis et al. (2014) stated that incentivizing cigarette producers to incorporate a sustainable design for filters is "unachievable given the toxic, hazardous chemicals permanently embedded in the tobacco product". In jurisdictions with composting policy and infrastructure, consumer awareness of CFL toxicity and biodegradability could create problems if smokers were to discard CFL into the compost stream.

Feasibility

It would be political unfeasible for any state to try to incorporate product standards for biodegradable cigarette filters due to federal preemption by the Family Smoking Prevention and Tobacco Control Act of 2009 which granted the FDA the sole authorization to regulate product standards (Freiberg 2013). These product standards are indicated to include the construction, components, ingredients, additives, constituents, and properties of the product (Freiberg 2013). So, the application of sustainable design to cigarette filters is deemed both unfeasible and ineffective in terms of mitigating CFL in California.

Deposit-Refund

A deposit-refund system places a visible surcharge (deposit) on a consumer good at the point of purchase for a given commodity; once the commodity is returned at an established collection point, the deposit is refunded to the consumer (Kulshreshtha & Sarangi 2001). Typically, an initial deposit is paid for by the manufacturer or the distributor and is passed down through the value chain to the consumer (Figure 16). The goal of a deposit-refund system is to incentivize material recovery so that a product is not sent to the landfill or disposed of as litter (Hogg et al. 2011). The incentive is particularly appropriate for materials with hazardous contents or materials that are frequently littered or otherwise illegally disposed (Hogg et al. 2011). Unredeemed deposits can be used to finance programs that mitigate a negative externality, such as anti-litter outreach and education programs (Numata 2009). In other cases, such as in Germany, surplus deposits are kept by retailers (Rademaekers et al. 2011). Deposit-refund systems fall under the umbrella of EPR-PS; they involve the consumer for participation, non-profit recycling centers for operations, and government agencies for authorization and subsidization.

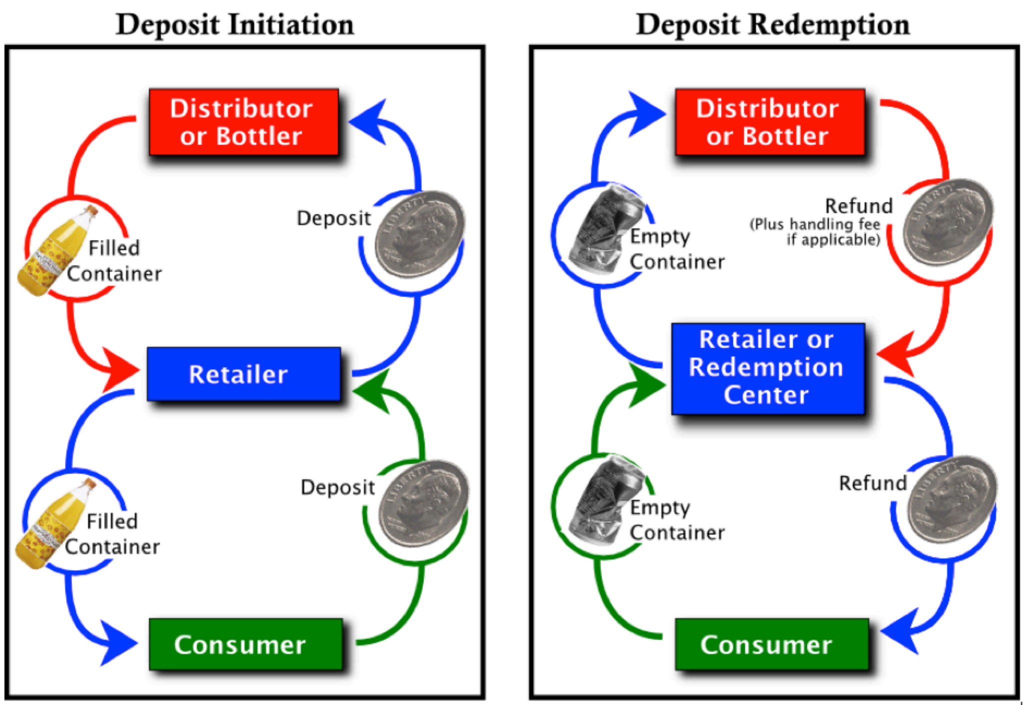


Figure 16. Flow chart for deposit-refund payout structure
Distributors typically pay the deposit amount to the governing agency and then pass the cost down to the retailer, which in turn passes the deposit amount onto the consumer (Container Recycling Institute 2007).

Examples

Deposit-refund systems have been utilized for beverage containers, lead-acid batteries, motor and lubricating oils, tires, white goods (such as refrigerators, stoves, and washing machines), electronics, automobiles, and various hazardous materials (Ten Brink et al. 2009, Walls 2011). Legislation that creates deposit-refund systems for beverage containers are known as "bottle bills" (Novotny et al. 2009). The U.S. began passing bottle bills in the 1970's and today there are 10 states, as well as Guam, which implement bottle bills that vary according to materials handled as well as pricing (Container Recycling Institute 2016). The following European nations have deposit-refund systems for beverage containers: Croatia, Denmark, Finland, Germany, Malta, Netherlands, Norway, and Sweden (Rademaekers et al. 2011, Ten Brink et al. 2009). In California, of the 18 billion beverage containers recycled annually, about 90% have been processed through a recycling center certified by the state bottle bill (Collins 2016).

