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# Complexity and Anticipatory Socio-Behavioral Assessment of Government Attempts to Induce Clean Technologies

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## ABSTRACT

Governments are increasingly resorting to technology mandates to force development and commercialization of socially-desirable technologies that the market, for various reasons, seems unable or unwilling to provide in a timely manner. This Article analyzes three recent examples of government-imposed technology mandates, including explicit or de facto government requirements for electric vehicles, digital TV, and non-incandescent light bulbs. The analysis demonstrates that while all three mandates were motivated by legitimate and worthy goals, all three mandates encountered controversy, delays, confusion, and at best partial success. Three major conclusions can be drawn from these three cases studies: (1) Technology mandates should be a last resort for government to induce beneficial technologies; (2) When government resorts to technology mandates it should do a better job of trying to anticipate the social, economic, and technological implications of the intended technology change; and (3) When government resorts to technology mandates it should put into place mechanisms for ongoing review and adjustment of technology mandates.

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## INTRODUCTION

Society would sometimes benefit from new technologies that the free market is unable or unwilling to deliver, either at all or within the optimal time period for its arrival. Governments may intervene in such circumstances to encourage or induce the development of those desired technologies.[1] Governments have used a variety of tools to promote beneficial technologies that the private sector failed to deliver on its own initiative. These tools include applied research and development (R&D) programs to develop desired technologies in government laboratories, targeted grants and other forms of research funding to entities outside of the government, government purchasing specifications to jump-start demand for such technologies, and technology-forcing regulation.[2] In addition, governments have available a series of other tools to encourage greater innovation and technology development generically, including nontargeted R&D funding, tax credits, intellectual property protection, and antitrust policy.[3]

These various government tools to encourage technology innovation have generally been successful in bringing a wide range of beneficial technologies to the market, ranging from information and communications technologies to pollution control technologies. A more radical but more direct approach that governments can take is to mandate a specific type of technology, by requiring companies to produce that product or technology as a condition for operating in the market. This strategy is more radical in that it involves a greater government intrusion into product development by private companies and is more representative of a centralized government than the traditional market-based U.S. approach to innovation. Yet there may be reasons for federal or state government to consider this relatively extreme measure when the more common government innovation tools are inadequate or too slow to overcome market failures.

In this Article, I critically examine three examples in which governments have arguably tried to mandate specific technologies—electric vehicles, energy

1. *See* Adam B. Jaffe et al., *Environmental Policy and Technological Change*, 22 ENVTL. & RESOURCE ECON. 41, 43–46 (2002).
2. *See* OFFICE OF TECH. ASSESSMENT, OTA-BP-ITC-165, INNOVATION AND COMMERCIALIZATION OF EMERGING TECHNOLOGIES 3–4 (1995), *available at* http://ota.fas.org/reports/9539.pdf [hereinafter OTA]; Gary E. Marchant, *Sustainable Energy Technologies: Ten Lessons From the History of Technology Regulation*, 18 WIDENER L.J. 831, 834 (2009).
3. *See* OTA, *supra* note 2, at 3–4.

efficient lighting, and digital television. I begin by looking at the reasons why a government may consider technology mandates, and the types of market barriers such a mandate is intended to overcome. I then assess each of the three case studies, reviewing the specific reasons why the government entity involved chose to use a technology mandate, and the challenges, complications, and successes they had in mandating each. The basic story for each of the three technologies is the same. The government entity at issue had compelling reasons for wanting to drive to market a specific technology, and in the end the technology mandate was at least partially successful in achieving that goal. But in between the objective and the outcome, each of the three mandates resulted in substantial confusion, animosity, inefficiency, delays, and frustration.

Many if not most of these problems could and should have been anticipated, and could have been at least partly mitigated. Yet the governments mandating the technologies failed to anticipate such impediments, or really to undertake any type of anticipatory assessment except for feasibility analyses of the technologies themselves. The government entities simply did not consider the second-order economic, social, and environmental implications of mandating these technologies. The conclusions from these three case studies are that, first, technology mandates are a challenging governance tool that should only be used as a last resort when no other approach is feasible. Second, when mandating technology change, governments need to undertake a careful anticipatory assessment of the potential technological, economic, and social barriers to achievement of the desired technological change. Third, a reflexive and adaptive oversight mechanism is needed for early identification and redress of problems as they arise that could not be anticipated at the time of adopting the regulatory mandate.

## I. TECHNOLOGY MANDATES AS A GOVERNANCE TOOL

New technologies are critical to achieving many societal goals, including environmental protection, energy security, food supply, health, education, communication, job creation, and public convenience and entertainment.[4] Markets will often respond to public demand to satisfy these societal needs, but various types of market failures can also prevent or delay some societal demands from being met. For example, private companies may have a shorter time horizon than society in general, thus discounting investments in some future

4. Of course, many other potential economic or policy interventions are also needed to address these major problems. Technology is a necessary but not a sufficient part of the solution to many of our most urgent problems.

technologies that may be socially beneficial over the long-term. Path dependency, sunk costs, preferences for maintaining the status quo, and risk aversion may limit some private actors from leaving their comfort zones and moving into emerging technologies and markets. Complementary technologies are essential for some new technologies, and the inability to predict or control the availability of those complementary technologies may deter a company from investing in a new technology.

These market failures and barriers, whether real or perceived, often drive legislatures and regulatory agencies to enact policies to accelerate the development, adoption, and use of beneficial new technologies that they conclude are needed to achieve societal goals. For example, the U.S. Congress has driven the development and use of improved motor vehicle emission control technology by directing implementation of a series of increasingly stringent technology-forcing standards, which provide vehicle manufacturers a specified lead time to develop new technologies needed to meet performance levels unattainable at the time of adoption.[5]

In recent years, governments have resorted to much more direct measures to mandate specific technologies. The three examples examined herein are express or de facto technology mandates imposed by state or federal government entities for electric vehicles (EVs), digital TV (DTV), and compact fluorescent light bulbs (CFLs). Mandating specific technologies is a relatively new approach that runs counter to a longstanding consensus that government regulators should focus on performance rather than design standards, leaving the market to select and develop the best technologies and solutions for achieving the performance goals set by the government.[6] Mandating technologies requires governments to pick winners among competing technologies as well as the timeline in which that technology can be brought to fruition, undertakings that are highly uncertain, complex, and risky. Governments have a poor track record of trying to pick the winning technology—"Here the historical record seems . . . unequivocal. Unequivocally negative."[7]

5. *See* COMM. ON STATE PRACTICES IN SETTING MOBILE SOURCE EMISSIONS STANDARDS, NAT'L RESEARCH COUNCIL, STATE AND FEDERAL STANDARDS FOR MOBILE-SOURCE EMISSIONS 115–17 (2006); *cf.* D. Bruce La Pierre, *Technology-Forcing and Federal Environmental Protection Statutes*, 62 IOWA L. REV. 771, 772–73 (1977).

6. *See* Richard B. Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CALIF. L. REV. 1256, 1268 (1981) (noting that performance standards provide companies more flexibility to select least burdensome compliance option); *cf.* Jaffe et al., *supra* note 1, at 50 (discussing potential problems with government regulation and benefits of market-based solutions).

7. Richard R. Nelson & Richard N. Langlois, *Industrial Innovation Policy: Lessons From American History*, 219 SCI. 814, 817 (1983).

Governments nevertheless have recently been resorting to technology mandates in limited circumstances to require the development of targeted technologies (although, as discussed below, governments sometimes frame a de facto mandate as a performance standard).[8] Not surprisingly, such technology mandates tend to be controversial and are often seen as unduly intrusive interventions into the marketplace. Nevertheless, the government entities adopting such measures have found it necessary, for the various reasons that are discussed herein, to invoke such a radical regulatory tool to bring about dramatic and speedy technological change. Yet, as also demonstrated herein, these technology mandates are risky and rife with potential pitfalls and failed expectations. Accordingly, government attempts to mandate specific technologies need to be undertaken cautiously, if at all, with a full and thorough attempt to anticipate potential consequences and problems in advance. Unfortunately, the three examples assessed herein were ones in which the government failed to provide a holistic life cycle assessment that considers the economic, social, behavioral, and environmental implications of such a mandate, as they have in many attempts to force specific technologies in the past. While some of these unintended effects of a technology mandate could likely not have been anticipated in advance, many others could have been predicted and avoided or at least mitigated by an anticipatory technology impact assessment.

## II. CALIFORNIA'S ELECTRIC VEHICLE MANDATE

In 1990, California adopted a zero emission vehicle (ZEV) mandate that was originally scheduled to phase in beginning in model year (MY) 1998. This ZEV mandate required 2 percent of each large-volume vehicle manufacturer's total California vehicle sales in MY 1998 to be certified as ZEVs, which increased to 5 percent in MY 2001 and 10 percent in MY 2003. Although the requirement was phrased in technology-neutral performance language (namely, "zero emission"), the reality was that battery-powered EVs were the only possible technology that could achieve zero emissions, as defined by the regulation, within the timeline provided.[9] As the California regulators noted in adopting the ZEV

8. Such a de facto mandate occurs when a government regulator prohibits an existing technology for all or part of the market, and there is only one feasible technology to replace the prohibited product in the relevant time period. Therefore, even though the replacement technology is not formally mandated, it is de facto the only choice available. There is always the possibility, however, that companies may develop another substitute technology eventually, so the affirmative de facto mandate may be limited in time.

9. *See* Louise Wells Bedsworth & Margaret R. Taylor, *Learning From California's Zero-Emission Vehicle Program*, CAL. ECON. POL'Y, Sept. 2007, at 1, 5.

mandate, "[a]t present, only battery-powered electric vehicles are candidates to be ZEVs, although it is conceivable that other technology (such as fuel cells) could be developed in the future."[10] The ZEV mandate was therefore a de facto mandate to produce and sell EVs.[11]

The federal Clean Air Act (CAA) gives California unique authority to adopt and enforce its own state-level vehicle emission standards, subject to approval by the EPA, because of its "pioneering" role in regulating vehicle emissions and the unique "compelling and extraordinary" air pollution problems it faces.[12] Under this authority provided in CAA section 209(b), California adopted a series of progressively more stringent emission standards throughout the 1970s and 1980s that became precursors for subsequent federal standards.[13] In 1990, the California Air Resources Board (CARB), the state agency responsible for air pollution control, adopted its most aggressive vehicle emission standards to date, known as the Low-Emission Vehicle (LEV) program.[14] This program required vehicle manufacturers to reduce emissions sharply over a multiyear period and measured compliance by the fleet-wide average emission rate for each manufacturer. The LEV program provided a broad performance standard that gave vehicle manufacturers flexibility to craft individual compliance strategies.[15]

Perhaps due in large part to the flexibility provided by the program, the LEV program overall was an enormous success, achieving reductions in emissions and advances in emission technology beyond those anticipated at the time the aggressive LEV program was adopted in 1990.[16] As the lead California regulator commented several years after the successful implementation of the program, "we've seen the near impossible accomplished with gasoline vehicles: zero evaporative emissions, exceedingly clean exhaust—cleaner, in some cases, than the outside air entering the cabin for ventilation purposes, and emission

