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What is a clean bus? Object conflicts in the greening of urban transit

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Object conflicts—struggles over the design, definition, and diffusion of technologies—are analyzed to understand the changing history of the greening of bus technologies in the United States from the late 1980s to 2006. Conflicts are examined over the controversy between compressed natural gas (CNG) and emissions-controlled diesel (ECD) buses in four fields: regulations, research on emissions differences, fleet-purchase decisions, and political mobilizations from bus users and environmental justice groups. Given rapidly changing scientific research on emissions and health effects and rapidly changing bus technology, controversies tend not to stabilize or close for long. In general, the trend has been for some of the largest city bus fleets to reverse pro-CNG decisions in favor of ECD. A framework for the analysis of “object conflicts” is developed to elucidate the factors behind the choices between ECD and CNG and to provide a general model for thinking about technology politics and sustainability.

KEYWORDS: motor vehicles, urban environments, technology policy, risk factors, emission measurement, decisions, social action, public health

Introduction

Because the greening of urban transit bus fleets is simultaneously technological, scientific, economic, and political, understanding the controversies over definitions of a clean bus requires a multidisciplinary framework. The framework developed here, which is potentially valuable for other sustainability problems where scientific and technical issues intersect with a variety of interested social actors, examines how the different actors interact in a variety of fields of action. In this case, the fields of action include regulations, emissions assessments, purchase decisions, and social movement mobilizations. A broad view of sustainability politics as involving a range of perspectives illuminates why local decision making may vary significantly, and why some regions may end with opposing solutions to a similar problem.

Background

The existing literature on the greening of diesel transit buses and controversies over emissions controlled diesel (ECD) versus compressed natural gas (CNG) is limited to technical reports that evaluate bus emissions and the relative costs of different types of bus technology. There has been a handful of social science studies on sustainable transportation (e.g., Rosen, 2001) and the transition to fuel-cell vehicles (e.g., Hekkert & van de Hoed, 2004; Cohen 2006), but the current study is the first to analyze controversies over clean fuel and bus technology in the United States from a social science perspective. A companion report in this journal issue examines a parallel dispute over ECD and CNG buses in Colombia (Valderrama & Beltran, 2007). In the American case, the legacy of civil rights issues around urban public transit that date back at least to Rosa Parks and the Montgomery bus boycott has added a dimension to the choice of bus technology and contributed to highly polarized debates. The work of Robert Bullard and other researchers at the Environmental Justice Resource Center at Clark Atlanta University provides background on the general politics of “transportation racism” and historical insight into the cases of Atlanta and Los Angeles (Bullard et al., 2004).

The natural gas-versus-diesel controversy can be approached theoretically in many ways; this study develops a framework drawn from science and technology studies (STS). Beginning with Winner’s (1986) work on the politics of design, the field has focused on how choices in the design of technological artifacts are simultaneously choices among political values. Ostensibly technical and neutral issues, such as an emissions standard or the design of an emissions technology, can become highly contentious politically. Different groups in society often have dramatically different viewpoints on the optimum technological choice. In some cases, the groups arrive at a middle path that has been studied under the ru-
bric of “boundary objects,” that is, compromise formations that emerge from the negotiations across social worlds (Star & Greisemer, 1989; Clarke & Montini, 1993). Relevant social groups involved in a technological controversy sometimes also are able to achieve closure and settle on a stabilized design (Pinch & Bijker, 1999).

This study contributes to the literature on technology and design by drawing attention to what is termed here “object conflicts,” or definitional struggles over a technology, product, or other form of material culture and the related conflicts over the object’s design and diffusion. In the current case, the analysis centers on the struggle to define what constitutes a “clean bus.” Although in many of the cities discussed here the controversies result in the creation of boundary objects such as “clean fuel” buses, this study draws attention to the instability of such categories and instead directs attention to the ongoing conflicts that emerge around new objects. The lack of stability occurs partly because the technology design, research on health effects, and emissions standards are changing rapidly, but it also occurs because efforts to define a clean bus take place across various fields of action and power, a concept drawn from Pierre Bourdieu’s work (2001). The current study identifies four main fields: regulations, assessments of emissions, fleet-purchase decisions, and public opposition and participation. Rather than define conversion to cleaner buses as a single controversy that can be brought to full closure, the framework developed here takes into account the phenomenon of ongoing technological innovation and scientific research that occurs alongside outcomes in other fields of action. The outcomes in one field reverberate to another to result in ongoing change and controversy.

As a mode of analyzing the politics of technology, a focus on object conflicts provides several benefits over the network models of the 1980s and 1990s (Bijker et al. 1987). The goal of an analysis of fields of object conflicts is not to follow an actor—such as a bus manufacturing firm or an environmental justice group—as it builds a heterogeneous network to achieve success or failure. Although network analyses can provide helpful insights into understanding those processes, the analysis of object conflicts suggests a broader perspective on interlocking fields of conflict. Regulators, emissions researchers, bus manufacturers, fleet managers, and environmental justice groups not only interact, but they work through internal divisions, and they do so in different fields at different times. The outcomes of parallel conflicts and negotiations may create patches of new consensus that reverberate across the other fields, in turn to reopen conflicts or settle ongoing ones. The value-laden conflicts lead to definitions of and choices for the material culture that mediate our relationship to the environment and our own health.

Methodologically, this study is an historical analysis of the diesel-CNG controversy in the United States from approximately 1990 to 2006. The research is based on a comprehensive review of primary sources in the form of electronic and print reports (including government documents), environmental justice group statements, and journalistic reports. Those sources are supplemented by case studies that were developed as part of a broader project on the politics of sustainability and urban design undertaken with Langdon Winner and four graduate students (Hess & Winner, 2005). Of the project’s 30 case studies, four (all conducted by the author) were based on prominent cases of the greening of municipal bus fleets in the United States: Seattle and San Francisco (because of their purchases of hybrid-electric diesel buses); Alameda-Contra Costa County (because of its use of hybrid-electric buses); and Chattanooga (because of its use of electric buses) (Hess, 2005a-d). During the course of the interviews, the CNG-diesel controversy came up repeatedly, and it was central to the San Francisco case.