Effectiveness

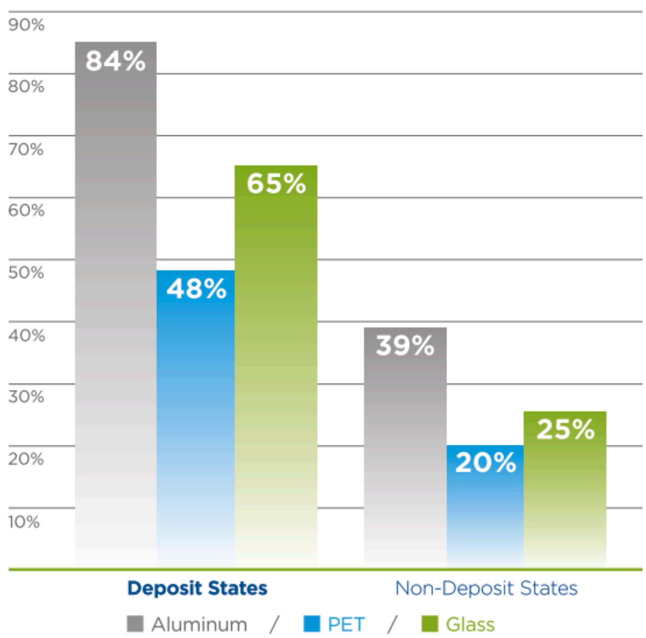
For the intents and purposes of this project, the deposit-refund model would probably be the most effective policy mechanism in terms of litter mitigation. After implementing bottle bills, 7 U.S. states reported lowered littering rates for beverage containers (Table 17). Hawaii, the most recent state to adopt a bottle bill, saw a 60% reduction in beverage container litter between 2005 and 2008 (Waterfront Partnership of Baltimore & Abell Foundation 2011). Beverage container litter is about 30% lower in Canadian provinces with mandatory bottles bills compared to provinces without them (Curtis et al. 2014). Germany originally adopted a system where containers could only be returned to the point of sale; when this was changed to a multi-point refund system, recycling rates went from 20% to over 98% (Rademaekers et al. 2011).

Table 17. Litter reduction after implementing deposit-refund programs
Bottle bills have consistently shown a decrease in litter after implementation (Reclay StewardEdge 2014).

State	Beverage Container Litter Reduction	Total Litter Reduction
Iowa	76%	39%
Maine	69-77%	34-64%
Massachusetts	N/A%	30-35%
Michigan	84%	41%
New York	70-80%	30%
Oregon	83%	47%
Vermont	83%	35%

Bottle bills have also been successful in terms of increasing recovery and recycling. The Oregon bottle bill is credited for having increased container recycling to 90% and for having reduced roadside litter of bottles from 40% to 6% (Novotny et al. 2009). Malta has had a similar recover rate of 90% (Ten Brink et al. 2009). U.S. states with bottle bills have recycling rates of 84%, 48%, and 65% for aluminum, polyethylene terephthalate (PET), and glass bottles, respectively, as compared to the recycling rates of non-bottle bill states with rates of 39%, 20%, and 25% (Gitlitz 2013, Table 18*).* California's decentralized deposit-refund model generates a large stream of post-consumer material with minimal environmental impact and that the locations of reclamation centers are the most significant factor influencing post-consumer impacts (Kuczenski & Geyser 2012). The manufacture of beverage containers from recycled content—when compared to the same manufacture from virgin resources—saves energy, emits fewer greenhouse gases, and utilizes natural resources more efficiently (Gitlitz 2013). Also, there is evidence that bottle bills reduce the number of lacerations caused by broken glass in the environment (Hogg et al. 2011).

Table 18. Recycling rates of bottles: states with and without bottle bills
Bottle bills have consistently shown an increase in recycling after implementation (Gitlitz 2013).



However, administrative and operational costs are relatively high for a deposit-refund system (Rademaekers et al. 2011). Saphores et al. (2014) argued that—based on a 2006 national survey on recycling attitudes—deposit-refund systems are not very effective because of limited scope, a relatively low refund per container, and opposition from beverage manufacturers. Nahman (2010) stated that a South Africa government-operated deposit-refund system for plastic bags was ineffective in terms of creating a viable plastic bag recycling industry, implying that industry initiatives are more effective than government regulation for stimulating the recovery of packing waste for recycling.

A variety of factors can influence deposit-refund effectiveness, including the pricing of both deposits and refunds, the entity that is remitted surplus deposits, the geographic distribution of collection points, and the marketability of the collected materials. In terms of reducing consumption, a returnable deposit on cigarettes could reduce smoking if the deposit were large enough (Khalili et al. 2013); I recommend that future studies measure the elasticity of demand before and after a deposit-refund model is implemented because this data is lacking. Deposit-refund systems become more effective when the value of secondary PET plastic outweighs the associated costs of producing PET from virgin materials (Kuczenski & Geyser 2012). Deposit-refund programs also produce net positive job creation (Reclay StewardEdge 2014).

In California, the bottle bill directly employs at least 3,000 people, generates over $8 million in state tax revenues annually, and channels a million tons of scrap materials away from landfills (Collins 2016). However, the system is currently facing problems. The California Department of Resource Recycling and Recovery, known as CalRecycle, subsidizes recycling centers' operations, but due to a continued fall in scrap commodity values as well as a fundamental flaw in CalRecycle's method that determines appropriate subsidization amounts, recycling centers have not received the subsidies that they require in order to operate (Collins 2016). On January 31, 2016, the state's largest beverage recycling company closed 191 recycling centers and laid off 278 employees; more than 400 redemptions have been closed in 2016 (Collins 2016). Additionally, it is possible that California loses $50 million annually from illegal interstate beverage container smuggling operations (Moffitt 2015). In 2010, California authorities arrested 32 people in five separate smuggling cases and estimated that those people had altogether defrauded the state out of more than $10.5 million (Jenkins 2011). Smuggling and funding are both important issues when gauging the effectiveness and feasibility of a deposit-refund model for CFL in California. To prevent illegal redemptions, CalRecycle pre-certifies all recycling centers, administers maximum daily redemption load limits (by weight), and authorizes vehicle inspections (CalRecycle 2016).