10. CAL. AIR RES. BD., PROPOSED REGULATIONS FOR LOW-EMISSION VEHICLES AND CLEAN FUELS: STAFF REPORT 5 (1990) [hereinafter CARB (1990)].
11. *See* Bedsworth & Taylor, *supra* note 9.
12. COMM. ON PUB. WORKS, AIR QUALITY ACT OF 1967: AMENDING THE CLEAN AIR ACT AS AMENDED, S. REP. NO. 90-403, at 33 (1967).
13. NAT'L RESEARCH COUNCIL, *supra* note 5, at 91–97.
14. *See* CAL. AIR RES. BD., PROPOSED REGULATIONS FOR LOW-EMISSION VEHICLES AND CLEAN FUELS: TECHNICAL SUPPORT DOCUMENT (Aug. 13, 1990).
15. *See* NAT'L RESEARCH COUNCIL, *supra* note 5, at 165–168.
16. *See id.* at 174–75.

control systems that are twice as durable than their conventional forebearers, forecasted to last an astonishing 150,000 miles."[17]

The ZEV mandate was embedded within the larger LEV program and was a notable departure from the flexibility provided to vehicle manufacturers in the rest of the LEV program, which allowed manufacturers to customize their own compliance schedules and strategies. CARB nonetheless decided to mandate specified percentages of ZEVs for several compelling reasons. First, CARB determined that the only way it could achieve the extremely challenging goal of ensuring healthy air levels in southern California was to reduce emissions from consumer driving to essentially zero over the long-term and thus saw the ZEV mandate as an essential first step to that goal. CARB noted that EVs not only produced no exhaust emissions, but also produced no evaporative or refueling emissions, which are other significant sources of air pollution from internal combustion engines.[18] Moreover, the degradation of emission control performance of internal combustion vehicles over the lifetime of the vehicle had begun to interfere with CARB's efforts to limit air pollution, a problem that the ZEV mandate could help address since EVs produce zero emissions throughout their lifetime.[19]

Another rationale for an inflexible mandate was to provide certainty for producers of complementary technologies needed for EV implementation. While vehicle manufacturers made the electric vehicle itself, they were dependent on battery manufacturers to produce batteries of sufficient quality and in numbers necessary to enable the deployment of large numbers of EVs. Yet, in a classic chicken-and-egg problem, battery manufacturers were reluctant to move forward with the substantial investments required for the development and manufacturing of EV batteries if they had no assurance that vehicle manufacturers planned to produce large volumes of EVs. Conversely, vehicle manufacturers were hesitant to develop advanced EVs if they were unsure about the commercial availability and viability of batteries needed to power those vehicles. Similarly, successful EV deployment required a significant investment in EV infrastructure such as public recharging stations from electric utilities and municipalities, not vehicle manufacturers. Again, both industries wanted the other to go first; the vehicle manufacturers wanted to see recharging facilities in place and

17. Press Release, Cal. Air Res. Bd., ARB Modifies Zero-Emission Vehicle (ZEV) Regulation (Apr. 24, 2003) (quoting then-CARB Chairman Dr. Alan Lloyd), *available at* http://www.arb.ca.gov/newsrel/nr042403.htm.

18. *See* CAL. AIR RES. BD., PROPOSED REGULATIONS FOR LOW-EMISSION VEHICLES AND CLEAN FUELS: FINAL STATEMENT OF REASONS 48 (July 1991) [hereinafter CARB (1991)].

19. *See* Bedsworth & Taylor, *supra* note 9.

ready for their customers before producing EVs, while the cities and utilities saw no point in investing in EV infrastructure before the vehicle manufacturers were committed to producing substantial numbers of EVs. By mandating the production of sufficient numbers of EVs by vehicle manufacturers, CARB sought to resolve the uncertainties provided by the complementary technology roadblocks.

Another rationale for the mandate was that broad consumer demand for EVs had not yet developed beyond a few niche markets—and may never have developed if EVs remained costly and a novelty. By mandating that a large number of EVs be produced and offered for sale, CARB hoped to use demand stimulus to overcome the latent public demand by creating an economy of scale to drive down prices and to put a sufficient number of vehicles into service to overcome any novelty concerns.[20] Finally, California hoped that the ZEV mandate would provide an important economic boost for the establishment of clean production companies in California and nationwide. Thus, CARB hoped that the ZEV mandate would "contribute to national and state energy diversity and security" efforts and help "to revitalize California's economy through job creation and growth in an emerging industry."[21]

California's adoption of the ZEV mandate in 1990, scheduled to first apply in model year 1998, opened the door for other states to adopt the same requirement. Under section 177 of the CAA, other states may adopt vehicle emission standards "identical" to California's rather than apply the less stringent federal standards.[22] After California adopted its LEV program in 1990, several other states, most notably Massachusetts and New York, adopted the same program, including the ZEV mandate.

The auto industry expressed doubts about the feasibility and wisdom of California's ZEV mandate when it was adopted in 1990, and those concerns continued to grow in the following years.[23] When it first adopted its ZEV

20. *See id.;* Mark B. Brown et al., *Technological Innovation Through Environmental Policy: California's Zero-Emission Vehicle Regulation*, 19 PUB. PRODUCTIVITY & MGMT. REV. 77, 87 (1995).

21. CAL. AIR RES. BD., DRAFT TECHNICAL DOCUMENT FOR THE LOW-EMISSION VEHICLE AND ZERO-EMISSION VEHICLE WORKSHOP ON MARCH 25, 1994: ZERO-EMISSION VEHICLE UPDATE (Mar. 2, 1994).

22. 42 U.S.C § 7507(1) (2012).

23. When California first adopted the zero emission vehicle (ZEV) mandate in 1990, vehicle manufacturers did not focus very intensely on the ZEV requirement, treating it as a "footnote" to the larger Low Emission Vehicle program. Gustavo Collantes & Daniel Sperling, *The Origin of California's Zero Emission Vehicle Mandate*, 42 TRANSP. RES. PART A 1302, 1308 (2008). By 1994, vehicle manufacturers had grown much more concerned about the feasibility of the ZEV mandate and started requesting that CARB relax the mandate. NAT'L RESEARCH COUNCIL, *supra* note 5, at 170.

mandate, CARB established a biennial review process to assess the industry's progress in developing ZEVs. In its 1994 biennial review, CARB rejected manufacturers' suggestion to give partial credits for hybrid electrical vehicles, maintaining its position that pure electric vehicles were the long-term solution and that hybrids would diverge from that goal.[24] CARB gave the following reasons for rejecting the proposal to partially substitute hybrids for pure electric vehicles:

> The adopted regulations reflect a conservative stance toward special provisions for HEVs because, unlike ZEVs, HEV emissions are expected to deteriorate in-use due to the existence of the auxiliary engine. Also, as batteries deteriorate in HEVs, use of the auxiliary engine would probably increase. Incentives to produce HEVs, such as allowing HEV credits to substitute for the ZEV mandate, will delay battery development for better performing ZEVs (and, therefore, HEVs).[25]

In preparation for the 1996 review, CARB created an independent panel of battery experts to evaluate the readiness of battery technology for EVs. In its final report issued in December 1995, the panel determined that most vehicle manufacturers would try to meet the ZEV mandate in the 1998 model year using EVs with lead-acid batteries.[26] The panel found that EVs powered by lead-acid batteries would have range and cost limitations that would restrict them to "small market niches."[27] The panel concluded that commercially successful EVs would require "advanced" batteries, but those batteries, using formulations other than lead-acid, were still at the prototype stage of development.[28] In the best-case scenario, the panel determined that EVs with "commercial-production advanced batteries" would not be available until model year 2000 or 2001 at the earliest.[29]

In response to the independent experts' report, CARB concluded that going forward with the ZEV mandates for the period before model year 2003 would be counterproductive:

> [T]here is a substantial risk that due to various factors, including vehicle performance, e.g., range, and expected initial vehicle price, consumer demand may not support a market meeting the current

24. *See* NAT'L RESEARCH COUNCIL, *supra* note 5, at 169.
25. CARB (1991), *supra* note 18, at 51.
26. *See* BATTERY TECHNICAL ADVISORY PANEL, PERFORMANCE AND AVAILABILITY OF BATTERIES FOR ELECTRIC VEHICLES, REPORT PREPARED FOR THE CALIFORNIA AIR RESOURCES BOARD (Dec. 11, 1995).
27. *Id.* at IV-1.
28. *Id.* at iii–iv.
29. *Id.* at IV-5.

> regulatory requirements for model years 1998 through 2002, or alternatively that ZEVs introduced during that period may not meet consumer expectations and that the adverse effect of this situation may impact the viability of the market when advanced battery technologies are available.[30]

CARB was concerned that large-scale introduction of lead-acid ZEVs could "poison" the long-term prospects for ZEVs,[31] and ultimately determined that it would not be "prudent to rely upon a large scale introduction of lead-acid battery EVs to launch the consumer ZEV market."[32] Based on those determinations, while vehicle manufacturers were far into the process of finalizing vehicle production plans for model year 1998, CARB amended its regulations in 1996 to repeal the ZEV mandate for model years 1998–2002.[33]

The remaining 2003 ZEV mandate was progressively weakened and eventually eviscerated in subsequent annual reviews. In the 1998 biennial review, CARB relaxed the 2003 mandate by permitting manufacturers to meet the majority of their 2003 ZEV target with "partial ZEVs" (PZEVs) (in effect, advanced hybrid vehicles), which were a new category of vehicles achieving near-zero emissions.[34] In 2000, CARB appointed another panel of independent experts to assess battery performance and availability, which concluded that advanced technology batteries with adequate cost and performance characteristics would not be available to meet the 2003 mandate.[35] After much indecision and several flip-flops on how to respond to the battery experts' report, in January 2001 CARB decided to further weaken the 2003 mandate. Soon thereafter, manufacturers filed a successful lawsuit contending that the ZEV program was preempted by federal law, which resulted in the temporary injunction of the program. CARB settled the lawsuit by essentially eliminating the original ZEV mandate, allowing manufacturers to meet their 2003 obligation by producing a small number (250 for the total industry) of demonstration fuel

30. CAL. AIR RES. BD., RESOLUTION 96-12, at 6 (Mar. 28, 1996).
31. *See* CAL. AIR RES. BD., PROPOSED AMENDMENTS TO THE ZERO-EMISSION VEHICLE REQUIREMENTS FOR PASSENGER CARS AND LIGHT-DUTY TRUCKS 9 (Feb. 9, 1996).
32. *Id.* at 22.
33. *See* Bedsworth & Taylor, *supra* note 9, at 6–7.
34. *Id.* at 7–8.
35. *See* MENAHEM ANDERMAN ET AL., THE YEAR 2000 BATTERY TECH. ADVISORY PANEL, ADVANCED BATTERIES FOR ELECTRIC VEHICLES: AN ASSESSMENT OF PERFORMANCE, COST, AND AVAILABILITY 92–93 (June 22, 2000) (finding that neither of the two most promising advanced technology batteries—nickel metal hydride and lithium-ion—would be commercially available at the required cost goals by 2003 even under the most favorable assumptions).

cell vehicles by 2008, followed by a ramp-up of fuel cell vehicles development in subsequent years.[36]

This final nail in the coffin of the original ZEV mandate effectively replaced the original mandate for EVs with a requirement for short-term hybrid vehicle sales and long-term demonstration projects for fuel cell vehicles. In throwing in the towel on EVs, CARB concluded that "even at substantially increased production levels full function EVs would not be cost competitive with conventional vehicles, and that there does not appear to be a viable path that will result in commercialization for general markets."[37] "Under these circumstances," CARB conceded, "it is not surprising that the major automobile manufacturers express an unwillingness to develop or produce additional full-function battery EVs."[38] In all, the ZEV mandate was relaxed six times in the period from 1990 through 2003, progressively diluting the program into a pale imitation of its original grandiose goals and requirements, although not without imposing substantial compliance costs as companies invested enormous resources struggling to meet the infeasible ZEV mandate.[39]