The present analysis has several limitations. A comparison of the CNG-versus-diesel controversy in other countries is beyond its scope, as is research on other types of fuels and vehicles. Likewise, many American cities have used either diesel or CNG or both, but this study will focus on the cities with large fleets and, where information is available, the reasons for choosing between CNG and diesel. In addition, the discussion of environmental justice politics will focus only on cities with identifiable mobilizations around the CNG-versus-diesel issue rather than broader environmental justice and air quality issues.

Sustainability Studies and the Clean Bus

Many studies that invoke the term “sustainability” begin and end with the Brundtland report’s emphasis on cross-generational access and preservation in the well-known phrase of meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Although the emphasis has its place, two other perspectives are valuable.

First, an ecological perspective suggests a focus on the level beyond which human consumption of resources and deposits of wastes into an ecosystem (or globally) lead to the failure of the system to regenerate itself or process the wastes (Daly, 1990).
From the ecological perspective, the current wave of debate over a “clean bus” could be considered a mirage. No matter how clean the configuration of diesel or natural gas fuels, both are fossil fuels that deplete natural resources and generate greenhouse gases. In this sense, only a hydrogen- or electric-powered bus based on a renewable energy source such as wind would be considered sustainable. When one discusses the issue with fleet managers, they tend to agree: ECD, like CNG, is only a step toward a long-term solution. Other than serving as a bridge technology that makes public transit more attractive, from an ecological perspective neither technology is particularly sustainable. However, recognition of the lack of sustainability can be used to argue in favor of one technology or another. For example, advocates of ECD suggest that hybrid-electric diesel buses are a better bridge technology to hydrogen than CNG because they develop electric power systems. More generally, the “clean bus” controversy as it currently stands suggests that sustainability studies analysts need to consider existing bridge technologies in addition to long-term technological goals.

A second perspective comes from the view that discussions of sustainability can only be ecologically and socially effective if they include equity and justice issues (Agyeman et al. 2003; Hess, 2007). The health effects of urban diesel bus pollution, and especially the pollution of bus idling and bus barns, have become a heated environmental justice issue in some American cities. Because a disproportionate burden of the air pollution from urban bus fleets can fall on low-income urban neighborhoods where people of color reside, the issue of sustainability, at least in some cities, is closely related to that of social justice. The highly polarized politics of urban transit, which have been at the center of American race politics for at least half a century, are prominent in the cases discussed. Race and class politics have converged with health politics to develop an environmental justice basis for opposition to diesel exhaust. Environmental justice concerns have probably been more influential than purely environmental concerns, such as global warming, in creating the political will that has been mobilized to require the greening of United States diesel fleets. Although cleaning up diesel bus emissions would reduce greenhouse gas emissions, the effect of diesel bus emissions on climate change is not the primary issue. The health risks are substantial enough that federal and state government agencies have continued to issue end-of-pipe mandates even in an era of neoliberal governance and under political administrations that have weakened other environmental regulations. As a result, a second contribution to sustainability studies is to develop a better understanding of how environmental justice issues interact with sustainability concerns in situations of technology policy and technological decision making.

**Regulating the Clean Bus**

Health research has increasingly pointed to the risks of lung cancer, asthma, and other diseases associated with exposure to diesel exhaust. For example, by 1988 and 1990, the National Institute for Occupational Safety and Health and the State of California had each in turn declared diesel exhaust to be a carcinogen, and continued documentation over the subsequent two decades from government units such as the National Toxicology Program and the Environmental Protection Agency (EPA) confirmed the determination (Weinhold, 2002). Similar statements were issued at an international level. The International Agency for Research on Cancer (1989) reviewed the literature and declared that diesel exhaust was a probable carcinogen, and a 1996 report by an international body sponsored by the World Health Organization and several other organizations conducted a similar appraisal on the carcinogenicity of diesel exhaust and recommended actions to reduce exposure (International Programme on Chemical Safety, 1996). In the United States, California became a center for research and policy directed at diesel emissions. For example, emissions were estimated to contribute approximately 70% of the cancer risk from air pollution (South Coast Air Quality Management District, 2000). A report from the California Air Resources Board (1998) noted that diesel exhaust contains 41 toxic air contaminants as defined by the State of California.

Advocacy groups responded to the information by calling for immediate action to clean up diesel fuel, to add particulate traps, and to reduce emissions by other means, such as by switching to natural gas. In 1998, the Natural Resources Defense Council (NRDC) published a report that reviewed the health risks of diesel exhaust and called upon public and private fleets to switch to clean fuels. The health studies that linked diesel exhaust to disease were largely based on diesel-exposed workers and animal experiments, and there was little research on the health effects for bus users or residents along bus lines. However, there was general consensus that diesel exhaust was a carcinogen, and the average outdoor concentration of diesel exhaust in California at that time was estimated to produce about 350 cancers per million people, or 12,000 additional annual cancer cases in California alone (NRDC, 1998). Other advocacy groups, such as the Clean Air Task Force, pointed to several studies of health effects published after 1998 that suggested ongoing risks not only for cancer but also for heart attacks, bronchitis, and
asthma (Schneider & Hill, 2005). The study called for action to remediate existing diesel vehicles rather than to wait until replacement vehicles came on line.