Feasibility

The could be some feasibility issues with the logistics of a CFL deposit-refund system. I submit that the existing recycling facilities for beverage containers could additionally be utilized for CFL, although the handling of CFL—both by collectors and by recycling operators—could raise legitimate health concerns and is seen as a challenge that could ultimately decrease its feasibility (Tobacco Control Legal Consortium 2013, Curtis et al. 2014). Smuggling would be a financial (although environmentally beneficial) threat, as the small size that makes filters easier to handle also makes them easier to transport illegally. As opposed to beverage containers, CFL does not have value as a commodity; this condition is not a prerequisite for a feasible deposit-refund model (Kreisman 2014). Indeed, lessons learned from the California bottle bill suggest that the funding mechanism for such an operation should be independent of commodity values. With that said, the system could be more cost-effective if CFL was worth something. There are indeed applications for cigarette filters that could create a market demand, such as inhibiting corrosion on steel pipes (Zhao et al. 2010), conducting heat for clay-fired bricks (Sarani & Kadir 2015), and serving as an insecticide for mosquito larvae (Dieng et al. 2013). TerraCycle is willing to pay $1.00 for every pound of CFL to strategically partnered registered non-profit organizations and schools in certain locations (S. Ericksen, personal communication, March 25, 2016). One man in San Diego created a recycling system that pays $3 per pound of CFL (Karlman 2012), but like TerraCycle, this does not qualify as a robust market. With that said, there is potential that CFL could one day function as a commodity.

Politically, attempts to implement a CFL deposit-refund model have been blocked. In 2001, Maine state representatives Joseph Brooks and Scott Cowger proposed a Returnable Tobacco Bill that would implement a deposit-refund system for CFL (Lee 2012, J. Brooks, personal communication, April 1, 2016, S. Cowger, personal communication, April 1, 2016). Consumers would have deposited and refunded $0.05 for each cigarette, which would be specially stamped for eligibility in the program (J. Brooks, personal communication, April 1, 2016). As the collected CFL was to be sent to incineration plants or landfills, the system was not designed to recycle CFL but rather to remediate it from the environment (J. Brooks, personal communication, April 1, 2016, S. Cowger, personal communication, April 1, 2016). The bill did not receive much support as there was disagreement from various industry associations, the governor, as well as the Maine Bureau of Health, which feared that children would collect the CFL and be repeatedly exposed to nicotine (J. Brooks, personal communication, April 1, 2016, S. Cowger, personal communication, April 1, 2016). New York State Senator Toby Ann Stavisnky has had two similar attempts sponsoring legislation that would institutionalize a CFL recycling program using a deposit-refund model, and currently she is sponsoring another, Senate Bill S3425, which is in the early stages of the legislative process (New York State Senate 2016). In California, Proposition 26 could legally challenge a deposit-redemption model for CFL in California (Freiberg 2013), although such a challenge is unprecedented.

Like the other EPR-PS options, a deposit-refund model for CFL is risky compared to other policy options. I submit that California is too big of a state for such a system to be piloted. With that said, I propose that a CFL deposit-refund model (a "butt bill") be piloted in Hawaii. Hawaii is heavily hit by CFL; during the 2007 International Coastal Cleanup, CFL comprised 44.7% of all land-based items and 12.3% of all underwater items observed in the state (State of Hawaii 2008,

Table 19). Hawaii is the most recent state to adopt a bottle bill, and its 106 certified recycling centers could be utilized to collect CFL (State of Hawaii 2008). Also, as a group of islands, Hawaii has a natural aversion to interstate smuggling.

If such a system were implemented, it is recommended that the deposit-refund price model involve phases in order to avoid bankruptcy to the system caused by refunding the CFL that existed before the policy was adopted—referred to as "orphaned" butts (Kreisman 2014). For example, a deposit of $0.05 per cigarette could initially refund $0.01 per filter; then as orphaned butts are redeemed over time, the deposit amount could gradually decrease to $0.01, or the refund amount could gradually increase to $0.05 (S. Chiv, personal communication, February 17, 2016). To protect against smuggling, the state should follow CalRecycle and implement certification standards and maximum weight limits. Ultimately, the operation could be funded by responsible stakeholders, particularly producers.

Table 19. Top 5 litter items found in Hawaii in 2007
Hawaii has a very high CFL-ALR: 44.7% on land and 12.3% underwater. Notice how much larger the land cleanup sample size is. This data was originally provided by the Ocean Conservancy's International Coastal Cleanup (State of Hawaii 2008).

Land Cleanups Only	**Number of Debris Items**	**Percent of Total Collected**
1. Cigarettes & Filters	72,053	44.7%
2. Caps & Lids	21,210	13.1%
3. Food Wrappers and Containers	16,554	10.3%
4. Beverage Containers *(glass, metal, plastic)*	10,505	6.5%
5. Cups, Plates, and Utensils	7,331	4.5%
Underwater Cleanups Only	**Number of Debris Items**	**Percent of Total Collected**
1. Fishing Line	1081	54%
2. Beverage Containers *(glass, metal)*	393	19.6%
3. Cigarettes, Filters, & Cigar Tips	248	12.3%
4. Food Wrappers and Containers	55	2.7%
5. Caps & Lids	39	1.9%

Product Ban

Theory

When a product is deemed to be particularly damaging, presenting unreasonable risks to health or the environment, governments can restrict or eliminate the manufacture, sale, distribution, consumption, or disposal of that product (U.S. Congress 1995). Product bans can prevent pollution and littering by eliminating or limiting the products that create unnecessary and adverse environmental risks (U.S. Congress 1995). In theory, a ban is appropriate when it is cost-effective; it should be well-tailored to a given situation, whereby the product's use poses unacceptable risks and limited benefits (U.S. Congress 1995). With that said, product bans may have unintended impacts and should be thoroughly reviewed before implementation (Ten Brink et al. 2009).