Ironically, shortly after CARB abandoned its initial focus on EVs, vehicle manufacturers started showing renewed interest in EVs. Several vehicle manufacturers announced plans to commercialize EVs, including the Nissan Leaf, the GM Volt, and the Toyota plug-in Prius. But, as CARB itself noted, the driver of this renewed focus on EVs was not CARB's ZEV mandate but rather that "long-term commercial success and corporate environmental stewardship" had become the primary motivations for manufacturers.[40] The 1990 California mandate no doubt had some incremental beneficial impact in encouraging the development of EV batteries and other technologies that now seem to be coming to fruition.[41] A study commissioned by CARB found that the ZEV mandate provided significant secondary benefits in the development and applications of batteries and other technologies for hybrid and EVs.[42]

36. *See* Bedsworth & Taylor, *supra* note 9, at 8–9 & tbl.2.
37. CAL. AIR RES. BD., FINAL STATEMENT OF REASONS: THE 2003 AMENDMENTS TO THE CALIFORNIA ZERO EMISSION VEHICLE PROGRAM REGULATIONS 51 (Jan. 2004).
38. *Id.* at 17.
39. *See* NAT'L RESEARCH COUNCIL, *supra* note 5, at 169.
40. CAL. AIR RES. BD., WHITE PAPER: SUMMARY OF STAFF'S PRELIMINARY ASSESSMENT OF THE NEED FOR REVISIONS TO THE ZERO EMISSION VEHICLE REGULATION 14–15 (Nov. 25, 2009).
41. *See* Bedsworth & Taylor, *supra* note 9, at 9–11.
42. *See* A.F. BURKE ET AL., STUDY OF THE SECONDARY BENEFITS OF THE ZEV MANDATE 72–77 (2000) (discussing various battery technologies and their relation to the ZEV program).

Yet, notwithstanding these indirect benefits, the California ZEV mandate was a policy failure.[43] Hundreds of millions if not billions of dollars were wasted by vehicle manufacturers in frantic programs to attempt to rush EVs to market prematurely to comply with the ZEV mandate.[44] While some such vehicles did see the light of the market, such as the GM EV1 and the Honda EV Plus, they encountered very low consumer demand, primarily limited to niche markets of EV enthusiasts, and their programs were soon cancelled. As Alan Lloyd, the Chairman of CARB at the time the original ZEV mandate was finally repealed, ruefully conceded, "We have put a lot of faith in battery electric vehicles to meet the [zero-emission vehicle] mandate but, in spite of significant efforts, batteries have inherent limitations."[45]

The failure of the California ZEV mandate can be attributed to a number of factors. To begin with, CARB faced a difficult task in picking both the winning technology and a realistic timeline. Several clean vehicle technologies were on the horizon, including hybrids, alternative-fueled (for example, natural gas, propane, or ethanol) vehicles, battery EVs, and fuel cell vehicles. CARB decided to place all its bets on EVs—rejecting manufacturer suggestions in the early 1990s to give partial credits for hybrid electric vehicles (HEVs).[46] Moreover, the compliance schedule adopted by CARB in 1990 was not feasible for fuel cell vehicles and thus effectively excluded them from its de facto mandate for battery EVs. Unfortunately, the aggressive timeline CARB selected turned out, at least in retrospect, to be unrealistic.

At the end of 2013, some twenty-three years after CARB put all its bets on battery EVs, major uncertainties remain about the future of cleaner vehicles. Some companies such as Tesla are convinced that EVs are the vehicle of the future, while others such as Toyota and Honda, which have been leaders in hybrid electric vehicles, remain skeptical about pure EVs and are putting much of their efforts in hydrogen fuel cell cars that they see as better alternatives to EVs.[47] The CARB ZEV mandate prematurely tried to decide this debate between competing technologies, which remains undecided today. Vehicle manufacturers

43. *See* NAT'L RESEARCH COUNCIL, *supra* note 5, at 169 ("[T]he ZEV experiment has fallen short of its original expectations to promote the widespread use of electric vehicles.").
44. *See id.* (discussing General Motors's estimated $1 billion investment in ZEVs that are unlikely to be widely used).
45. Gary Polakovic, *State Takes Sharp Turn on Emissions*, L.A. TIMES, Sept. 15, 2002, articles.latimes.com/print/2002/sep/15/local/me-cars15 (alteration in original) (quoting CARB Chairman Alan C. Lloyd).
46. *See supra* notes 24–26 and accompanying text.
47. *See* Brad Plumer, *Some Automakers See Hydrogen Cars as the Wave of the Future*, ST. LOUIS POST-DISPATCH, Nov. 28, 2013, http://www.stltoday.com/business/local/some-automakers-see-hydrogen-cars-as-the-wave-of-the/article_8e1562fe-8ac4-5ae6-8c7d-65d6eeaa6ef4.html.

who favor EVs over fuel cells often cite sunk costs. Even if fuel cells are the better technology choice, because vehicle manufacturers have invested billions of dollars in EVs, and because EVs are the only technology capable of complying with CARB's initial ZEV mandate timetable, it is arguably too late to switch focus to fuel cells.[48] Thus, because of this path dependency effect, the premature CARB mandate has had a permanent distorting impact on the development of clean car technologies for the future.

The difficulty of picking winning technologies and their development timelines makes technology mandates risky, but if CARB was nevertheless determined to attempt such a mandate, it could have done a better job trying to anticipate and consider the full range of technological, economic, business, environmental, consumer, and social impacts and uncertainties about the technology it sought to advance. For example, CARB's unrealistically optimistic estimates of EV costs, feasibility, and timeline were a contributing factor to the program's failure. When it first adopted its ZEV mandate in 1990, CARB claimed that "by 2000, electric vehicles would be comparable in cost to conventional vehicles except for the additional cost of batteries," which CARB estimated at the time would cost only about $1350 per EV,[49] a number that CARB admitted was greatly underestimated just a few years later.[50] In 1990, CARB likewise dismissed concerns that EVs might not provide the performance most vehicle buyers expected and thus might not be commercially viable, stating that "there is little concern of the commercial viability and public acceptance of electric vehicles."[51] Just four years later, in its 1994 review of the ZEV mandate, CARB had increased its estimate of the incremental additional costs of an EV from its initial estimate of $1350 per vehicle to a new estimate of $5000 (low scenario) to $10,000 (high scenario).[52] By the 2000 program review, CARB had increased its estimate of the incremental cost of a freeway-capable ZEV to at least $17,000 more than a conventional vehicle, more than an order of magnitude higher than the estimate CARB had provided when it adopted its ZEV mandate in 1990.[53]

48. *See* Dominic Basulto, *Hydrogen-Powered Cars? Get Excited.*, WASH. POST (Nov. 25, 2013, 9:28 AM), http://www.washingtonpost.com/blogs/innovations/wp/2013/11/25/hydrogen-powered-cars-get-excited.
49. CARB (1990), *supra* note 10, at 63.
50. *See* NAT'L RESEARCH COUNCIL, *supra* note 5, at 169.
51. CARB (1991), *supra* note 18, at 48.
52. CAL. AIR RES. BD., STAFF REPORT: 1994 LOW EMISSION VEHICLE AND ZERO-EMISSION VEHICLE PROGRAM REVIEW 65 (Apr. 1994).
53. *See* CAL. AIR RES. BD., STAFF REPORT: 2000 ZERO EMISSION VEHICLE PROGRAM BIENNIAL REVIEW 127 (Aug. 7, 2000).

This increasing cost estimate was necessitated by CARB's erroneous assumption in 1990 that current (lead-acid) battery technologies would be adequate for a commercially viable EV in the initial years of the ZEV mandate, and their underestimate of the challenges and timeline for the availability of advanced technology batteries. By 2010, over a decade after the CARB ZEV mandate was initially scheduled to take effect, the cost and performance of EV batteries were still not predicted to become competitive with the internal combustion engine for several more years, if not a decade or more.[54] More broadly, CARB's flawed cost and performance estimates suggest a failure to seriously consider the full range of opinions and uncertainties about the future of EVs, as the agency uncritically adopted the most optimistic opinions and estimates that aligned with its own preferences while dismissing more critical estimates from industry and other experts without serious consideration.

CARB also failed to consider the perspectives of key stakeholders. EVs could only be a success and provide the air quality benefits CARB was seeking if consumers felt comfortable buying and driving EVs and would be willing to switch to EVs in large numbers. Other than small niche markets, most consumers had several concerns about EVs, including dislike of their look and design, worries about the reliability of unfamiliar technologies, dissatisfaction with overall power and performance, anxiety about driving range, and concern about the time needed to recharge battery packs.[55] As a recent MIT conference report succinctly stated the issue: "for EVs to successfully penetrate US markets, consumer acceptance is essential. Without this, the answer to the question 'Who killed the electric car?' will likely not involve a sinister conspiracy but will instead simply be 'the American consumer.'"[56]

Yet the artificial timeline that CARB imposed exacerbated rather than helped to address these consumer concerns by forcing the premature production of EVs that cost more, performed worse, and had many more uncertainties than a conventional gasoline-fueled vehicle. In addition, EVs were not appropriate for many consumers, including those who needed their vehicle for trips greater than the approximately one hundred mile maximum range of an EV (under ideal conditions), or those who did not park their car in a garage or other location with a nearby recharging capability. Indeed, studies available when CARB adopted its

54. *See* MASS. INST. OF TECH. ENERGY INITIATIVE, ELECTRIFICATION OF THE TRANSPORTATION SYSTEM: AN MIT ENERGY INITIATIVE SYMPOSIUM (2010), *available at* http://mitei.mit.edu/system/files/electrification-transportation-system.pdf [hereinafter MITEI].

55. *See* J.D. POWER & ASSOCS., DRIVE GREEN 2020: MORE HOPE THAN REALITY? 2 (2010).

56. MITEI, *supra* note 54, at 15.

ZEV mandate indicated that vehicle range was a critical factor for consumers in deciding whether to purchase EVs.[57]

CARB simply ignored concerns about the limited range of EVs and the widespread range anxiety that made EVs unattractive to most consumers. Not surprisingly, EV purchases were limited to the small niche of EV enthusiasts, and the initial EVs produced under the ZEV mandate (before it was essentially repealed) sold or were leased in the hundreds of units rather than the tens or even hundreds of thousands needed to make a major impact on air quality. CARB seemed to assume that if it could force the supply of EVs, the demand for EVs would follow—a premise that turned out to be faulty absent greater effort to build consumer demand. EVs, especially with the range and other performance limits that existed in the late 1990s and first decade of the 2000s, were not going to sell themselves in any significant numbers.