The EPA had already taken some steps through the initiation of the Clean Fuel Program that had been authorized by the Clean Air Act of 1990. The program targeted an emissions standard for new fleet purchases beginning with the 1998 model year, identified 22 non-attainment cities in terms of air quality, and mandated that those cities purchase clean-fuel fleets (NRDC, 1998). The goal was for fleet purchases of clean-fueled vehicles to reach 30% in 1998, 50% in 2000, and 70% in 2001. However, the 1998 NRDC report accused the EPA of backpedaling on its own goals in several ways: weakening the emissions standards, delaying implementation, and allowing most non-attainment regions to opt out by demonstrating equivalent reductions through other programs. Although the mandates were weakened, they did pressure urban transit agencies to consider switching to CNG or liquid natural gas (LNG) as a clean fuel. One reason was that fleet purchases are a long-term investment and the predicted future trend was toward regulation in favor of cleaner fuels.

The EPA’s emissions standards for an urban bus for the 1998 model year were 4.0 grams per brake horsepower hour (g/bph-hr), or a measure of the pollution produced per unit of energy consumed by the vehicle) for nitrous oxide (NOX) and 0.05 for particulate matter (PM). Diesel bus manufacturers designed new buses that met those standards, but in 2000 the EPA issued new standards set to begin with the 2007 model year. Those standards were scheduled to drop to 0.2 g/bph-hr for NOX, 0.01 for PM, and 0.2 for nonmethane hydrocarbons, with the three-year phase-in beginning in 2007 for NOX and nonmethane hydrocarbons (Washington State University Energy Program, 2004). In 2000, the EPA also reduced sulfur content mandates in highway diesel fuel by 97% from 500 parts per million (ppm) to 15 ppm, with a stepped phase-in from 2007 to 2010. The diesel industry struggled to meet the new standards, and the low level for NOX presented an especially critical design challenge (EPA, 2006).

The development of federal standards interacted with two other processes. On an international level, United States standards for diesel vehicles have tended to be higher (that is, mandating lower emissions) than European Union standards. Reasons for the divergence may include geographical differences that affect air quality policy as well as concern with effects of emissions policies on diesel manufacturers. In any case, there has been an ongoing drive to harmonize standards (Peckham, 2003). Arguably, of greater influence has been a second process of standards set at the state governmental level. The most influential state-level regulatory agency in the United States is the California Air Resources Board (CARB), partly because of the size of the state and partly because CARB sometimes enacts more stringent standards than the EPA. For example, in 2000 CARB mandated that transit agencies had to commit either to a diesel or to an alternative fuel path by 2001 (Peckham, 2001; CARB, 2005b). Forty-eight transit agencies across the state opted to pursue the clean diesel path, among them the Alameda-Contra Costa Transit District of the East Bay and Muni of San Francisco, whereas 28 agencies, including Los Angeles and Sacramento, opted for the alternative path (mostly CNG and LNG) (CARB, 2005b). CARB also enacted NOX standards more stringent than the EPA mandates. Whereas federal standards were scheduled to begin in 2007 with 1.2 g/bph-hr for NOX, and a phase-in to the 0.2 g/bph-hr standard in 2010, CARB required the level of 0.2 g/bph-hr for NOX to begin in 2007 (Green Car Congress, 2005a). The three-year difference may seem trivial, but it was important for the diesel industry and bus fleets that rely on diesel.

In 2005, CARB discussed its more stringent standards with bus manufacturers and concluded that the manufacturers would not meet the lower level of emissions until 2010. As a result, the agency proposed three possible amendments: harmonize down to federal standards, do nothing, or require that all diesel-path agencies switch to a clean fuel (which generally meant natural gas) (CARB, 2005b). The Bay Area agencies immediately claimed that the third option would cost hundreds of millions of dollars, and some transit officials protested that the ruling was politically suspicious because Governor Schwarzenegger had recently received a large contribution from a vehicular natural gas company owner (Berthelsen & Marinucci, 2005). CARB eventually opted to harmonize regulations down to the federal standard for the 2007 to 2010 period.

As the proposed CARB amendments suggest, regulatory standards can become hotly contested when the regulations would force a shift away from ECD and place a heavy burden on the diesel industry and urban bus fleets. They have also become contentious from an environmental and health perspective. Environmental groups such as NRDC suggest that the standards have not gone far enough or have undergone retrenchment. The instabilities and changes in regulatory standards have become one significant set of object conflicts in defining what constitutes a “clean” bus and which clean bus technologies will become widely diffused.
Assessing Emissions

The 1998 NRDC study drew on data from CARB to compare the emissions of diesel with CNG buses of the 1996 model year. The data show that emissions of PM, NOx, and hydrocarbons were 2-3 times higher for diesel than CNG, and the carbon dioxide (CO2) emissions were about 12% higher for diesel. NRDC also presented a comparison between a hybrid-electric diesel bus of that time and a CNG bus, again showing that the PM and NOx emissions favored the CNG bus. The study considered battery and hydrogen technology as other clean fuel alternatives but dismissed them as not practical. In other words, at that time natural gas and diesel were the two available alternatives. The report’s success stories focused on CNG and LNG as providing significant emissions improvement on the performance of diesel buses. NRDC’s position in favor of CNG was politically important because it potentially influenced regulatory agencies which it criticized as overly lax, and the organization’s report was used as a resource in some of the local environmental justice mobilizations against “dirty diesel” (NRDC, 1998).