Examples

On a federal level, the U.S. EPA and the U.S. Consumer Product Safety Commission have the authority to prohibit consumer goods deemed to be so dangerous that labelling the product is not adequate enough to protect consumers (U.S. Product Safety Commission 2012). An extensive list of all banned products in the U.S. is available on the U.S. Consumer Product Safety Commission website (U.S. Product Safety Commission 2012). Historically, California product bans have involved single products, although recently the California Department of Toxic Substances Control has initiated a process to identify, prioritize, and potentially ban product categories (Raphael 2013). When a product ban is imposed before the product is introduced into a marketplace, a government regulatory agency reviews the product's risks for damages and places limits that are designed to bring such risks to a reasonable level (U.S. Congress 1995). Historically, though, product bans and limitations have been implemented after the products were well-distributed through commerce and already causing problems (U.S. Congress 1995).

Prohibition on products that pollute and/or litter the environment has been more recent. Expanded polystyrene (commonly referred to as the brand Styrofoam ™) bans have been implemented in at least 10 U.S. states; there have been at least 65 local ordinances in California, including San Francisco in 2007 (Surf Rider Foundation 2016), which became the first major American city to ban single-use plastic bags at supermarkets and drugstores during the same year. Since then, 118 similar ordinances have been passed in the state, covering 147 local jurisdictions, and at least 16 other states have passed local bag ban ordinances (Californians Against Waste 2016, Surf Rider Foundation 2016). In October 2015, California became one of the nine U.S. states to ban the production and/or sale of microbeads. Microbeads are plastic fragments ranging in size from 5 μm to 1 mm and are considered to be a primary source of micropastics, as opposed to CFL which is a secondary source of microplastics (Rochman et al. 2015). The phase-out of microbeads in California would have begun in the year 2020 (Willon 2015, Trager 2016); however, only two months after the state law was passed, the federal Microbead-Free Waters Act was approved by Congress, effectively phasing out the manufacture of personal care products and cosmetics containing microbeads in July 2017, the sale of cosmetics in July 2018, and the sale of over-the-counter drugs in July 2019.

Effectiveness

In San Francisco, during the two years after the plastic bag and expanded polystyrene bans were implemented, the percentage of retail plastic bag and polystyrene litter decreased respectively by 18% and 41% compared to the amount of all large litter observed (Table 20). In the two years since the plastic bag ban in Guam, diversion of plastic bags from landfill increased from 11% to 32% (Blumenfeld 2016). I have been unable to locate further information regarding the effects that product bans have on litter.

Table 20. Street litter before and after San Francisco product bans
The change in observed street litter in plastic bags and expanded polystyrene during the 2 years after the products were banned locally (HDR et al. 2009).

Summary - Retail Plastic Bags Litter

	% of Total Large Litter		
2007	2.49%		
2008	4.08%	-64%	Decrease from 2007
2009	2.05%	50%	Decrease from 2008
		18%	Decrease from 2009 vs 2007

Summary - Polystyrene Litter

	% of Total Large Litter		
2007	1.81%		
2008	1.16%	36%	Decrease from 2007
2009	1.07%	8%	Decrease from 2008
		41%	Decrease from 2009 vs 2007

Feasibility

California could simply ban the sale of filtered cigarettes if a significant and avoidable environmental and human health hazard were determined (Curtis et al. 2014, Novotny & Slaughter 2014). Although the California Ocean Protection Council (2008) stated that a ban on filtered cigarettes is inappropriate because filters "perform an important function", the Surgeon General has reported in various accounts that not only have cellulose acetate cigarette filters shown no benefit to human health, but that they may even contribute to a histologic shift in the predominant lung cancer found in smokers from squamous cell to the more aggressive adenocarcinoma (U.S. Department of Health and Human Services 2010, Novotny & Slaughter 2014, Curtis et al. 2016). Therefore, filtered cigarettes are certainly not necessary, but rather avoidable. A legitimate concern with banning filtered cigarettes would be a further increase the littering behavior of consumers. Like the design for environment option, a product ban would mitigate the negative externalities associated with plastic litter, but it is unclear how toxic risks would be mitigated. I submit that there may be multiple ways that California could ban filtered cigarettes—either through state legislation or through a state government agency—and I will now discuss each in turn with further analysis.

California Product Ban Options

State legislation may be a relatively feasible option to ban filtered cigarettes. Proposition 26 does not affect a product ban. The California microbeads ban was a significant piece of state legislative prohibition designed to protect environmental damage; Rochman et al. (2015) offered a concise and comprehensive explanation about the scientific evidence used to support the microbeads ban as well as the political movement that successfully led to its passage. Lessons can be learned from the microbeads ban case and be applied to a ban on filtered cigarettes. Other lessons learned may come from the California plastic bag ban, Senate Bill 270, which is currently going through the political process. After a decade of lobbying by environmentalist constituencies, the California bag ban passed through the state senate and was signed by Governor Brown in 2014 (Lapis 2016). However, in March 2016, the plastic bag lobby, led by the American Progressive Bag Alliance, acquired enough signatures to place the bill on the ballot as a veto referendum, effectively delaying its implementation until November 2016 when voters will decide if Senate Bill 270 takes effect; the bag lobby has spent over $3.2 million campaigning against the bill (Lapis 2016). Any constituencies hoping to ban filtered cigarettes in California must be prepared to deal with similar resistance from Big Tobacco.

In January 2014, California Assemblyman Mark Stone introduced Assembly Bill 1504, a piece of legislation designed to prohibit the sale, gifting, or furnishing of all cigarettes with single-use filters in the state, subject to a $500 penalty (California Legislative Information 2015). The bill was voted down in the legislative process in May 2014; opposition argued that such a policy would: 1) not necessarily reduce litter; 2) increase fire risks; 3) violate the U.S. Tobacco Control Act of 2009 by mandating a product standard; 4) essentially prohibit cigarette sales because virtually all cigarettes sold in the state contain filters; 5) lose the state hundreds of millions of dollars of tax revenue, and; 6) increase smuggling and induce a black market for filtered cigarettes (California Legislative Information 2015). There is no evidence to support arguments 1 and 2. Argument 3 will be addressed in the next paragraph. Argument 4 carries little weight, as cigarettes could still be sold so long as they did not contain filters. Argument 5 is unfounded; in fact, the health costs of tobacco consumption far outweigh any revenue collected from tobacco taxes (Brossart et al. 2014). Argument 6 is the only argument that may have some validity.