CARB also failed to consider the incentives and interests of the companies it depended on for the success of the ZEV mandate. By mandating that every major vehicle manufacturer produce the same percentage of EVs in the same time period, CARB unwittingly undermined any competitive advantage that a vehicle manufacturer might gain from seeking to be an industry leader in the EV field. General Motors (GM) was actively developing and planning to commercialize its own EV, originally named the Impact, before CARB decided to mandate EVs.[58] By imposing a rigid and what appeared to many (including those in industry) infeasible EV mandate, CARB turned GM from a proponent of the vehicle it was developing on its own to an EV (or at least an EV mandate) critic. For example, GM was the only vehicle manufacturer to sue to overturn the ZEV mandate.[59] Thus, one of the strongest proponents of EVs became one of their strongest opponents, and CARB turned a potential ally on the commercialization of EVs into a well-funded and determined opponent.[60]

CARB also failed to understand the dynamics and incentives of battery manufacturers, simply assuming that if it mandated the vehicles, battery manufacturers would quickly and automatically fall in line and start mass

57. *See* John E. Calfee, *Estimating the Demand for Electric Automobiles Using Fully Disaggregated Probabilistic Choice Analysis*, 19 TRANSP. RES. 287, 294 (1985).

58. *See* Collantes & Sperling, *supra* note 23, at 1306.

59. John O'Dell, *GM Sues to Overturn State's Zero Emission Vehicle Mandate*, L.A. TIMES, Feb. 24, 2001, http://articles.latimes.com/2001/feb/24/business/fi-29699.

60. The author represented General Motors (GM) as an attorney on electric vehicle (EV) issues in this time period and observed first-hand the counterproductive impact of the ZEV mandate inside the company. Although GM tried to distinguish its opposition to the ZEV mandate from its support and interest in EVs, those two positions were hard to reconcile in both internal and external contexts.

producing the batteries needed by vehicle manufacturers. The reality was much more complicated. Given the uncertainties about battery types and performance needed for commercially successful EVs, and given the changing perspectives about the best battery technologies, battery manufacturers had no assurance that vehicle manufacturers would purchase any particular battery technology the battery manufacturer would have to commit to in building mass production capacity.

CARB also failed to address the full life cycle environmental impacts of EVs. When it adopted the ZEV mandate, CARB emphasized the benefits of EVs in producing zero emissions throughout their life cycle, including from the tailpipe (especially as the vehicle aged), from evaporative emissions, and from refueling. Notwithstanding these clear environmental benefits, there remains the issue of environmental impacts from the electricity generation used to charge the EVs. This has proven to be a controversial and contested issue, perhaps due in part to CARB's failure to address this issue openly and fully at the time it adopted its ZEV mandate. While most analyses show that EVs in California would provide a clear environmental benefit given the relatively clean fuels used to generate electricity in California, that may not be the case for other states that also adopted a ZEV mandate identical to California's but that rely much more heavily on coal to generate electricity.[61] In fact, a recent National Research Council report concluded that the adverse health and environmental impacts of EVs in 2030 under various assumptions and scenarios would be consistently worse than for conventional vehicles.[62] Another analysis suggested that vehicle manufacturers would spread the costs of the ZEV mandate over their fleet of other new vehicles, raising new vehicle prices and causing some consumers to hold on to their vehicles longer, resulting in environmental harm that outweighs the environmental benefits of the ZEV mandate.[63]

CARB also did not address other potential environmental concerns related to EVs, such as the disposal and recycling of the large battery packs used by EVs. Almost all EV manufacturers are currently planning to use lithium batteries,[64] yet few recycling companies are currently accepting lithium batteries from laptops

61. Daniel Sperling & Deborah Gordon, *Advanced Passenger Transport Technologies*, 33 ANN. REV. ENV'T & RESOURCES 63, 70 (2008).

62. *See* NAT'L RESEARCH COUNCIL, HIDDEN COSTS OF ENERGY: UNPRICED CONSEQUENCES OF ENERGY PRODUCTION AND USE 202–03 (2010).

63. Howard Gruenspecht, *Zero Emission Vehicles: A Dirty Little Secret*, RESOURCES, Winter 2001, at 7, *available at* http://www.rff.org/rff/Documents/RFF-Resources-142-zeroemmis.pdf.

64. *See* Tony Markel, Plug-In Electric Vehicle Infrastructure: A Foundation for Electrified Transportation 2 (Apr. 8, 2010) (unpublished manuscript), *app. to* MITEI, *supra* note 54 ("Lithium-ion battery technology is the likely energy-storage candidate for near-term vehicles.").

and cell phones, raising concerns that lithium batteries from EVs may create disposal problems.[65] A recent analysis of the life cycle impacts of EVs conducted for the Low Carbon Vehicle Partnership in the European Union (EU) found that the production of EVs would produce substantially more $CO_2$ than the production of conventional vehicles because of battery pack production, although the EVs produce lower whole-life overall carbon emissions (assuming EVs are able to complete their life spans without replacement battery packs).[66] Another factor overlooked by the ZEV mandate is that a shift to EVs would negatively impact water resources, primarily because of increased water cooling of thermoelectric power plants.[67]

Finally, CARB did not consider other social and economic second-order impacts of the EVs it was mandating. One such impact is that because EVs do not need to purchase gasoline, they do not pay the highway tax built into the price of gasoline that is used to fund highway construction and maintenance in the United States. As the highway fleet shifts toward electric and hybrid vehicles, this could present a serious budgetary problem. Some jurisdictions, including Oregon and Texas, are already considering imposing a vehicles miles traveled (VMT) tax on EVs, using a GPS chip in the car to keep track of mileage.[68] The mandatory GPS chip would raise privacy and access concerns.

In his 2011 State of the Union speech, President Barack Obama called for one million EVs to be on the road in America by 2015.[69] Every major vehicle manufacturer has one or more EVs in commercial development, and so achievement of the one million vehicles by 2015 is not an impossible national goal, although there are increasing doubts about the feasibility of the timing as the year 2015 approaches. For example, a recent National Research Council report concluded that "a significant market penetration" of EVs by 2030 "is unlikely."[70] An October 2010 assessment by J.D. Power and Associates estimates that there will be only 108,000 battery-powered EVs sold in the United States in

65. Mike Ramsay, *Environmental Lift of Battery Cars Is Limited*, WALL ST. J., Oct. 18, 2010, http://online.wsj.com/news/articles/SB10001424052748703794104575546071601126064.

66. JANE PATTERSON ET AL., RICARDO, PREPARING FOR A LIFE CYCLE $CO_2$ MEASURE 47–53 (2011), *available at* http://urbact.eu/fileadmin/Projects/EVUE/documents_media/Preparing_for_a_Life_Cycle_CO2_Measure.pdf.

67. Carey W. King & Michael E. Webber, *The Water Intensity of the Plugged-In Automotive Economy*, 42 ENVTL. SCI. & TECH. 4305, 4309–10 (2008).

68. Timothy Hurst, *Is the Electric Car's Tax-Free Ride Coming to an End?*, REUTERS (Apr. 11, 2011), http://www.reuters.com/article/2011/04/11/idUS175572720320110411.

69. *See* Katherine Ling, *Obama Pushes Clean Energy in SOTU Speech as Part of His New Centrist Agenda*, N.Y. TIMES, Jan. 26, 2011, http://www.nytimes.com/gwire/2011/01/26/26greenwire-obama-pushes-clean-energy-in-sotu-speech-as-pa-59612.html.

70. NAT'L RESEARCH COUNCIL, *supra* note 62, at 198–99.

2020.[71] The cost of batteries, one of the chief impediments to wider commercialization of EVs, is not expected to significantly decrease for at least several years and may, in fact, increase because of shortages of many of the key metals required for battery production.[72]

Regardless of the projections about the future, what is no longer in doubt is that California's attempt to force more than one million EVs on the road in California alone by 2003 was plainly premature. Though it was pursuing a legitimate (and perhaps necessary) objective, CARB failed to provide a realistic scenario and timeline for EVs because it failed to consider the full range of economic, business, consumer, social, and environmental impacts and challenges of EVs. A fuller and more robust analysis up front might have avoided many of the pitfalls and wasted resources and opportunities that are the legacy of the failed ZEV mandate. To its credit, CARB did put in place a biennial review process to monitor and adjust the ZEV mandate compliance schedule in response to the rapidly changing circumstances, which resulted in the frequent amendment and eventual replacement of the original ZEV mandate (albeit perhaps too slowly for vehicle manufacturers' preferences).

## III. DIGITAL TV MANDATE

A second example of a technology mandate was the congressional requirement to transition television from analog to digital broadcast signals by 2009. After several delays, this transition was eventually accomplished, so in the end the statute achieved its ultimate goal. But success was not achieved without a lot of controversy, disruption, and inefficiencies that could have been avoided or at least reduced by a more thorough and deliberate anticipation of potential technological, economic, business, social, and consumer impacts and responses to the technology mandate.

Digital TV (DTV) offers a number of advantages over analog TV. It enables better quality picture and sound transmission, free of the ghosting and fuzziness that often afflicts analog broadcasts. It also permits interactive services such as viewer-controlled feedback, as well as other digital computer-like voice and data applications, including emailing and software delivery. DTV also permits more exotic services such as multicasting, which allows several different feeds to be transmitted simultaneously to a single viewer (enabling the viewer, for

71. J.D. POWER & ASSOCS., *supra* note 55.

72. Eric Loveday, *Frost & Sullivan: EV Production Could Be Hindered by Shortage of Battery Parts*, AUTOBLOGGREEN (Sept. 3, 2010, 10:55 AM), http://green.autoblog.com/2010/09/03/frost-and-sullivan-ev-production-could-be-hindered-by-shortage-of.

example, to watch several basketball games on the screen at the same time). Perhaps most importantly to government, digital broadcasts use significantly less spectrum than analog signals, freeing up valuable spectrum for other important uses (and government revenues).[73]

Despite these important benefits, the government and many industry experts concluded that the market would not transition to the superior digital technology in a timely manner on its own. The major obstacle was the chicken-and-egg problem with three complementary and essential industry participants—the equipment manufacturers needed to produce DTV sets, the content providers needed to produce digital versions of TV shows, and the television stations needed to broadcast digital content. It was not in the interest of any one of these three distinct industry sectors to break the deadlock and begin the transition to digital. For example, why should a content provider produce a digital version of a TV show if there were no TV stations capable of transmitting digital content and no consumers with DTVs capable of receiving such content? This chicken-and-egg problem among complementary technologies was exacerbated by the latent public demand for DTV—since consumers generally had little or no experience or knowledge about the benefits of DTV, there was very little consumer push for the technology.

To break this logjam, the Federal Communication Commission (FCC) and Congress mandated that all broadcast TV channels switch to digital broadcasts by a specified date, which was delayed several times.[74] The FCC adopted the initial DTV transition plan in 1998 after a decade-long proceeding to consider the future of advanced technology TV.[75] It required TV stations to start broadcasting a digital channel by May 2002, but also temporarily loaned each TV station a second frequency so that it could simulcast its programs on both an analog and a digital channel for an interim period. The analog channel would be shut down at some point and the spectrum allocation returned to the government to be auctioned off at the completion of the transition. Congress passed a "Sense of Congress" resolution in 1997 specifying an original target date of December 31, 2006 for shutting down and returning the analog spectrum to the government, but provided a failsafe mechanism that would delay the deadline if 85 percent of homes did not have equipment that could handle a digital signal

73. *See generally* Bob Dole, *Giving Away the Airwaves*, N.Y. TIMES, Mar. 27, 1997, http://www.nytimes.com/1997/03/27/opinion/giving-away-the-airwaves.html (arguing the Clinton administration should auction off licenses for broadband television instead of giving them away for free).

74. *See* LENNARD G. KRUGER & LINDA K. MOORE, CONG. RESEARCH SERV., RS22217, THE DIGITAL TV TRANSITION: A BRIEF OVERVIEW 2 (2006).