The technology was changing very rapidly, and test data for new ECD buses, which ran on ultralow sulfur fuel and used particulate traps, soon became available. For example, a 2002 CARB study compared existing CNG buses with the new ECD buses equipped with particulate traps. The preliminary study only compared ECD with the old CNG buses, and a report by NRDC cried foul. Another confounding factor was that particulate traps need to be changed after 150,000 miles, and consequently any real-world applications would require a monitoring system (NRDC, 2002). CARB’s follow-up study provided a more head-to-head comparison between an ECD bus and a CNG bus that had a new oxidation catalyst, a device that played an equivalent role for CNG that the particulate traps did for diesel. The ECD bus had about double the NOx emissions, but the PM emissions were equivalent. Although the PM emissions for the ECD bus were more toxic, the CNG bus emitted more aldehydes and more ultrafine particles, which may have higher health risks than larger particles (CARB, 2002a; 2002b; 2004; 2005a). Based on the comparisons that showed risks associated with both technologies, transit agencies could conclude that from an emissions viewpoint ECD and CNG were roughly equivalent.

Subsequent studies attempted to translate emissions differences into health effects. Using a cost and “quality adjusted life years” ratio model, one analysis suggested that CNG and ECD bus technologies produced similar reductions in expected health damages in comparison with older diesel buses, but CNG had a “slight edge” due to the lower rate of NOx emissions. However, the ECD buses accomplished the reductions in expected health damages at much lower cost than CNG, and consequently one could defend a choice of ECD because it would allow a more rapid retirement of older, dirty diesel buses (Cohen, 2005). Another study of a CNG bus with no after-treatment versus ECD buses showed that the CNG bus emitted more benzene and formaldehyde and that its emissions had higher mutagenic activities (Kado et al. 2005). In brief, the health-effects studies did not clearly favor ECD or CNG. They suggested substantial interpretive flexibility in assessing comparative health effects, with much depending on technical issues such as the type of emissions technology being compared and the assumptions made about the relative value of health savings versus the relative cost of the different technologies. The new ECD technology had closed the gap substantially on the comparative health risks of diesel and natural gas.

By the early 2000s, hybrid-electric diesel bus technology was becoming widely available, and additional CNG-diesel comparisons were undertaken. The Northeast Advanced Vehicle Consortium (2000) performed for the United States Navy a series of tests showing that when the hybrid-electric diesel buses were operated on ultralow sulfur fuel, their levels of PM, NOx, and nonmethane hydrocarbons were comparable to those of the CNG buses with oxidation catalysts. The hybrid-electric diesel buses also had double the fuel economy of CNG buses (based on an algorithm that converted natural gas to an equivalent in gallons of diesel fuel), emitted 10–40% lower levels of greenhouse gases, and released much lower levels of carbon monoxide. In other words, the new diesel technology had become clearly favorable to CNG on several significant metrics. Although hybrid-electric CNG buses were not tested, the hybrid-electric diesel tests included a condition in which the regenerative braking was turned off. The additional condition allowed a more accurate comparison between the diesel and natural gas buses.

In 2006, the National Renewable Energy Laboratory (NREL) announced the results of tests for the Washington Metropolitan Area Transportation Authority of CNG buses with lean burn engines and oxidation catalysts versus diesel buses with particulate traps and ultralow sulfur fuel. The definition of “clean diesel” did not include hybrid-electric diesel, but a variety of both CNG and diesel buses was tested, including some diesel buses that had exhaust-gas recirculation. The results varied substantially by bus but generally favored CNG on the metric of NOx and PM, and the study concluded that aldehydes from both types of buses approached ambient background levels (Melendez et al. 2005).

Hess: What is a Clean Bus?
Giving the rapidly changing technological innovations and the instability of emissions data, two types of intersecting issues emerged. Diesel technology was innovating more rapidly and in some ways had leapfrogged over CNG, but if similar technologies were employed on CNG, then CNG might be cleaner. As a result, at any point in time the two alternatives were roughly equivalent. Diesel did not fare as well as CNG on the metric of NOx emissions, but future health research might show that the ultrafine particles especially associated with CNG constituted a more serious health risk. The ambiguity of the scientific research on emissions levels was important, because different parties could draw different conclusions. In other words, fleet managers who saw cost and convenience advantages in diesel could opt to return to diesel, whereas environmental justice groups could conclude that where head-to-head tests were done with equivalent levels of technological innovation, CNG was a safer and cleaner fuel. The absence of closure in emissions testing and bus-technology design helped create continuing shifts in purchase preferences and differential outcomes of grassroots mobilizations.

Making a Purchase Decision

The technical data on emissions intersected with emerging economic data from the transit agencies on the relative costs of purchase price, infrastructure investments, maintenance, and fuel for natural gas versus diesel buses. Because the decisions were especially complicated and have changed over time, this section will be somewhat more detailed than the two previous sections. It will focus on cities with data, either from interviews or publicly available sources, about reasons for the choice in favor of CNG or ECD (see Table 1).

One of the complicating factors that affected the choice between ECD and CNG was the emergence of hybrid-electric diesel buses. A study by the New York Metropolitan Transportation Authority in 2003 that noted, for the 2003-2004 purchase, hybrid-electric diesel buses had come down in price from US$465,000 to US$385,000 each, in comparison with US$290,000 per bus for conventional ECD and US$320,000 per bus for CNG (Chandler et al. 2002). Satisfied with the hybrid-electric diesel buses, the agency ordered 500 more vehicles in 2005 (Green Car Congress, 2005b). A subsequent study released in 2006 by NREL compared CNG and hybrid-electric diesel buses in New York City and found that hybrid-electric diesel buses had fewer repairs and higher fuel economy than the CNG buses (Chandler et al. 2006).

Although hybrid-electric buses cost more than conventional ECD, a test by Seattle-based Metro Transit, which as of 2005 had one of the largest hybrid-electric diesel fleets in the country, found that those vehicles rapidly made up costs in comparison with ECD. Based on extensive testing and experience, the fleet manager estimated that the new hybrid-electric diesel buses would last 14-16 years and would pay for themselves within eight years due to lower repair costs and more efficient fuel consumption than conventional ECD (Hess, 2005c).