Argument 3 refers to the Family Smoking Prevention and Tobacco Control Act—discussed previously in the design for environment section—which pre-empts regulatory powers to the FDA over state laws regarding the manufacture, components, ingredients, additives, constituents, and properties of a cigarette (Freiberg 2013). However, the Family Smoking Prevention and Tobacco Control Act expressly granted local enforcement agencies—such as state and municipal governments—the authority to regulate the distribution, possession, sale, advertising, promotion, and fire safety of cigarettes (Curtis et al. 2016, Freiberg 2013). So, although the tobacco industry could legally prevent California from requiring cigarette manufacturers to produce unfiltered cigarettes, California has the authority to prohibit the sale of filtered cigarettes in the state (Freiberg 2013).

Assemblyman Stone attempted to re-introduce a statewide product ban on filtered cigarettes in December 2014, this time including enforcement provisions to address the potential threat of black markets for filtered cigarettes (California Legislative Information 2016). Despite findings that recent safeguards have proven effective in preventing black market evasion of cigarettes, AB 48 died pursuant to Article IV, Section 10(c) of the Constitution in January 2016 (California Legislative Information 2016, Horton 2014). It must be noted that the cigarette industry has had a long and powerful influence in state and federal politics, where financial resources and lobbyists work against tobacco control efforts (Mondardi & Glantz 1998). Policy decision makers that have received campaign contributions from Big Tobacco have been found to vote against tobacco control policies (Bialous et al. 2001). In 2006 and 2010, the tobacco industry contributed $2.3 million and $2.8 million, respectively, to California legislators and lobbyists (California Tobacco Control Program 2015). Challenges from the cigarette industry are to be expected; indeed, such challenges can be viewed as a sign of effectiveness for efforts by tobacco control advocates (Brossart et al. 2014).

Alternatively, it may be possible for a ban on filtered cigarettes to happen through the California Department of Toxic Substances Control. In 2013, the CDTSC began implementing the Safer Consumer Products Regulations, requiring manufacturers and other responsible entities to seek safer alternatives to harmful chemicals used in a variety of products (Raphael 2013). This authority includes the regulatory power of product information, use restrictions, product sales prohibition, end-of-life product management programs, and the advancement of sustainable alternatives. The regulatory framework involves identifies “priority products” that are defined as containing one or more chemicals—called “candidate chemicals”—that have a hazard trait that can harm human and/or environmental health (California Department of Toxic Substances Control 2016). CFL may have the potential to qualify as a priority product. The regulation of filtered cigarettes through the California Department of Toxic Substances Control could be a more realizable approach compared to state legislation due to an avoidance of the legislative political process. Witkowski (2014) discusses in detail the possibility of using California hazardous waste law to address CFL.

Discussion: Federal Legislation

Before concluding, it should be recognized that federal programs exist that aim to mitigate litter in California. The federal taxes that Californians pay for these programs have not been included in my financial costs section. The Clean Water Act and the Coastal Zone Management Act will now be briefly discussed to provide context about current federal efforts to mitigate litter in California. These efforts are expensive and remedial in nature (as opposed to preventative) although there may be lessons learned from these federal policies for California decision makers moving forward.

Clean Water Act

The U.S. Clean Water Act requires every state to set water quality standards which designate appropriate uses for a given water body, define the pollutants in that water body, nominate the streams from which each pollutant is generated, set an acceptable total maximum daily load for the pollutant, and incorporate mandatory measures such as discharge permits as well as best managing practices—such as structural retrofits and operational and behavioral changes—to mitigate the pollutant; this process may take 6 to 8 years

(Blumenfeld 2016, Herzog 2015). Los Angeles has been innovatively applying the Clean Water Act regulatory power to litter in municipal storm water systems (Herzog 2015). U.S. EPA Region 9, which includes California, set a "zero trash" (zero litter) goal for the Los Angeles River by 2016. The California State Water Board set the total maximum daily load for trash in the Los Angeles River in 2002, and its implementation took effect in 2008 (Herzog 2015, U.S. EPA Region 9 2016); it required that trash be reduced by 40% below a calculated baseline in the first year of compliance and an additional 10% for each following year. Twenty-two local jurisdictions sued the U.S. EPA, arguing that the goal of "zero trash" is unreasonably expensive, if not impossible (Herzog 2015).

California has surpassed its obligations, having prevented more than 1.2 million pounds from entering waterways and reducing trash entering the Los Angeles River by 69% (National Ocean Council 2011, U.S. EPA 2016). Nearly 100,00 full capture devices have been installed, as well as "trash booms" designed to capture litter at outfalls (Herzog 2015). Some jurisdictions have reduced waterway litter pollution by 98% (Blumenfeld 2016). On April 7, 2015, the California State Water Board adopted what is known as "The Trash Amendments", which has the objectives to provide statewide consistency for the regulatory approach to protect aquatic life and public health, to reduce environmental issues associated with trash in state waters, and to focus its limited resources on high trash generating areas (De la Paz Carpio-Obeso & Perreira 2015). Herzog (2015) suggested that future policies could shift the responsibility of financing trash total maximum daily load compliance towards producers of commonly littered items, thus incorporating a product stewardship framework that eases financial burdens on governments and incentivizes alternatives for environmentally damaging products.