75. Carriage of the Transmissions of Digital Television Broadcast Stations, 63 Fed. Reg. 42,330 (proposed Aug. 7, 1998).

by a specified time before the deadline.[76] This safety valve was indeed triggered, with less than 3 percent of American households having TV sets capable of receiving digital signals by early 2005 (although many more could receive digital broadcasts through their cable or satellite systems), and accordingly the FCC delayed the implementation for two additional years to December 31, 2008.[77]

The Digital Television Transition and Public Safety Act of 2005 extended the deadline by a few weeks to February 17, 2009 to avoid inconveniencing viewers during the holiday football bowl games and Super Bowl. By January 2009, just a few weeks before the scheduled cutoff of the analog signals, the DTV transition was in a state of "disarray" and "turmoil," according to the Washington Post.[78] Facing widespread opposition and lack of preparation, a divided Congress once again extended the deadline in the DTV Delay Act of 2009 to June 12, 2009. Stations were given the option of proceeding with the original February 2009 date, and approximately 40 percent of U.S. stations made the transition at that time.[79] When the final transition occurred in June 2009, an estimated eleven to twelve million homes (10 percent of U.S. households with TVs) were still at risk of losing TV reception and had not installed a converter box.[80] Nevertheless, the reported complaints and disruptions at the time of the final transition were relatively minor according to some accounts, described by one reporter as a "minor hiccup."[81] In contrast to these optimistic accounts, the FCC call center received almost one million calls per week around the time of the transition.[82] Moreover, the people who were most likely to have lost their TV reception tended to be poor, non-English-speaking, undereducated, and rural

76. Jeffrey A. Hart, *The Transition to Digital Television in the United States: The Endgame*, 1 INT'L J. DIGITAL TELEVISION 7, 21 (2010).

77. *Id.*

78. Kim Hart, *Turmoil Over TV Switch Grows*, WASH. POST, Jan. 14, 2009, http://www.washingtonpost.com/wp-dyn/content/article/2009/01/13/AR2009011303060.html.

79. Jill M. Boyce, *The U.S. Digital Television Broadcasting Transition*, IEEE SIGNAL PROCESSING MAG., May 2009, at 109, 109.

80. Brian Stelter, *Changeover to Digital TV Off to a Smooth Start*, N.Y. TIMES, June 13, 2009, http://www.nytimes.com/2009/06/14/business/media/14digital.html. Approximately three million of these households relied on analog sources only and were expected to lose all TV reception, while approximately nine million households had one TV connected to a cable or satellite but had other TVs in the house that were not connected and thus would likewise lose reception. Stephen Labaton, *Millions Face Blank Screens in TV Switch*, N.Y. TIMES, June 5, 2009, http://www.nytimes.com/2009/06/06/technology/06digital.html?pagewanted=all&_r=0; Stelter, *supra*.

81. Stelter, *supra* note 80.

82. *See* Brian Stelter, *Switch to Digital TV Broadcasts Is a Work in Progress*, N.Y. TIMES, June 17, 2009, http://www.nytimes.com/2009/06/18/technology/18digital.html (noting that, during one week close to the transition, the FCC call center received approximately 900,000 calls).

residents, who may be the least knowledgeable and least capable of registering their complaints with the appropriate authorities.[83]

The mandated transition to DTV resulted in enormous confusion, resistance, and delays, notwithstanding its ultimate (delayed) success. Again, many of these problems were because of the government's failure to consider the full range and life cycle of potential impacts and responses. Perhaps most significantly, the government failed to anticipate and prepare to address the public response to having their analog TV cut off. When the policy was being implemented, as many as one in five American households[84] received their TV broadcast through antennas and would lose all TV reception using those systems unless they purchased a converter. As one writer stated the challenge, "the 21 million households using a conventional set with rabbit ears or a rusty roof antenna—typically people who are poor, elderly, or living in rural America—will turn on their TVs and see . . . nothing."[85] One member of Congress described the risk as follows, "The government can do a lot of things, but you mess up people's televisions, and they're going to be very upset. It's going to be a real mess when it rolls out in the real world."[86]

The FCC initially relied primarily on industry efforts to educate consumers about the pending transition, but this effort was inadequate, resulting in widespread consumer ignorance and confusion about the transition.[87] The chairman of the FCC announced a "major DTV consumer education initiative" called "DTV—Get It!" in October 2004, but the effectiveness of this program was limited and it was criticized for being uncoordinated.[88] In 2009, then Commerce Secretary Gary Locke criticized the government's DTV transition

83. Labaton, *supra* note 80; *see* Stelter, *supra* note 82.

84. Jacques Steinberg, *Converters Signal a New Era for TVs*, N.Y. TIMES, June 7, 2007, www.nytimes.com/2007/06/07/technology/07digital.html.

85. Michael Antonoff, *Digital TV at Last?*, SCI. AM., Feb. 2007, at 70, 71.

86. Kim Hart, *Lawmakers See Challenges for TV Transition*, WASH. POST, Sept. 17, 2008, http://www.washingtonpost.com/wp-dyn/content/article/2008/09/16/AR2008091603283.html (quoting Rep. Heather A. Wilson).

87. U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-05-940R, DIGITAL TELEVISION TRANSITION: ISSUES RELATED TO AN INFORMATION CAMPAIGN REGARDING THE TRANSITION 8–9 (2005) [hereinafter GAO], *available at* http://www.gao.gov/assets/100/93555.pdf.

88. *E.g.,* Kim Hart, *Digital TV Ready to Rule the Tube, Leaving Some Viewers in the Dark*, WASH. POST, June 11, 2009, http://www.washingtonpost.com/wp-dyn/content/article/2009/06/10/AR2009061003978.html. A poignant anecdote that perhaps summarizes the public education program is that at one point the government sponsored a NASCAR race car emblazoned with the logo "The Digital TV Transition," but the car promptly crashed in a race. Eric A. Taub, *In Move to Digital TV, Confusion Is in the Air*, N.Y. TIMES, Nov. 22, 2008, http://www.nytimes.com/2008/12/22/technology/22iht-22digital.18859106.html?pagewanted=all&_r=0.

education program for failing to provide adequate information to consumers.[89] For example, the educational campaign informed consumers they would need to buy converter boxes to receive the new digital signals on their existing TV sets, but did not inform consumers that they likely would need new antennas as well and would have to rescan their TVs to find the new channels.[90] One expert stated: "This transition is possibly one of the worst understood consumer education programs in modern times."[91] In contrast, other governments, such as those in Berlin and the United Kingdom, had undertaken much more thorough public education campaigns in advance of their DTV transitions, which resulted in much smoother transitions.[92]

Facing the reality that many consumers either did not understand or were not willing to buy their own converters, Congress created a hastily crafted federally funded program to provide consumers a coupon for forty dollars (limited to two coupons per household) toward the purchase of a converter box. This subsidy program was limited by Congress to $1.5 billion (enough to fund 33.5 million coupons).[93] The agency official in charge of this program estimated that the demand would range from ten to twenty-six million coupons,[94] which substantially underestimated the actual demand that resulted. By the end of 2008, forty million coupons had been requested, but only sixteen million had been redeemed.[95] The government stopped providing coupons starting January 5, 2009, as the authorized budget for issuing such coupons had been exhausted, with over one million consumers on the waiting list to get a coupon.[96] Congress authorized an additional $650 million for coupons in February 2009. By the time of the final transition, fifty-nine million coupons had been issued and thirty-one million had been redeemed,[97] far more than were initially anticipated by the program developers.

In January 2009, the incoming Obama Administration, supported by several consumer groups and members of Congress, proposed a further delay of the DTV mandate given the shortcomings of the coupon program and the fact that many Americans were still unprepared for the transition scheduled for the

89. Labaton, *supra* note 80.
90. Hart, *supra* note 88.
91. Taub, *supra* note 88 (quoting Richard Doherty, Envisioneering Group analyst).
92. GAO, *supra* note 87, at 9–10.
93. John Dunbar, *Feds Share Coupons to Help TV Transition*, FOX NEWS (Jan. 1, 2008), http://www.foxnews.com/printer_friendly_wires/2008Jan01/0,4675,DigitalTV,00.html.
94. *Id.*
95. Hart, *supra* note 76, at 24–25.
96. Kim Hart, *Obama Urges Delay in Digital TV Switch*, WASH. POST, Jan. 9, 2009, http://www.washingtonpost.com/wp-dyn/content/article/2009/01/08/AR2009010802586.html.
97. Hart, *supra* note 76, at 26.

following month. According to the letter sent to Congress by the co-chair of the incoming administration's transition team, "with coupons unavailable, support and education insufficient, and the most vulnerable Americans exposed, I urge you to consider a change to the legislatively-mandated analog cutoff date."[98] Congress passed a four-month extension of the deadline, which President Obama signed on February 11, less than one week before the transition was to take effect. In signing the legislation, President Obama stated that "[m]illions of Americans, including those in our most vulnerable communities, would have been left in the dark if the conversion had gone on as planned."[99]

The government also failed to accurately anticipate how companies in the various industry sectors would respond to the DTV mandate. Most TV stations, the industry sector directly subject to the digital mandate, did not comply with the original deadline to start broadcasting a digital station.[100] The cost of the transition, particularly for smaller stations, along with the lack of any perceived benefits or consumer demand given the rarity of consumers with DTV sets, was responsible for the tardy compliance. The National Association of Broadcasters, the trade association of TV stations, actively lobbied for a delay in the implementation of DTV.[101]

TV equipment manufacturers resisted phasing out the production and sale of analog sets and, even after the government's adoption of its DTV transition plan, continued to sell twenty-five million analog TVs per year. The FCC finally had to step in, and in 2002 it required equipment manufacturers to stop marketing technologically obsolete analog sets by 2007. The manufacturers sued the FCC to try to stop this part of the mandate, but their claims were rejected by the court.[102] Cable and satellite providers were not subject to the digital mandate, even though they provided television programming to 80 percent of U.S. homes.[103] These companies objected to pressure to carry both analog and digital

98. Hart, *supra* note 96 (quoting John Podesta, co-chair of the Obama-Biden Presidential Transition Team).

99. Kim Hart & Peter Whoriskey, *Stalled Switch to Digital TV a Classic Tale of Breakdown*, WASH. POST, Feb. 14, 2009, http://www.washingtonpost.com/wp-dyn/content/article/2009/02/13/AR2009021303504.html.

100. Stephen Labaton, *MEDIA; Most Commercial Broadcasters Will Miss Deadline for Digital Television*, N.Y. TIMES, Apr. 29, 2002, http://www.nytimes.com/2002/04/29/business/media-most-commercial-broadcasters-will-miss-deadline-for-digital-television.html; Eric A. Taub, *The Big Picture on Digital TV: It's Still Fuzzy*, N.Y. TIMES, Sept. 12, 2002, http://www.nytimes.com/2002/09/12/technology/the-big-picture-on-digital-tv-it-s-still-fuzzy.html?pagewanted=all&src=pm.

101. Jube Shiver Jr., *Broadcasters Seek to Delay Digital TV*, L.A. TIMES, July 30, 2001, http://articles.latimes.com/2001/jul/30/business/fi-28189.