The up-front purchase price differential between CNG and ECD buses was also declining, and for fleet managers who were already on a CNG track, the closing of the initial purchase price gap made CNG increasingly attractive. In the late 1990s, a CNG bus cost US$65,000 to US$75,000 more than its diesel equivalent, but by the time of the New York study the differential had declined to only about US$30,000 (Eudy, 2002). However, for fleet managers who were contemplating a switch from diesel, or who had not fully invested in CNG, other factors made the comparison less attractive for CNG. For example, conversion to CNG required a substantial investment in refueling stations and staff training. Regarding infrastructure investment, in Los Angeles a contract for three refueling stations in 1999 cost US$35 million (Energy Futures, 2000), and regarding operating costs, a study by the Greater Cleveland Transit Authority, which had used both diesel and CNG buses, found that the fuel cost for ECD and CNG in 2003 was equivalent, but the labor and parts costs were significantly higher for CNG. Taking into account the difference in purchase price, fuel, labor, and parts, the Cleveland agency concluded that a CNG bus was about 20% more expensive to operate per mile than an ECD bus (Heywood et al. 2002). Likewise, a comprehensive survey of transit agencies using CNG, conducted by NREL and published in 2002, found that most fleets reported higher costs for CNG than diesel (Eudy, 2002). However, a few fleets experienced lower CNG fuel and maintenance costs. The

### Table 1 The CNG/ECD Controversy in Eight Large Cities in the United States

| City          | Returned to Diesel | Stayed with Diesel | Stayed with CNG |
|---------------|--------------------|--------------------|-----------------|
| Atlanta       |                    |                    | X               |
| Boston        | X                  |                    |                |
| Cleveland     | X                  |                    |                |
| Los Angeles   |                    |                    | X               |
| New York      | X                  |                    |                |
| Oakland       |                    |                    | X               |
| Seattle       |                    |                    | X               |
| Washington, DC| X                  |                    |                |
study suggested that transit agencies with large CNG fleets and a high degree of training were more likely to experience the lower CNG costs. However, even the Los Angeles Metropolitan Transportation Authority, with its large CNG fleet, noted that although fuel costs were equivalent for CNG and diesel, annual maintenance costs were 15-20% higher for CNG (Energy Futures, 2000). Another study, written for the natural gas industry, admitted that another drawback for CNG was a lower range and payload than diesel but argued that reliability and fuel economy problems had been overcome by the late 1990s (Watt, 2000). Again, the claims about overall cost differentials allowed some interpretive flexibility.

Statistics from the American Public Transportation Association (2003) indicate that in the early 2000s the aggregate number of CNG buses continued to grow, while that of diesel buses shrank. However, if one looks more closely at the trends in some of the large fleets, during the early 2000s several of the cities with large, mixed fleets were attempting to shift back to diesel, whereas some of the large transit agencies that had committed to CNG were close to completing their conversions. Consequently, the growth in CNG may have reached a plateau by 2004, and barring a regulatory intervention or a dramatic shift in the relative difference of fuel costs, diesel was winning in some of the largest cities.

One factor in favor of the shift back to diesel was the deregulation of the natural gas industry. During the mid 1990s, the industry had convinced some agencies to shift to CNG, but its role as an advocate of CNG had weakened by the early 2000s. According to one fleet manager, during the early- and mid-1990s sales were relatively flat for the natural gas industry, and bus fleets were seen as a potential area for growth (Hess, 2005a). Offers from natural gas companies to build some of the refueling facilities converged with other factors to make CNG attractive at that time: the impending implementation of the EPA standards in 1998, the emerging data on the lower emissions of CNG than the mid-1990s diesel buses, and the transit agencies’ genuine preference for cleaner buses.

Some transit agencies resisted the natural gas industry entreaties and offers. For example, Alameda-Contra Costa County Transit District (AC Transit) was “pushed very heavily” to shift to natural gas (Hess, 2005a). The agency tested CNG buses, but decided not to adopt them because of cost and reliability concerns. Later, the higher levels of ultrafine particles, as well as of formaldehyde, became a factor in support of ongoing decisions in favor of diesel. The natural gas industry also pressured Metro Transit of the King County area surrounding Seattle during the mid-1990s. In response to what the fleet manager described as a “full-court press,” the transit agency expressed numerous concerns to the county council: the high increase in refueling time in a system that did not leave any slack, the small size of existing gas lines (which could not fuel the fleet during the 11 pm to 4 am shift), concern that the heavy draw on the gas system might extinguish pilot lights on furnaces for residential and business customers, apprehension about possible explosions from natural gas in existing or converted diesel bus barns, and an estimated total cost of US$100 million to buy the more expensive CNG buses and retrofit existing bus barns (Hess, 2005c). The county council ignored the transit agency’s advice and decided to mandate the fleet’s conversion to liquid natural gas (which the agency saw as somewhat more acceptable), but shortly afterward an election resulted in a change of the party composition of the city council, and the new Democratic majority reversed the decision (Hess, 2005c).

However, not all transit agencies rejected the CNG option. In southern California, where air quality issues were particularly strong and regulatory mandates were different, several transit agencies pursued the CNG path. Likewise, the Metropolitan Atlanta Rapid Transit Authority (MARTA) opted to begin purchasing CNG buses in 1994, when the Atlanta Gas Light Corporation offered to pay for the entire cost of a $2.5 million refueling facility, maintain the facility, and help the agency purchase CNG buses (Transit Cooperative Research Program, 1998). In addition, the federal government provided some support for CNG as part of an effort to showcase clean transportation during the 1996 Olympics (Ashburn, 2004). By 2001, half the agency’s bus fleet was CNG, and by 2004 the proportion of CNG buses had grown to 74% (Ashburn, 2004). In 2000, the Washington Metropolitan Area Transportation Authority (or Metro Transit of Washington, DC) entered the CNG market with a purchase of about 100 CNG buses, and it continued to purchase CNG buses through 2004, when the projected number was at about 400 (compared to approximately 1,200 diesel buses) (Washington Metropolitan Area Transportation Authority, 2006a; 2006b). By 2002, several large and mid-sized transit agencies had CNG fleets, including El Paso, Long Island, Los Angeles, Orange County, Pierce County, Phoenix, Sacramento, San Diego, Syracuse, Tempe, and Tucson (Natural Gas Vehicle Coalition, 2003).