Coastal Zone Management Act

The Coastal Zone Management Act was enacted by Congress in 1972 and amended in 1990 by the Coastal Zone Act Reauthorization Amendments. The amendments require that all coastal states with approved coastal zone management programs must address nonpoint pollution impacting or threatening coastal water quality by developing a Coastal Nonpoint Control Protection Program (Gordon 2006). Such a program identifies urban areas as one of the five main sources of nonpoint water pollution and also identifies litter as a pollutant that is carried by urban runoff (Gordon 2006). It is the responsibility of the State Water Resources Control Board and the California Coastal Commission to identify pollutant source categories and implement management measures; currently, 28 state agencies are working through the Interagency Coordinating Committee to implement the plan which includes a Model Urban Runoff Program that guides local governments how to develop, finance, implement, and enforce a comprehensive program to manage storm water pollution (Gregg & Fagundes 2016). These costs may be substantial, and I recommend that future research quantitatively assesses the extent to which federally-mandated litter remediation programs are costing California.

Discussion: Recent California Legislative Action

On May 4th 2016, six proposed tobacco control regulation policies survived the California legislative process, and Governor Brown signed five of them into action (Adler 2016). Senate Bill 7 will raise the minimum cigarette purchasing age to 21 years old for the entire state (with active duty military personnel exempted). This is a big step towards mitigating cigarette consumption with the only drawback of requiring time to take effect. Assembly Bills 7 and 9 will extend smoking bans in owner-operated businesses, bars, gaming clubs, charter schools, district offices, and vehicles. Clean indoor air laws are correlated with lower average daily smoking among adults (Tauras 2006) although they may increase littering when people are obliged to smoke outdoors (Novotny & Slaughter 2014). Assembly Bill 11 will increase tobacco licensing, distributor, and wholesaler fees, essentially raising the price floor on cigarettes throughout the state. Governor Brown vetoed Assembly Bill 10, which would have allowed counties to tax the distribution of cigarettes, subject to voter approval. Although the California constitution prohibits the legislature from imposing local taxes, the legislature may authorize local governments to impose them (California Legislative Information 2016). I submit that the governor recognized the pushback that Big Tobacco would have given if he had signed Assembly Bill 10—either in the form of a ballot referendum or legal recourse—which may conflict with the requirements set forth by Proposition 26. Notwithstanding, this is a very exciting time for tobacco control regulation policy in California as scientists, consultants, and politicians are recognizing the importance of mitigating the negative externalities caused by cigarette consumption—and acting accordingly.

V. Conclusion

The negative externalities caused by CFL warrant policy action towards its mitigation in the State of California. Financially, CFL costs the state over $1.227 billion annually; 67% of these costs come in the form of abatement, 26% in the form of damages to the tourism industry, 4% in the form of damages caused by fires, and 4% in the form of damages to the fishing industry. Other damages to society are intangible and/or unquantifiable, including child ingestion and the diminishment of the quality of life. CFL poses environmental risks by emitting toxic leachate, serving as source of plastic ingestion to animals, and degrading into microplastics.

Policy instruments aim to internalize the costs that CFL places on society. Each option has advantages and disadvantages (Table 21). Market-based instruments, such as taxes, fees, charges, and price floors reduce consumption of cigarettes. Market-based instruments are beneficial because they involve relatively low intervention from governing agencies, and they may raise revenue for the government. With that said, market-based instruments do not have specific goals in terms of litter mitigation, and they do not address the core issues of responsible recovery and consumer behavior. Also, market-based instruments may encourage cigarette smuggling and tax evasion. In California, taxes and fees may be politically unfeasible due to Proposition 26.

Regulatory policy instruments set, monitor, and enforce specific goals. The drawback is that regulatory policies involve more governmental resources. Consumer behavior regulations include locational bans, minimum age purchasing requirements, and littering fines. These policies are relatively feasible so long as they are enforced appropriately. Extended producer responsibility and product stewardship programs, including a deposit-refund model, provide the main benefit of recovering litter. However, these mechanisms do not aim to reduce consumption. Also, they are untested for CFL and may involve operational and administrative uncertainties. Product bans are relatively straightforward, especially because cigarette filters have shown no benefit to human health. However, although banning filtered cigarettes would mitigate certain environmental risks, it is unclear whether the option would mitigate toxic environmental risks. The same is true for a mandate that would require cigarette manufacturers to design a compostable filter.

Table 21. Policy option pro's and con's
A summary of available policy options to mitigate CFL. The advantages and disadvantages of each pertain to the scale of California.

Category	Mechanism	Pro's	Con's
Market-based instrument	Tax	Reduces consumption Raises government revenue	Subject to Proposition 26 May stimulate smuggling and tax evasion
Market-based instrument	Fee	Reduces consumption Raises government revenue	Subject to Proposition 26 May stimulate smuggling and tax evasion
Market-based instrument	Charge	Reduces consumption Not subject to Proposition 26	Does not raise revenue for government May stimulate smuggling and tax evasion
Market-based instrument	Price floor	Reduces consumption Not subject to Proposition 26	Does not raise revenue for government May stimulate smuggling and tax evasion
Consumer regulation	Littering fine	Should reduce littering behavior	Poorly enforced Current minimum fines are too high
Consumer regulation	Locational ban	Correlated with lower consumption Encourages cultural norms	May increase littering May increase fires Outdoor bans are poorly enforced
Consumer regulation	Minimum age	Reduces consumption	May take years to take effect
EPR-PS	Product stewardship organization	Funded by relevant stakeholders Responsible recovery Provides outreach	Involves infrastructure and maintenance No proof of concept
EPR-PS	Deposit-refund	Reduces litter Increases recovery and recycling Raises government revenue Creates jobs	Sanitation concerns Involves infrastructure and maintenance No proof of concept for CFL Possible logistical and funding issues No market for CFL
EPR-PS	Design for environment	Eliminates plastic litter risks	Does not address toxic risks Pre-empted by the FDA
Producer regulation	Product ban	Eliminates plastic litter risks	Does not address toxic risks

This is an innovative and exciting time for tobacco product control policies in California. Combining the efforts of environmental advocates and human health advocates may be the best strategy to mitigate the negative externalities caused by CFL.