102. Consumer Elecs. Ass'n v. Fed. Commc'ns Comm'n, 347 F.3d 291, 293 (D.C. Cir. 2003).

103. Taub, *supra* note 100.

channels without necessarily earning more revenue and were finally forced to carry both analog and digital signals by the FCC "must carry" rules that were adopted relatively late in the transition process.[104]

The government also failed to anticipate and address performance problems with DTV, which were predictable when the policy was adopted. Digital broadcast suffer from a limitation known as the "digital cliff"—if there is any interference with a signal, the screen goes completely blank, instead of becoming fuzzy like analog TV. Also, digital signals do not typically travel as far as analog signals.[105] Thus, many consumers found that their new digital systems failed to obtain proper reception either because they lived outside the small coverage area of a station or because the signal was partially obstructed by buildings, a tree, other objects, or even bad weather.[106] The DTV antennas also require more precise positioning than their analog predecessors.[107] The federal government did not make any serious effort to educate consumers about these reception problems, creating even more consumer frustration with the transition.[108]

Finally, the U.S. government failed to consider up front and try to limit the environmental impacts of its DTV mandate. Many consumers were motivated to buy new DTVs (as opposed to the alternative of buying a converter for their existing TV), and consequently millions of now obsolete analog TVs were discarded into landfills. While proper recycling of TV sets is possible, there was little or no organized effort to educate consumers about this during the DTV transition. As one environmentalist reported, "[w]e are seeing now a huge anticipated spike in the amount of electronic waste, really a tsunami of electronic waste coming through because of this digital transition."[109] The federal government completely ignored this issue until the EPA launched a campaign entitled "The Digital Television Transition: Don't Kick Your TV to the Curb—eCycle Instead," but this effort was not launched until June 11, 2009, just one day before the DTV transition was completed.[110]

104. Hart, *supra* note 76, at 22–23.
105. Kim Hart, *Digital TV Transition Not as Easy as Advertised*, WASH. POST, May 20, 2008, http://www.washingtonpost.com/wp-dyn/content/article/2008/05/19/AR2008051902730.html.
106. *Id.*; Hart, *supra* note 88.
107. Hart, *supra* note 105.
108. *See id.* (claiming that "[t[he government's message for consumers . . . that all they need is a converter box or digital TV" is an "oversimplification").
109. Erik Palm, *DTV Transition: Avoiding an E-Waste 'Tsunami,'* CNET (June 9, 2009), http://news.cnet.com/8301-11128_3-10260174-54.html (quoting Casey Harrell, Greenpeace International campaigner).
110. U.S. ENVTL. PROT. AGENCY, *The Digital Television Transition: Don't Kick Your TV to the Curb—eCycle Instead* (June 11, 2009), http://yosemite.epa.gov/opa/admpress.nsf/a7b2ee8e45551c138525735900404444/4e82cf227f701313852575d20056d38d!OpenDocument.

Overall, the government's handling of the U.S. digital transition was heavily criticized.[111] Critics described the program as a "disastrous failure of public policy,"[112] "a train wreck,"[113] "fiendishly complex,"[114] and "like Hurricane Katrina."[115] There was confusion, modifications, delays, and uncertainty throughout the ten-plus year transition process. As the FCC's own key official responsible for implementing the transition commented in the middle of the process: "We're midstream in a boat that some say has leaks. We're patching the leaks and trying to get to shore."[116] A Washington Post writer commented: "The transition from analog to digital television may have inflicted more confusion on the American public than any other electronic upgrade in history. No other technological switch . . . seems to have puzzled, frightened and in some cases angered so many people."[117] The repeated delays in the implementation of the transition, made necessary by the poor planning and anticipation of problems, not only sowed confusion among consumers but also imposed major problems and costs on the companies subject to the requirements and other affected parties.[118]

One key problem throughout was the lack of a focused, coherent, and consistent government policy. The Government Accountability Office (GAO) issued a scathing report criticizing the federal government for lacking a comprehensive plan to implement the DTV transition that would provide for a more coherent rollout and facilitate better planning and risk management.[119] Indeed, the U.S. digital transition was so long, convoluted, and confusing that it had the effect of freezing innovation by affected industries, undermining much of the promised benefits of the DTV conversion.[120] As one commentator wryly noted, while digital technology was supposed to provide many exciting,

111. *See* Hart, *supra* note 76, at 27; Taub, *supra* note 88.
112. *Transition to Digital Television: Hearing Before the S. Comm. on Commerce, Sci., & Transp.*, 107th Cong. 78 (2001) (statement of Thomas W. Hazlett, Resident Scholar, American Enterprise Institute for Public Policy Research).
113. *Id.*
114. Paul Farhi, *Broadcast TV Never Converted Its Digital Dream*, WASH. POST, June 10, 2009, http://www.washingtonpost.com/wp-dyn/content/story/2009/06/09/ST2009060903803.html ?sid=ST2009060903803.
115. Hart, *supra* note 96 (quoting Professor David Waterman).
116. Taub, *supra* note 100 (quoting W. Kenneth Ferree).
117. Rob Pegoraro, *TV's Digital Transition Doesn't Have to Cause Headaches*, WASH. POST, Jan. 22, 2009, http://www.washingtonpost.com/wp-dyn/content/story/2009/01/22/ST2009012200066.html.
118. *See* Hart, *supra* note 78.
119. *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-08-43, DIGITAL TELEVISION TRANSITION: INCREASED FEDERAL PLANNING AND RISK MANAGEMENT COULD FURTHER FACILITATE THE DTV TRANSITION 12–18 (2007), *available at* http://www.gao.gov/assets/270/269612.pdf.
120. *See* Farhi, *supra* note 114.

innovative, and interactive benefits, the reality was quite different: "So after enduring loads of hassle—coupons! deadlines! converter boxes!—the net impact of the digital conversion will be a few more channels and the chance to see Mr. T again."[121] The one consolation, according to the Washington Post, is that "after all the angst the digital transition has inflicted on home viewers and policy makers alike, it will be a long time before anybody suggests another mandatory upgrade over the public airwaves."[122]

## IV. CFL BULB MANDATE

The third and final example of a technology mandate is the transition to more efficient light bulbs. In the United States, and virtually every other industrialized country that has adopted similar measures,[123] the transition to more efficient lighting has not involved any formal technology mandates or bans, but rather a performance standard with a phased implementation schedule that will have the effect of gradually eliminating traditional incandescent light bulbs from the market.[124] Specifically, the Energy Independence and Security Act (EISA) of 2007 established minimum efficiency and lifetime requirements that were phased in from January 1, 2012 to January 1, 2014.[125] The practical effect of these increasingly stringent performance requirements was to prohibit the hundred-watt incandescent bulb in 2012, the seventy-five-watt incandescent bulb in 2013, and the sixty-watt incandescent bulb in 2014 for general service applications, with some exceptions for special purpose and decorative products.

Notwithstanding the deliberate performance-based phrasing of the legislation, its practical effect will be to ban the traditional incandescent light bulb, and given the limited compliant replacement lighting technologies available within the mandated deadlines, to de facto mandate the replacement technologies. In particular, the timing of the U.S. phase-out of the traditional

121. *See id.*
122. Pegoraro, *supra* note 117.
123. *See* PAUL WAIDE, INT'L ENERGY AGENCY, PHASE OUT OF INCANDESCENT LAMPS: IMPLICATIONS FOR INTERNATIONAL SUPPLY AND DEMAND FOR REGULATORY COMPLIANT LAMPS 9 (2010), *available at* http://www.iea.org/publications/freepublications/publication/phase_out-1.pdf.
124. *See* JEFFREY LOGAN, CONG. RESEARCH SERV., RS22822, LIGHTING EFFICIENCY STANDARDS IN THE ENERGY INDEPENDENCE AND SECURITY ACT OF 2007: ARE INCANDESCENT LIGHT BULBS "BANNED"? 3 (2008), *available at* https://www.fas.org/sgp/crs/misc/RS22822.pdf (discussing the performance standard and its practical effects for the continued sale of incandescent light bulbs).
125. H.R. 6, 110th Cong. § 321(a)(3) (2007); *see also* NAT'L RESEARCH COUNCIL, ASSESSMENT OF ADVANCED SOLID-STATE LIGHTING 20 (2013).

incandescent bulb was premised on, and to some extent required, the replacement of incandescent bulbs with compact fluorescent lamps (CFLs). Not surprisingly, therefore, the public and political debate about the legislation frequently uses the terms "ban" and "mandate," even though these terms are technically inaccurate.[126]

There is widespread expert agreement that the traditional incandescent light bulb is a wasteful, obsolete technology whose replacement with a more efficient technology holds great potential for substantial savings in cost, energy, and pollution prevention.[127] The incandescent light bulb is notoriously inefficient, converting less than 5 percent of the energy it uses into light while emitting most of the energy as heat.[128] Since lighting consumes more than 20 percent of all electricity generated in the United States, mostly by inefficient incandescent bulbs, transitioning to a more efficient lighting technology holds enormous potential and is seen as a low hanging fruit for saving energy and preventing pollution (including carbon dioxide) emissions.[129] The incandescent bulb is a mature technology, and very little technological progress has been made over the past hundred years in improving its performance, so it needs to be replaced rather than improved. The key issue is the availability and timing of suitable alternative technologies that are more efficient but that also satisfy consumer demands.

Experts anticipated that, as a result of the legislation, the CFL would replace the incandescent bulb, at least in the short- to medium-term. Indeed, the CFL was seen by many as "the natural alternative" to traditional bulbs.[130] The CFL is more energy efficient and long lasting than the incandescent bulb. CFLs have an efficiency of approximately 13 percent, which means they are roughly five times more efficient than incandescent bulbs.[131] The Congressional Research Service estimates that a typical hundred-watt incandescent bulb used $18.30 in energy per

126. *See, e.g.*, Andrew Rice, *Bulb In, Bulb Out*, N.Y. TIMES, June 3, 2011, http://www.nytimes.com/2011/06/05/magazine/bulb-in-bulb-out.html?pagewanted=all&_r=0.

127. *See, e.g.*, ENERGY STAR, U.S. ENVTL. PROT. AGENCY, PRODUCT RETROSPECTIVE: RESIDENTIAL LIGHTING 1, 4 (2012) [hereinafter EPA], *available at* http://www.energystar.gov/ia/products/downloads/Residential_Lighting_Highlights.pdf (outlining the potential benefits of CFL and LED bulbs).

128. *See* Inês Lima Azevedo et al., *The Transition to Solid-State Lighting*, 97 PROC. IEEE 481, 482 (2009).

129. *See id.* at 481–82.

130. *See* Corrado Di Maria et al., *Shedding Light on the Light Bulb Puzzle: The Role of Attitudes and Perceptions in the Adoption of Energy Efficient Light Bulbs*, 57 SCOTISH J. POL. ECON. 48, 48 (2010); *see also* Julie Scelfo, *Any Other Bright Ideas?*, N.Y. TIMES, Jan. 10, 2008, http://www.nytimes.com/2008/01/10/garden/10lighting.html?pagewanted=all (describing the public reception to varying light bulb technologies introduced as a result of the energy bill restrictions).

131. *See* Azevedo et al., *supra* note 128, at 485.

year compared to only $4.90 for an equivalent CFL bulb, and the CFL bulb would last for ten thousand hours while the incandescent bulb would only last one thousand hours.[132] The CFL thus appears to offer great potential to save energy and money and to minimize environmental externalities such as $CO_2$ emissions from generating the electricity needed to operate the bulb.