Various internet searches and interviews did not uncover evidence of subsidies or pressure from the diesel industry similar to those of the natural gas industry. From the 1990s to the present probably the primary incentive in favor of diesel was the lower upfront cost per bus, the lower maintenance cost (at least for inexperienced agencies undergoing a transi-
tion), and the comfort level that most transit agencies had with the familiar technology. During the late 1990s and early 2000s, two major changes started to shift the preferences of agencies that leaned toward CNG or were considering switching to it. First, agencies found that they could reduce diesel emissions significantly by retrofitting buses with particulate traps and switching to ultralow sulfur fuel; as a result diesel and CNG emissions became more equivalent (as the 2002 CARB study indicated). Second, the natural gas industry was deregulated, and as a result support programs for natural gas declined. For example, in 1999 Atlanta Gas Light Corporation shifted from marketing and service to wholesale, and its resources shifted into competition for customers rather than support for natural gas fleets (Ashburn, 2004). Furthermore, natural gas prices increased after deregulation, and fueling stations for natural gas declined in the city. By 2004, the Atlanta Gas Light Corporation had cut its natural gas fleet from 600 to 9 vehicles, and other companies in the city (such as Checker Cab and Bell South) had also cut their fleets down to a minimal level. However, Atlanta’s regional transit agency already had two natural gas refueling facilities, so it was less dependent on the disappearing public fueling stations than were the private corporate fleets (MARTA, 2004). The existing reports give no reasons why MARTA remained on the CNG path; sunk costs were probably a factor as well as the environmental justice issues being raised regarding neighborhood air pollution levels across race and class lines.

As a result of the changes in both diesel technology and the natural gas industry, several large transit agencies that had invested in CNG began to shift back to diesel. For example, in 2005, the Greater Cleveland Regional Transit Agency had 160 CNG buses (in a fleet of 650), but it decided to shift to clean diesel (Exner, 2005). The agency argued that CNG buses had more mechanical problems and were more expensive. Likewise, New York’s transportation agency stated in 2005 that it wanted to stop buying CNG and shift to hybrid-electric diesel buses (DieselNet.com, 2005).

Another example of the shift back to diesel occurred in Washington, DC. The momentum for CNG appeared to be going strongly until May, 2004, when the new chairman of the board, Robert Smith, began pushing the agency to shift away from CNG (Layton, 2004). The board debated a proposal to purchase 200 more CNG buses versus using the same funds to buy 196 diesel and 50 hybrid-electric buses that would run on either diesel or natural gas. Smith (2004) argued that the effects on aggregate emissions of a switch from CNG were minimal, but the lower cost of new diesel buses would allow the agency to purchase more buses and therefore decommission the older diesel buses more quickly. Furthermore, he argued that the CNG buses presented a security risk because a terrorist could commandeer a CNG bus and drive it into a building (Layton, 2004). The proposal prompted a critical editorial from representatives of NRDC and the Sierra Club who supported CNG buses over new diesel. They argued that new diesel would not meet the 2007 federal standard and suggested that hybrid-electric diesel buses were not a viable option because the buses were still experimental (Negin & Wenzler, 2004). In an editorial reply, Smith argued again that the agency could buy more clean buses and noted that other transit agencies were shifting to hybrid-electric diesels (Smith, 2004). In 2005, the agency approved a purchase of ECD and hybrid-electric diesels (Ginsburg, 2005).

Another shift back to diesel occurred in Boston in 2002, when the Massachusetts Bay Transportation Authority (MBTA) obtained from the state’s Department of the Environment a modification of a consent decree. The change allowed the regional transit agency to purchase any clean-fuel technology but in return required the purchase of 200 new buses to replace its oldest vehicles. That same year the agency received an expert-panel report that recommended new purchases of ECD buses over CNG (Heywood et al. 2002). The reasons given were the minimal difference in emissions between the two bus types, lower operating costs and initial expense for ECD buses, need to economize on initial purchases to retire more of the older buses, and delays in the construction of natural gas infrastructure facilities. The agency shifted back to diesel in 2004, when it purchased 600 low-emission diesel buses and said that it would retrofit the remaining buses (Gandelman, 2004). At that point, 120 CNG buses were in operation, but in a draft report for 2004 the agency mentioned only 44 CNG buses in the total bus fleet of about 1,000 (MBTA, 2004).

In summary, the shifts in the purchasing preferences of some of the largest transit fleets suggest that diesel had recovered after the setbacks of the mid 1990s. However, the idea of “clean diesel” did not always play well with bus rider groups and environmental justice organizations, and, as a result, not all agencies were equally in a position to select “clean diesel.”

**Mobilizing Political Change**

In some cities, grassroots mobilizations by environmental justice groups affected the shift to CNG or diesel buses. Mobilizations were prominent in five cities: Atlanta, Boston, Los Angeles, New York, and San Francisco. In all cases, environmental justice
groups entered the political arena to restrict the decision-making leeway of transit agencies and to shift spending preferences in favor of cleaner vehicles. In New York and Boston the groups achieved changes from their respective state governments, in San Francisco the groups worked through the city government and city-level voter proposition system, and in Atlanta and Los Angeles the groups operated through the courts.