Management Recommendations

Effectively mitigating CFL in California may involve implementing a variety of policy tools. For any other state, taxes and fees would be recommended as a feasible option. In California, acquiring a supermajority vote in the legislature is difficult, but not impossible.

With that said, Proposition 26 is relatively new and has not been tested thoroughly in the legal system. There may be ways around it depending exactly on how a market-based instrument is administered, and subjection to Proposition 26 may ultimately depend on a judge's discretion. For now, the safe strategy would be to continue raising price floors and administering charges, although these options do not generate government revenues. Future policy strategies may depend on how Big Tobacco reacts from the recent California tobacco control regulations.

Regarding consumer behavior regulations, raising the purchasing age to 21 should reduce consumption, although it will take time and will not address social norms regarding CFL. Locational bans will address this latter point, although indoor smoking bans may increase outdoor littering. Effectively, enforcing littering fines is instrumental. This goes to say no matter what other policies are adopted. I recommend that CFL is exempted from the California penal code so that littering fines can be lowered and more easily administered. Such enforcement could also be more reasonable if collection infrastructure were established through an EPR-PS system.

Implementing an EPR-PS program—either in the form of a product stewardship organization or a deposit-refund model—would be most effective at mitigating CFL although such a program is not recommended to be piloted at the scale of California due to uncertain administrative and operational risks. I do recommend that such a model be piloted within a smaller scale (state), particularly Hawaii. Once a proof of concept is established, based on the effectiveness of such a pilot, lessons could be learned and the model could be expanded to other states. A deposit-refund model for CFL is particularly intriguing, especially if the program were funded by entities that generate CFL such as producers, consumers, and possibly sellers and other entities involved in the product life cycle. If CFL were scientifically assessed as a household hazardous waste that creates a toxic liability for landfills, then an EPR-PS system would be the most appropriate option to responsibly recover the material. The design for environment tenant of product stewardship is not recommended for cigarette filters because it is both politically unfeasible at a state level and because it would not mitigate toxic externalities. It also could encourage littering behavior.

These previous points are also true for a product ban, which would in itself not be compatible with a deposit-refund model nor a product stewardship organization for practical purposes. With that said, if policy makers decided to take the legislative approach to banning filtered cigarettes—as has been attempted twice in the state—I recommend that lessons be learned from the state microbeads ban which involved the cooperation of grassroots level advocacy groups, multinational corporations, and governments. The alternative approach would be to administer a product ban through the California Department of Toxic Substances Control; this strategy would bypass the legislative process, although such an attempt is unprecedented.

Future scientific research should investigate the toxic effects of unsmoked filters, filter biodegradation, and the toxic impact of CFL on landfills. Other potentially valuable research pursuits would include determining further applications of CFL for marketability, determining demand elasticity before and after deposit-refund models are implemented, conducting street sweeping audits to see the composition of the collected debris, and determining how labelling might affect cigarette consumption. I also recommend that further research and development goes into technologies that could streamline CFL infrastructure in a PS-EPR system.

It is generally recommended, for both environmental and financial reasons, that policies designed to mitigate CFL prioritize prevention ahead of remediation. The Ocean Conservancy has remediated 52 million filters over 27 years (Curtis et al. 2016) but trillions are littered annually; this status quo is unsustainable and unacceptable. The inherent nature of the environmental and financial damages caused by CFL is going to require the continued cooperation between health and environmental advocates, innovation from technology developers and policy makers, and the political will to ensure an acceptable level of health for the State of California.

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Appendices

Appendix 1. Global littering rate inference

		Amount Littered (trillions)	
		4.5	4.95
Amount Consumed (trillions)	6	75.0%	82.5%
	6.3	71.4%	78.6%
		Average Litter Rate	76.9%

Appendix 2. California and U.S. CFL-ALR's

California CFL-ALR = 36.31%
U.S.A. CFL-ALR = 30.87%
(36.31% / 30.87%) - 1 = 17.63%

Appendix 3. California and U.S. adult smoking prevalence ratio

CA	USA - CA	Ratio CA/USA - CA
13%	20%	65%

Appendix 4. California and U.S. per capita cigarette consumption ratio

CA	USA - CA	Ratio CA/USA - CA
31	54	57%

Appendix 5. Business abatement calculation, methodology 1

Cost Per Employee	$ 79.48	X
Number CA Employees	13,401,863	
Litter Cost	$ 1,065,180,071	X 36.3% CA CFL-ALR
CFL Cost	$ 386,766,884	X 1.1 CPI
2009-2016 Inflation Adjustment	$ 429,311,241	

Appendix 6. Business abatement calculation, methodology 2

Average Business Spending Litter Abatement	$	2,435	X
Florida CFL Composition		33%	
Average CFL abatement	$	808	
# Businesses CA		874,243	X
CA CFL Business Abatement	$	706,244,618	
		1.43	
CPI Adjust	$	1,009,929,804	

Appendix 7. Volunteer organization abatement cost calculation

National Cost	$	240,600,000	
Adjustment for CA Population	$	29,537,509	X .12
CFL Ratio	$	10,725,070	X 36.3%
2009-2016 Inflation Adjustment	$	11,904,827	X 1.11

Appendix 8. Educational institution abatement cost calculation

National Cost to Abate all Litter	$	240,600,000	X .12
Adjustment for CA Population	$	29,537,509	X 36.3%
CFL Ratio	$	10,725,070	X 1.11
2009-2016 Inflation Adjustment	$	11,904,827	

Appendix 9. Calculation of tourism industry damages

2000 CA Coastal Tourism and Recreation Value	$	22,367,879,303	X 1.38 CPI
2016 CA Coastal Tourism and Recreation Value	$	30,867,673,438	
Damage to CA Tourism Industry caused by Litter	$	926,030,203	X 36.3%
Damage caused by CFL	$	336,279,161	