While fluorescent lights have been used since the 1930s, they were not generally available for residential applications until the advent of the compact fluorescent bulb. The CFL was first discovered in 1976 but only made commercially available in the 1990s as a result of technological advances such as the ability to cost-effectively manufacture bulbs consisting of tightly coiled gas-filled fluorescent tubes.[133] The CFL did not make major inroads into the residential market until the early 2000s when utilities and other entities began major programs to encourage CFL adoption. CFL bulbs now represent approximately 25 percent of all U.S. light bulb shipments, which, compared to traditional incandescent bulbs, is estimated to reduce U.S. electrical bills by $6.4 billion and reduce greenhouse gas emissions by forty-six million metric tons.[134] Yet market acceptance of CFLs has been slower than anticipated and CFLs now face significant consumer backlash.[135] Congress barely considered these impediments in adopting its phase-out of the incandescent bulb in favor of CFLs as the presumptive replacement.

Perhaps the biggest impediments to wider adoption of the CFL are the problems encountered with CFL performance and consumer satisfaction. These issues include that (1) CFLs have a slower ramp-up to full luminosity compared to the standard incandescent bulb; (2) most CFLs are not dimmable; and perhaps most significantly (3) some consumers perceive the quality of light from CFLs as inferior to traditional lighting sources, with frequent complaints that the light is "too dim," "harsh and unflattering," "too blue," or otherwise "not right."[136] For

132. *See* LOGAN, *supra* note 124, at 4 tbl.2.

133. *See* NAT'L RESEARCH COUNCIL, *supra* note 125, at 28; *see also* L.J. SANDAHL ET AL., U.S. DEP'T OF ENERGY, COMPACT FLUORESCENT LIGHTING IN AMERICA: LESSONS LEARNED ON THE WAY TO MARKET 1.1–1.2 fig.1.1 (2006), *available at* http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/cfl_lessons_learned_web.pdf (explaining the evolution of compact fluorescent lamp designs).

134. *See* EPA, *supra* note 127, at 1, 4.

135. *See* LIGHTING RESEARCH CTR., RENSSELAER POLYTECHNIC INST., INCREASING MARKET ACCEPTANCE OF COMPACT FLUORESCENT LAMPS (CFLS) 18–19 (2003), *available at* http://www.lrc.rpi.edu/programs/lightingTransformation/colorRoundTable/pdf/MarketAcceptanceOfCFLsFinal.pdf (presenting survey results wherein consumers criticized CFL bulbs); Diane Cardwell, *This Little LED of Mine*, N.Y. TIMES, Nov. 1, 2013, http://www.nytimes.com/2013/11/02/business/energy-environment/this-little-led-of-mine.html.

136. *See* LOGAN, *supra* note 124, at 6; NAT'L RESEARCH COUNCIL, *supra* note 125, at 30–31; Rice, *supra* note 126.

example, one focus group of consumers found that perceived color variations in CFLs was a major barrier to consumer acceptance.[137] The study also found that consumers have a negative connotation with the word "fluorescent," likely a residue of the "unfriendly" fluorescent tube lighting used in many commercial establishments.[138] Another recent survey of consumers found that the brightness of the light the bulb produces was the most important factor for consumers in evaluating light bulbs, a finding that suggests some vulnerability for CFLs.[139]

In addition, some CFLs and, in particular, many of the cheaper bulbs that were included in various utility and other incentive programs were of poor quality and did not meet expectations in terms of quality of light and life span. For example, some cheaper CFL bulbs had to be recalled because they presented a fire risk.[140] The promised extended lifespan of the CFL is also sometimes not achieved in practice, further leading to consumer disenchantment and disappointment. For example, one analysis found that 2 to 13 percent (depending on brand) of CFLs failed early and that half of reflector CFLs used in recessed lighting had dimmed by at least 25 percent by halfway through their rated lifetime.[141] Another study performed for the California Public Utilities Commission found that the average useful life of a CFL in California was 6.3 years, considerably shorter than the projected useful life of 9.4 years.[142] Moreover, frequently turning a CFL on and off (many times per day) will significantly reduce its life span.[143]

Light bulbs are perceived as low technology and low interest products by consumers, who want convenient, simple, and inexpensive replacement bulbs that do not present any "issues" or "problems."[144] Consumers are also very

137. *See* LIGHTING RESEARCH CTR., *supra* note 135, at 19–20.

138. *See id.* at 23.

139. *See* KRC RESEARCH, SYLVANIA, OSRAM SYLVANIA SOCKET SURVEY 6.0: 2013 RESEARCH RESULTS 9 (2013), *available at* https://assets.sylvania.com/assets/Documents/Socket%20Survey%206%200%202013%20web.ace8e42b-1aa1-4d10-897c-78e40ff72ccb.pdf.

140. *See Trisonic Compact Fluorescent Light Bulbs Recalled Due to Fire Hazard*, CONSUMER PROD. SAFETY COMM'N (Oct. 5, 2010), http://www.cpsc.gov/en/Recalls/2011/Trisonic-Compact-Fluorescent-Light-Bulbs-Recalled-Due-To-Fire-Hazard.

141. *See* Amber Angelle, *Will LED Light Bulbs Best Your CFLs and Incandescents?*, POPULAR MECHANICS (Aug. 4, 2010, 1:00 PM), http://www.popularmechanics.com/science/environment/will-led-light-bulbs-best-cfls-and-incandescents.

142. *See* Rebecca Smith, *The New Light Bulbs Lose a Little Shine*, WALL ST. J., Jan. 19, 2011, http://online.wsj.com/news/articles/SB10001424052748704259704576033890595565026.

143. *See When to Turn Off Your Lights*, U.S. DEP'T OF ENERGY (Aug. 30, 2012, 7:53 PM), http://www.energysavers.gov/your_home/lighting_daylighting/index.cfm/mytopic=12280.

144. *See* APPLIED PROACTIVE TECHS., THE U.S. REPLACEMENT LAMP MARKET, 2010–2015, AND THE IMPACT OF FEDERAL REGULATION ON ENERGY EFFICIENCY LIGHTING PROGRAMS 20–21 (2010) [hereinafter APT], *available at* http://www.appliedproactive.com/uploads/pdf/USLampMarket_and_EELightingPrograms_APT_Final.pdf.

sensitive to initial price, even if the longer life span of a CFL or other more efficient bulb will reduce replacement costs and cost less in the long term.[145] Consumers apply a very high implicit discount rate—as high as 300 percent compared to the typical 2.5 to 10 percent used in most economic analyses—that deters consumer purchases of energy efficiency technologies that may cost more up front but save money over their lifetime because of lower energy and replacement costs.[146] This inflated consumer discount rate, sometimes referred to as the "energy paradox," is attributed to a number of factors, including lack of knowledge about cost savings, disbelief about lifetime savings, and lack of expertise in addressing the time value of money.[147] Thus, it is not surprising that CFLs that cost more up front and raise various performance issues have encountered consumer resistance, especially if the net advantages of new lighting technology are not clearly communicated to consumers.[148]

Another important, unanticipated concern about CFLs is their potential environmental impact and, in particular, their mercury content. Each CFL contains a small amount of mercury (generally 3 to 5 milligrams per bulb) that forms the vapor inside the glass tube that fluoresces. EPA and others have pointed out that CFLs may still result in a net decrease in mercury released into the environment; CFLs' improved energy efficiency may yield reductions in mercury emissions from coal-fired power that outweigh the mercury released from CFLs, especially if CFLs are handled and disposed of properly.[149]

Nevertheless, if the mercury from tens of millions of CFLs accumulated in landfills or other inappropriate disposal routes, it could total a significant amount of mercury released and present a significant environmental and occupational exposure risk.[150] As the New York Times editorialized:

> [A]lthough one dot of mercury might not seem so bad, almost 300 million compact fluorescents were sold in the United States last year. That is already a lot of mercury to throw in the trash, and the amounts

145. *See id.* at 21 (explaining that "[m]ost consumers are not eager to . . . spend more money than they traditionally have on [light bulb] purchases").

146. Azevedo et al., *supra* note 128, at 493.

147. Adam B. Jaffe & Robert N. Stavins, *The Energy Paradox and the Diffusion of Conservation Technology*, 16 RESOURCE & ENERGY ECON. 91, 97–100 (1994).

148. *See* NAT'L RESEARCH COUNCIL, *supra* note 125, at 31.

149. *See* ENERGY STAR, U.S. DEP'T OF ENERGY, FREQUENTLY ASKED QUESTIONS: INFORMATION ON COMPACT FLUORESCENT LIGHT BULBS (CFLS) AND MERCURY (2010), *available at* http://www.energystar.gov/ia/partners/promotions/change_light/downloads/Fact_Sheet_Mercury.pdf.

150. *See* David Appell, *Toxic Bulbs*, SCI. AM., Oct. 2007, at 30, 30–32 (describing mercury's adverse health effects as a potent neurotoxin and efforts to recycle CFLs); Michael Aucott et al., *Release of Mercury From Broken Fluorescent Bulbs*, 53 J. AIR & WASTE MGMT. ASS'N 143, 148–49 (2003).

> will grow ever larger in coming years. Businesses and government recyclers need to start working on more efficient ways to deal with that added mercury. . . . Even when warned, public officials are never great at planning.[151]

As this editorial notes, governments seem to not have anticipated or made any plans to address this predictable impact of the CFL-promoting legislation.

Moreover, in addition to environmental release, there is a concern about exposure from individual bulbs that break in the home. The EPA recommends somewhat frightening-sounding special precautions in using and disposing of CFLs if they break,[152] which may alarm some consumers. An EU scientific advisory committee calculated that ambient room exposures to mercury could exceed the Tolerable Daily Intake for mercury in children after breakage of a CFL, but concluded that such exposures are unlikely to present a significant health risk when proper waste management and ventilation practices are used.[153]

There have been various other health and environmental concerns expressed about CFLs, including allegations that CFLs may trigger migraine headaches, exacerbate skin problems, disrupt the body's production of melatonin, increase "electric smog," increase epileptic seizures, and release potential cancer-causing chemicals such as phenol, naphthalene, and styrene.[154] Although these allegations have not been validated or confirmed, they have increased public anxiety and concerns about CFLs, feeding on the public's normal fear of the different and unknown. Very little, if any, consideration was given to the significance of these health and environmental issues and how they might be best managed when the EISA was passed in 2007.

Another technology looming on the horizon is light-emitting diodes (LEDs), which many experts expect will be the longer-term solution to the lighting problem.[155] They have been used in decorative and other specialized

151. Editorial, *That Newfangled Light Bulb*, N.Y. TIMES, Feb. 17, 2008, http://www.nytimes.com/2008/02/17/opinion/17sun3.html.

152. *See Cleaning Up a Broken CFL*, U.S. ENVTL. PROT. AGENCY, http://www2.epa.gov/cfl/cleaning-broken-cfl (last visited Dec. 28, 2013) (recommending leaving the room for ten minutes, avoiding vacuuming, and checking with local government disposal requirements).

153. *See* SCIENTIFIC COMM. ON HEALTH & ENVTL. RISKS (SCHER), OPINION ON MERCURY IN CERTAIN ENERGY-SAVING LIGHT BULBS 9–10 (2012), *available at* http://ec.europa.eu/health/scientific_committees/environmental_risks/docs/scher_o_124.pdf.

154. *See* Stephen Adams, *Energy Saving Light Bulbs 'Could Trigger Breast Cancer,'* TELEGRAPH, Jan. 31, 2011, http://www.telegraph.co.uk/health/healthnews/8288982/Energy-saving-light-bulbs-could-trigger-breast-cancer.html; Victoria Ward, *Energy Saving Light Bulbs 'Contain Cancer Causing Chemicals,'* TELEGRAPH, April 20, 2011, http://www.telegraph.co.uk/health/8462626/Energy-saving-light-bulbs-contain-cancer-causing-chemicals.html.