In New York, an environmental justice mobilization focused on the fact that six of the eight bus depots in the city were located above 96th Street, that is, in or near low-income communities of ethnic minority groups (WE ACT, 2004a). In 1995, several members of the New York State Assembly, together with Manhattan Borough President Ruth Messinger, called on the New York Metropolitan Transportation Authority (MTA) to shift to CNG buses (Tri-State Transportation Campaign, 1996). WE ACT, an environmental justice group based in West Harlem, began a campaign against the diesel bus depots and advocated conversion to CNG (WE ACT, 2004b). Governor Pataki and state legislative leaders responded three years later by issuing the Clean Fuel Bus Plan, which included the following goals: retrofitting three depots for CNG, making all new depots CNG-compatible, retrofitting existing vehicles, and purchasing 250 hybrid-electric diesel and 300 CNG buses in a fleet of about 4,500 buses (Governor’s Office of New York, 2000). Six months later, WE ACT filed an administrative complaint with the federal Department of Transportation alleging that MTA located diesel bus depots and parking lots in a discriminatory pattern (WE ACT, 2000). WE ACT also developed a map with alternative locations for the bus depots.

In 2003, the transit agency responded in a way that was unsatisfactory to the coalition: it closed a bus depot downtown and reopened one in East Harlem that had been remodeled to include a roof. The agency did shift to ultralow sulfur diesel fuel, and it purchased 300 CNG buses (Tuhus-Dubrow, 2003). The federal Department of Transportation finally reached a decision that, according to WE ACT, “acknowledged the community’s cause for concern while declining to find actual civil rights violation” (Prakash & Corbin-Mark, 2006). In 2004, WE ACT and community residents began negotiations with MTA regarding the bus depots, and a year later the two sides developed a letter of agreement to meet regularly and to prioritize the cleanest buses for the depots in northern Manhattan. The agency also agreed to rebuild the oldest depot to minimize its impact on the neighborhood. However, as noted above, the agency was shifting away from CNG toward hybrid-electric diesel (Chan, 2005).

The Boston case is like that of New York on two major grounds: the goal of cleaner buses was achieved through action at the state-governmental level, and eventually the transit agency opted for clean diesel over CNG. In Massachusetts in 1996, Governor Weld pledged that MBTA would buy no more diesel buses, and the Boston area transit agency responded by testing two CNG and two hybrid-electric diesel buses (Duffy, 2000). After testing the buses, MBTA decided that because the hybrid-electric diesel buses at that time did not have enough power for the hills, CNG was the better option (Duffy, 2000). Again, the environmental justice mobilization occurred alongside the general policy shift. In 1997, the environmental justice organization Alternatives for Community and Environment led a coalition in the Clean Buses for Boston campaign, and three years later they formed the T Riders Union (Egleston Square Neighborhood Association, 2002; Heart of the City, 2005). The coalition pushed for CNG as a cleaner alternative to diesel, and in 2001 it obtained an administrative consent order from the Massachusetts Department of the Environment that required MBTA to purchase 350 clean-fuel buses and to retrofit existing buses (Daniel, 2002; Alternatives for Community and Environment, 2006). The agency responded by purchasing 350 new CNG buses, shifting to ultralow sulfur fuel, and retrofitting old diesel buses (MBTA, 2002). However, as noted above, in 2002 the agency obtained a modification of the consent order, which had allowed it to shift back to diesel in its 2004 purchase. Environmental justice advocates saw the decision as a setback, and they responded by obtaining an agreement with the agency on an extensive monitoring system to ensure attainment of the claimed emissions reductions (Saleos, 2003).

San Francisco faced similar pressure from environmental justice groups to shift to CNG, but the city’s transit agency, Muni, never made substantial CNG investments, and much of the battle was fought out through local political mechanisms rather than the state government. Environmental and health groups had the support of sympathetic members of the city’s Board of Supervisors, and beginning in 1997 the board began passing resolutions against continued diesel bus purchases (Kay, 2004). Muni’s fleet included some pre-1991 diesel buses that were particularly controversial because of their high emissions and the concern that they were adversely affecting air quality in low-income neighborhoods such as Hunter’s Point. A major controversy erupted in 2001, when Muni announced that it was going to purchase new buses (Hess, 2005d). The Board of Supervisors supported a coalition of health, environmental, and neighborhood groups that wanted the

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agency to purchase CNG buses, but Muni argued that the buses were less reliable and lacked power for the city’s hills. In an interview with me, a Muni spokesperson claimed that the coalition “lacked the expertise and the dedicated resources to really understand the transit agency’s operating realities, funding requirements, and technology” (Hess, 2005d). The coalition disputed the characterization and pointed to its experts from Pacific Gas and Electric, NRDC, the American Lung Association, and the city’s environment and public health departments.