Appendix 10. Calculation of fishing industry damages

2001 Value of California Fishing Catches	$	100,000,000	X 75.5%
Cost of Contamination Damages caused by Maritime Litter	$	75,500,000	X 36.3% CA CFL-ALR
Cost of Contamination Damages caused by CFL	$	27,417,115	X 1.34
2001 - 2016 Inflation Adjustment	$	36,738,934	

Appendix 11. Calculation of overall fire damages

U.S.A. Smoking Materials Fire Statistics, 2007-2011 Yearly Average					
Location	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage	% Started Vegetation
Homes	17,900	578	1281	$ 509,000,000	4%
Other Structures	9,900	57	160	$ 129,000,000	4%
Vehicles	4,200	7	54	$ 18,000,000	4%
Outdoor Vegetation or Special Property Fires	43,900	1	19	$ 7,000,000	60%
Outdoor Trash or Other Fires	32,700	3	42	$ 8,000,000	10%
Total	108,600	646	1556	$ 671,000,000	

U.S.A. CFL Fire Statistics, 2007-2011 Yearly Average				
Location	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage
Homes	716	23.12	51.24	$ 20,360,000
Other Structures	396	2.28	6.4	$ 5,160,000
Vehicles	168	0.28	2.16	$ 720,000
Outdoor Vegetation or Special Property Fires	26,340	0.6	11.4	$ 4,200,000
Outdoor Trash or Other Fires	3,270	0.3	4.2	$ 800,000
Total	30,890	26.58	75.4	$ 31,240,000

California CFL Fire Statistics, 2007-2011 Yearly Average				
Location	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage
Homes	88	2.84	6.29	$ 2,499,517
Other Structures	49	0.28	0.79	$ 633,473
Vehicles	21	0.03	0.27	$ 88,392
Outdoor Vegetation or Special Property Fires	3,234	0.07	1.40	$ 515,617
Outdoor Trash or Other Fires	401	0.04	0.52	$ 98,213
Total	3,792	3.26	9.26	$ 3,835,211

Appendix 12. Calculation of indirect fire damages

U.S.A. Fire Costs, 2008	
Direct Property Damages	$ 15,400,000,000
Indirect Costs	$ 149,600,000,000
Ratio Indirect - Direct	9.71
California CFL-Related Direct Property Damage	$ 3,835,211
California CFL-Related Indirect Damages	$ 37,256,336

Appendix 13. Calculation of death and injury costs

	Number	Direct Costs	Indirect Costs	Total
Deaths	6,529	$ 230,000,000	$ 3,460,000,000	$ 3,690,000,000
Injuries	13,247,000	$ 48,940,000,000	$ 92,730,000,000	$ 141,670,000,000
	Cost Per Capita	1992-2016 CPI Adjust	Cost caused by CFL-Related Fires in California	
Deaths	$ 565,171	$ 955,139	$ 3,116,733	
Injuries	$ 10,694	$ 18,074	$ 167,300	

Appendix 14. Kier Associates California CFL cost

Total Cost	$ 428,000,000	X
CA CFL-ALR	36%	
CA CFL Cost	$ 155,406,800	

Appendix 15. Abatement budget calculations: Kier Associates vs. San Francisco

Per Capita		
Street Sweeping	$ 4.04	
Manual Cleanup	$ 1.88	X
Total	$ 5.92	X
Population San Francisco	837,442	
San Francisco Cost DPW Abatement	$ 4,955,144	
DPW Budget		
FY 2014-2015		
Street Environmental Services	$ 37,400,000	

Appendix 16. Calculation of state tax CFL mitigation fund

CA Annual # Packs Cigarettes Consumed	$ 1,244,805,212	X $.087 State Tax
Annual CA Cigaratte Tax Revenue	$ 1,082,980,535	X .25/.87
Cigarette and Tobacco Products Surtax Fund	$ 311,201,303	X 1/3
Fund for CFL-Related Problems	$ 103,733,768	
CA CFL Financial Costs	$ 1,277,424,241	
% of CFL-Related Fund compared to Desired Fund	8.12%	

Appendix 17. Calculation of California cigarette fee

CA Annual Per Capita Pack Cigarette Consumption	31.8	X
Population CA	39,144,818	
CA Annual # Packs Cigarettes Consumed	1,244,805,212	÷
CFL Financial Costs	$ 1,277,424,241	
CA Cigarette Litter Abatement Fee (Per Pack)	$ 1.03	

Appendix 18. Calculation of California cigarette litter abatement fee

CA Annual Per Capita Pack Cigarette Consumption	31.8	X
Population CA	39,144,818	
CA Annual # Packs Cigarettes Consumed	1,244,805,212	÷
CFL Financial Costs	$ 860,030,565	
CA Cigarette Litter Abatement Fee (Per Pack)	$ 0.69	

Appendix 19. Estimation of CFL collected in Vancouver

Estimation of # CFL collected by Vancouver
(200 lbs X 16 oz/lb) ÷ .006 oz / 1 piece CFL = **533,333**

Appendix 20. Estimation of Litterati CFL-ALR

Plastic:	44,696	42.77%
Paper:	15,867	15.18%
Cigarettes:	11,797	11.29%
Can:	5,178	4.95%
Bottlecap:	4,084	3.91%
Marlboro:	3,463	3.31%
McDonalds:	2,614	2.50%
Straw:	2,240	2.14%
Glass:	2,229	2.13%
Styrofoam:	2,017	1.93%
Coke:	1,694	1.62%
Starbucks:	1,615	1.55%
Camel:	1,231	1.18%
Tacobell:	1,023	0.98%
Receipt:	956	0.91%
Newport:	899	0.86%
Wrigleys:	888	0.85%
Redbull:	731	0.70%
Trident:	660	0.63%
Swishersweets:	627	0.60%
Total Cigarette Litter	17,390	16.64%
All Litter	104,509	100.00%