155. *See, e.g.*, MCKINSEY & CO., LIGHTING THE WAY: PERSPECTIVES ON THE GLOBAL LIGHTING MARKET 7 (2d ed. 2012) (predicting light-emitting diodes (LEDs) will have 45

applications for many years and were just beginning to become available for residential use as the EISA phase-out began, although they are currently very expensive. As the price of LEDs comes down and the quality goes up over the next few years, LEDs are expected to become the predominant lighting technology over the next decade.[156]

The legislative dictate to switch lighting sources in the 2012–2014 period is therefore problematic, given that the superior technology (LEDs) was not projected to be widely available and economical in this transition period, but is waiting in the wings to assume a dominant role a few years later. Consumers will be forced to switch from their longstanding reliance on the incandescent bulb to an unfamiliar technology (CFLs) for only a short period before switching again a few years later to LEDs. Back-to-back disruptive changes are sure to create significant public confusion and frustration. It also creates a dilemma for manufacturers—it is not very appealing to invest in the R&D, the building manufacturing capacity, and the building of supply and distribution chains for a product that will be in the ascendency for at most only a couple of years. Accordingly, there are predictions that there will be significant shortages in supply of general service light bulbs in the United States between 2014 and 2015 when the de facto ban on incandescent light bulbs is fully implemented.[157]

The combined effect of these factors has provoked a political backlash against the legislative phase-out of the incandescent bulb, with the perceived shortcomings of the CFL catalyzing much of the controversy and opposition. Some consumers are stockpiling incandescent bulbs,[158] in many cases after trying and rejecting CFLs. For example, Professor Glenn Reynolds, author of the highly popular InstaPundit blog, wrote:

> I'm deeply, deeply disappointed with CFL bulbs. I replaced pretty much every regular bulb in the house with CFLs, but they've been failing at about the same rate as ordinary long-life bulbs, despite the promises of multi-year service. And I can't tell any difference in my electric bill. Plus, the Insta-Wife hates the light.[159]

percent of the lighting market by 2016 and 70 percent by 2020); NAT'L RESEARCH COUNCIL, *supra* note 125, at 1–5; Cardwell, *supra* note 135.

156. U.S. DEP'T OF ENERGY, ENERGY SAVINGS POTENTIAL OF SOLID-STATE LIGHTING IN GENERAL ILLUMINATION APPLICATIONS 37 (2012) (estimating that LEDs will represent 36 percent of U.S. lighting by 2020 and 74 percent by 2030).

157. *See* APT, *supra* note 144, at 24–25.

158. *See* Rice, *supra* note 126 (quoting Professor Howard Brandston).

159. Glenn Reynolds, INSTAPUNDIT (May 27, 2011, 11:51 PM), http://pajamasmedia.com/instapundit/121431.

Public resistance to the switchover is likely to grow as more consumers become aware of the legislative consequences when the phase-out of incandescent bulbs is completed in 2014. Some politicians have decried the "light bulb ban," with one congressman lambasting the legislation for involuntarily imposing on the public the harsh glare of those "little, squiggly, pigtailed" CFLs.[160] The CFL has become a focus for broader political debates and divisions in the country about the role of government in society and consumer freedom. Strongly worded rhetoric against the legislation is common, such as the following commentary published by Bloomberg:

> The bulb ban makes sense only one of two ways: either as an expression of cultural sanctimony, with a little technophilia thrown in for added glamour, or as a roundabout way to transfer wealth from the general public to the few businesses with the know-how to produce the light bulbs consumers don't really want to buy.[161]

Several bills have been introduced in Congress seeking to overturn the EISA requirements, and have garnered significant (in some cases majority) support, but have not succeeded in repealing the legislation to date.[162] Congress passed a rider in 2011 that prohibited the Department of Energy from spending any funds on implementing the lighting efficiency standards, but the rider has not had a major impact on the phase-out to date, which is still proceeding according to the statutory timetable.[163] In addition, numerous anti-CFL bills have been introduced in state legislatures, and in July 2011 Texas became the first state to implement legislation relating to the lighting restrictions, passing a law stating that incandescent bulbs manufactured in Texas do not involve interstate commerce and thus are not subject to the federal restrictions.[164]

Once again, the government phase-out of incandescent bulbs in favor of CFLs may be justified on substantive grounds, but its implementation is a growing controversy that has the potential to become a full-fledged fiasco in the next couple of years. A little more foresight and planning could have helped

160. *See* Rice, *supra* note 126 (quoting Rep. Joe Barton).

161. Virginia Postrel, *Need a Light Bulb? Uncle Sam Gets to Choose*, BLOOMBERG (June 10, 2011, 12:01 AM), http://www.bloomberg.com/news/2011-06-10/need-a-light-bulb-uncle-sam-gets-to-choose-virginia-postrel.html.

162. *See generally* Bob Tedeschi, *Basking in a New Glow*, N.Y. TIMES, Feb. 12, 2014, http://www.nytimes.com/2014/02/13/garden/basking-in-a-new-glow.html (noting that "little has changed in the consumer light bulb market" as "[m]anufacturers have tweaked the efficiency of their halogen incandescents to meet the new federal standards").

163. *See* Katie Howell, *House Votes to Block Funding for Light Bulb Standards*, GREENWIRE (July 15, 2011), http://www.eenews.net/greenwire/2011/07/15/stories/1059951657.

164. *See* Richard Simon, *Texas Aglow With Effort to Save the Incandescent Bulb*, L.A. TIMES, July 9, 2011, http://articles.latimes.com/2011/jul/09/nation/la-na-adv-texas-light-bulbs-20110710.

address or at least mitigate many of the concerns and controversies about the light bulb switchover.

## CONCLUSION

Government attempts to induce beneficial technology change are difficult and hazardous undertakings.[165] The three technology choices discussed in this Article—electric vehicles, digital TV, and CFLs—represent socially beneficial technologies that governments legitimately decided were needed but that market forces seemed unlikely to deliver promptly and independently. Yet, the attempt to mandate these technologies proved to be enormously difficult, complex, and controversial in all three cases. In one case (ZEV) the mandate failed at least in the time period initially targeted, in another (DTV) the mandate ultimately succeeded, and in the third (CFLs) the jury is still out.

Notwithstanding their outcomes, all three attempts were plagued by opposition, delays, unanticipated impacts, and controversies. One lesson from this analysis is that predicting the timing and course of future technologies is complex and uncertain, and so trying to fix technology availability by regulatory fiat is prone to problems. Such governmental failures in trying to pick technologies and timelines in advance, enforced through requirements that provided little or no flexibility if the initial assumptions turned out to be flawed, demonstrate the risks and challenges of such government mandates. These experiences suggest that mandates should only be employed as a last resort when no other regulatory or voluntary approach is feasible.

A second lesson from this analysis is that if and when governments decide to impose a technology mandate, they need to be more deliberate and thoughtful about the economic, environmental, social, stakeholder, and consumer implications and responses to the mandate. For example, the EV mandate adopted by California and other states did not consider the technological limitations and feasibility of essential complementary technologies like advanced batteries, the performance features of EVs across the range of environments in which they would operate, the public reticence to buy new, unproven vehicle types, and the need to build a recharging infrastructure.

165. *See, e.g.*, *Picking Winners, Saving Losers*, ECONOMIST, Aug. 5, 2010, http://www.economist.com/node/16741043 (noting the "expensive failures" of recent industrial policy); *see also* Marchant, *supra* note 2, at 834–36 (discussing the legal tools available to encourage sustainable energy technologies and the many obstacles to inducing technological change); Nelson & Langlois, *supra* note 7, at 816–17 (highlighting problems resulting from government involvement in the research and development of technology endeavors).

Similarly, the de facto ban on incandescent light bulbs did not consider potential mercury exposure or irritating performance issues associated with replacement CFL light bulbs, and the development cycles of CFL as compared to LED as replacement lighting sources. The mandate for DTV did not adequately consider the distributional impacts of the transition on low-income and rural citizens, the incentives for equipment manufacturers to continue producing analog TV sets, and the demand for converter equipment. In these and other cases, the governments' failures to fully anticipate and plan to mitigate the variety of environmental, health, social, and economic impacts that the technology mandates would induce substantially undermined the efficacy of and support for the intended technology transformations. A more multifactorial assessment of each technology across the life span of the technology, considering technological, environmental, competitive, social, and economic implications would have helped to prevent some of the controversies and problems associated with the technology mandates and would almost surely have improved the implementation and outcome of the technology mandates.

Given this record of systemic failure to anticipate the full life cycles, socio-behavioral implications, and consequences of technology mandates, it would behoove a legislative or regulatory body considering the imposition of such a mandate to undertake a careful and detailed foresight study in advance of the mandate. Such a study could be undertaken by a third party, such as the former Office of Technology Assessment, or could be conducted internally. The analysis would serve two purposes. First, it could anticipate and try to prevent potential problems by identifying them in advance and factoring them into the mandate design. Thus, for example, California's ZEV mandate might have initially provided additional flexibility for meeting the requirement with other types of clean fuel vehicles such as hybrids. The DTV transition might have included a requirement for equipment manufacturers to phase out analog TV sets up front. And the incandescent light bulb phase-out might have extended the timeline to take better advantage of emerging LED technology.

Second, the initial study would anticipate and prepare to address other problems. For example, the ZEV mandate might have better planned for the potential problem that battery performance and costs would not meet expectations, the DTV transition could have included a better-designed public education and coupon program up front, and the incandescent bulb phase-out could have included better preparation and infrastructure to ensure the recycling of mercury-containing CFL bulbs.

Finally, this analysis affirms the need for an adaptive, reflexive process to periodically review and adjust technology-inducing programs. There has been a

growing realization in the scholarly literature on the governance of emerging technologies that such a review and adjustment process is essential given the rapid pace of development of many new technologies and the large uncertainties about their benefits, risks, and trajectories.[166] In each of the three case studies analyzed herein, some of the unintended consequences of the technology mandate could have been anticipated in advance and preemptively addressed, but other unintended impacts and problems only emerged after the policy was in effect and could not have been reasonably foreseen. A periodic review mechanism, like that established by CARB for its ZEV mandate, could help regulators to identify such problems as early as possible and take proactive measures to manage unanticipated problems.

Responsive and responsible regulation requires regulators not only to respond to new information but also to learn from historical examples. There have now been empirical examples of technology mandates, including the three examined here. The consistent lessons that these historical examples provide suggest that caution and careful planning are needed when governments consider imposing technology mandates in the future.

166. *See* Gary E. Marchant, *Conclusion: Emerging Governance for Emergent Technologies*, *in* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES 254, 254–55 (Gary E. Marchant et al. eds., 2013); Marc A. Saner, *The Role of Adaptation in the Governance of Emerging Technologies*, *in* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES, *supra, at* 92, 92–107; Gary E. Marchant et al., *What Does the History of Technology Regulation Teach Us About Nano Oversight?*, 37 J.L. MED. & ETHICS 724, 726–27 (2009); Gurumurthy Ramachandran et al., *Recommendations for Oversight of Nanobiotechnology: Dynamic Oversight for Complex and Convergent Technology*, 13 J. NANOPARTICLE RES. 1345, 1347, 1351–52 (2011).