The city Board of Supervisors was sympathetic to the coalition and worked out a compromise with Muni that enabled the transit agency to purchase 100 new diesel buses instead of the proposed 200-300 buses and at the same time to test a CNG bus. After a delay, the agency tested two CNG buses and decided that they were less reliable than diesel buses (Kay, 2002). In 2002, the agency asked for 18–24 months to complete studies, and, in response to the delay, the coalition developed the “Dump Diesel” campaign to urge more immediate action (Our Children’s Earth, 2002). The coalition disputed the methodology of the tests and in 2004 introduced Proposition I, which required the agency to replace its pre-1991 buses. Because the proposition left open the question of bus design, ECD was potentially acceptable if it could meet state emissions standards. The proposition passed, but it was soon overtaken by a ruling from CARB, which mandated the phase-out of all old diesel buses (LACMTA, 2004, 2006b). Based on further use, the agency determined that methane-powered buses suffered from maintenance and reliability problems, so in 1995 the agency placed decisions on fleet-purchase a CNG path, with environmental justice concerns a contributing factor. Although in Atlanta a more influential factor was probably the huge sunk costs in infrastructural investment, environmental justice groups also pushed for conversion of the fleet to CNG. For example, in 1992, the Labor/Community Strategy Center formed the Bus Riders Union to advocate for a number of reforms that included the greening of bus emissions (Bus Riders Union, 2005b). LACMTA announced a fare increase two years later, and the Bus Riders Union sued the transit agency in federal court for civil rights violations (Berkowitz, 2005). The central legal claim, that the agency had developed a separate and unequal transit system, was based on the high subsidies and investments going into rail transit. The Bus Riders Union argued that the rail subsidy largely benefited middle-class and white customers, whereas bus transit suffered from inattention, disrepair, frequency problems, and poor safety records. To avoid a trial, in 1996 Mayor Riordan signed a ten-year consent decree that, in effect, put bus purchase decisions in the hands of a court-appointed “special master,” who supervised implementation (Berkowitz, 2005). The decree included a load-factor requirement that limited the number of standing passengers during a 20-minute period. When
the load limit was exceeded, the special master had the right to mandate that LACMTA add buses (Rabin, 1999). After a few years of negotiations, in 1999 the special master ordered LACMTA to relieve overcrowding by buying 532 additional CNG buses (in a fleet of about 2,200), that is, a figure over and above the 2,095 that LACMTA had promised to purchase before 2004 (Rabin, 1999). LACMTA chief called the decision “excessive” and said that it would cost over US$400 million during the following five-year period (Rabin, 1999). LACMTA ended up appealing the decree all the way to the United States Supreme Court, and it lost (Bus Riders Union, 2002).

In 2000, LACMTA staff recommended a purchase of 370 ECD buses. The Bus Riders Union, in coalition with NRDC and other groups, played a significant role in creating the groundswell of opposition that led the board of the transit agency to continue with the CNG-only policy (Bus Riders Union, 2000; Rabin, 2000). The Bus Riders Union framed diesel as “death on wheels,” called for “zero tolerance for carcinogens,” and threatened lawsuits (Bus Riders Union, 2000). With the purchase in 2000, the fleet was targeted to become about 86% CNG (Rabin, 2000). By 2005, the agency had 2,045 CNG buses in a total of about 2,700 buses and was in the process of converting completely to CNG buses (LACMTA, 2006a; 2006b). In that year the special master ordered LAMTA to purchase an additional 134 buses (Bus Riders Union, 2005a).

In summary, in Boston and San Francisco environmental justice groups adopted a relatively flexible attitude regarding what constitutes a clean bus. Although they favored CNG, some statements indicate sympathy with the argument that ECD and CNG have over time achieved comparable emissions, and that the cost savings of opting for ECD over CNG allows a more rapid retirement of older and more polluting buses. In contrast, in Los Angeles the Bus Riders Union emphatically equated diesel with racism and pushed for CNG. Although environmental justice organizations were less influential in other cities, in Los Angeles the consent decree and the decisions of the special master were a determining factor in fleet-purchase decisions during this period.

**Conclusion**

What constitutes a clean bus? The question suggests an analysis of the politics of definitions or “object conflicts” that articulate political and economic trade-offs with changing technology design and emerging scientific knowledge about health risks and emissions levels. As of 2006 there was rough parity in emissions between a CNG bus with an oxidation catalyst and a hybrid-electric diesel bus with ultralow sulfur fuel and a particulate trap. Because neither was a zero-emissions vehicle, decision makers and grassroots groups were left in a position of choosing their poison. New health research on the effects of ultrafine particles, aldehydes, and carbon monoxide indicated that the balance in favor of one type of “clean fuel” over another could shift, just as new technologies could allow one type of bus to leapfrog over the other. In the background hydrogen fuel-cell buses continued to be tested, but they remained prohibitively expensive. Biodiesel use was growing, but generally at mixes of 5–10% of the diesel fuel. A few cities had purchased electric-battery buses, but generally for short runs on flat surfaces, such as Chattanooga’s downtown circulator. Furthermore, to the extent that the fuel cell was powered by natural gas reformulation, or the electric battery was powered by a fossil-fuel burning electrical power plant, pollution was displaced to another point in the region or country.

Object conflicts that define a rapidly changing understanding of the “clean bus” take place in multiple arenas. In this case, the CNG-diesel controversy in the United States was traced in four fields of conflict and negotiation: regulations based largely on health risks, emissions-assessment studies, fleet-purchase decisions, and public mobilizations in the form of environmental justice groups that have influenced political leaders, state and local governments, the courts, and polls. The outcome of a controversy in one field can affect conflicts in another; sometimes a long, hard-fought battle at one level, such as San Francisco’s Proposition I, can be trumped (or, in this case, supported and made obsolete) by a decision from the state government’s regulatory agency. Likewise, emerging emissions data or health studies can rapidly shift the relative desirability of one technology over another, and changes in bus-emissions technologies also can shift economic and environmental assessments.

One hope of this author is that the concept of object conflicts and the methodology of analysis across fields of action may be of general value to sustainability researchers and policymakers. Much of what emerges as policy is a compromise formation that involves constant adjustments, as scientific research produces new insights and concerns, technological innovations respond to health and regulatory issues, cost considerations shift in response to global economic changes and technological innovations, and grassroots organizations interpret the changes and modify (or harden) goals. The question of “what is a clean bus” is one example of a politics of definitions that is constantly evolving and changing. From this perspective “sustainability” is not a goal that can be easily defined in a neutral and unbiased way, but a
field of contestation that involves ongoing negotiations over fundamental definitions.

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