

## Notes to Policy Analysis No. 341

The author would like to thank Harry Chernoff (Science Applications International Corporation), Michael Lynch (Massachusetts Institute of Technology), Lee Papayoti (Enron Corp.), Jerry Taylor (Cato Institute), and Tom Tanton (California Energy Commission) for helpful comments.

1. Joseph Stanislaw, "Emerging Global Energy Companies: Eye on the 21st Century," Cambridge Energy Research Associates, 1995, p. 6.
2. World non-fossil-fuel consumption of 15 percent in 1996 was composed of nuclear at 6 percent; hydropower at 8 percent; and wind, solar, geothermal, and biopower at 1.5 percent. Energy Information Administration, *International Energy Outlook 1998* (Washington: U.S. Department of Energy, 1998), p. 135. Wood or dung (biomass) burned for home heating or cooking, not counted as energy usage in this breakout, would add approximately 5 percent to this total. Intergovernmental Panel on Climate Change, *Climate Change 1995: Impacts, Adaptations, and Mitigation* (Cambridge: Cambridge University Press, 1996), p. 83.
3. Robert L. Bradley Jr., "Renewable Energy: Not Cheap, Not 'Green,'" Cato Institute Policy Analysis, no. 280, August 27, 1997, pp. 53-55; and Paul Ballonoff, *Energy: Ending the Never-Ending Crisis* (Washington: Cato Institute, 1997), pp. 52-56.
4. M. A. Adelman, *The Genie Out of the Bottle: World Oil since 1970* (Cambridge, Mass.: MIT Press, 1995), pp. 101-5, 163-66, 177-78, 189-90, 205-8, 211-13, 217, 220-22, 249, 253, 273, 283-84.
5. Energy Information Administration, *International Energy Annual 1996* (Washington: U.S. Department of Energy, 1998), pp. 13, 26, 31, 109, 111; EIA, *International Energy Outlook 1998*, pp. 37-38, 51; Enron Corp., *1997 Energy Outlook* (Houston: Enron Corp., 1997), p. 11; and World Energy Council, *1995 Survey of Energy Resources* (London: WEC, 1995), pp. 32-35. To cover all the conventional energies, uranium reserves and resources are equal to 84 years and 127 years of present usage, respectively, under a medium price assumption, and under high prices potential resources are estimated at approximately 450 years at present consumption rates. Organization for Economic Cooperation and Development, Nuclear Energy Agency, and International Atomic Energy Agency, *Uranium: 1995 Resources, Production and Demand* (Paris: OECD, 1996), pp. 26-27, 32;
6. Jack Belcher, "The Fourth Fossil Fuel," *Hart's Energy Market*, October 1996, pp. 24-27; Peter Eisen, "Orimulsion Gets Badly Needed Break in Europe," *Oil Daily*, February 27, 1998, p. 3; and "Orimulsion Gets Break in India," *Oil Daily*, July 10, 1998, p. 7.
7. Safaa Founda, "Liquid Fuels from Natural Gas," *Scientific American*, March 1998, pp. 92-95.
8. Martin Quinlan, "Gas-to-Liquid Processes Approaching Commercial Viability," *Petroleum Economist*, December 1997, pp. 18-20.
9. For an example of a vegetable-oil-powered motor vehicle in recent use, see Julian Simon, *The Ultimate Resource 2* (Princeton, N.J.: Princeton University Press, 1996), p. 564. Crop oil is also mentioned by Simon, pp. 16, 181.
10. Michael Lynch, *Facing the Elephant: Oil Market Evaluation and Future Oil Crises* (Boulder, Colo.: International Research Center for Energy and Economic Development, 1998), p. 2.
11. EIA, *International Energy Outlook 1998*, pp. 3, 38.
12. See endnote 5 for citations on reserve revisions.
13. See the technology articles in *American Oil and Gas Reporter* 41, nos. 4 and 7 (April and July 1998).
14. Conference brochure, "Deepwater '98," Third Annual Conference sponsored by the Strategic Research Institute, October 26-28, 1998.
15. Arthur Andersen and Co., *Oil & Gas Reserve Disclosures* (Houston, Tex.: Arthur Andersen, 1985), p. S-41; and Arthur Andersen and Co., *Oil & Gas Reserve Disclosures* (Houston, Tex.: Arthur Andersen, 1997), p. 10.
16. IPCC, *Climate Change 1995: Impacts, Adaptations, and Mitigation*, pp. 83-84.
17. See Simon, part 1.
18. It is assumed that fossil fuels are "nonrenewable" since "the world is currently using fossil fuels 100,000 times faster than they are being recreated by natural forces." James Cannon, "Clean Hydrogen Transportation: A Market Opportunity for Renewable Energy," Renewable Energy Policy Project Issue Brief, April 1997, p. 3. Is this bedrock assumption always right? The robust replenishment of supply behind the increasing reserve figures could be due to more

- than just increasing extraction percentages and locating new reservoirs of a “fixed” (in a mathematical, not an economic, sense) biogenic supply of decayed plants and animals. Some scientists suspect that oil and gas may have abiogenic origins deep in the earth. Carbon, some suspect, can move upward from the earth’s crust to replenish the near-surface supplies of petroleum and gas accessible by the drill bit. If so, substantial upward revisions would need to be made to the resource base, replacing estimates in the hundreds of years with estimates in the thousands of years, or even making probable resource estimates obsolete. See Thomas Gold, “An Unexplored Habitat for Life in the Universe,” *American Scientist*, September–October 1997, pp. 408–11. Empirical support for that hypothesis is described in “Gas Traces Found, Siljan Well Aims for 24,600 Ft.,” *Oil and Gas Journal*, February 2, 1987, p. 18.
19. Adelman, *The Genie Out of the Bottle*, p. 22.
  20. Douglas Bohi and Michael Toman, *Analyzing Nonrenewable Resource Supply* (Washington: Resources for the Future, 1984), p. 139.
  21. Richard O’Neill et al., “Shibboleths, Loaves and Fishes: Some Updated Musings on Future Oil and Natural Gas Markets,” U.S. Federal Energy Regulatory Commission, Office of Economic Policy, discussion paper, December 31, 1996, p. 22.
  22. M. A. Adelman, “Trends in the Price and Supply of Oil,” in *The State of Humanity*, ed. Julian Simon (Cambridge, Mass.: Blackwell, 1995), p. 292.
  23. Chevron, for example, failed to meet its \$6 billion capital budget for oil exploration and production in 1997 because of a lack of qualified staff, not drilling prospects. Loren Fox, “Help Wanted: Oil-Industry Professionals,” *Wall Street Journal*, December 26, 1997, p. B4.
  24. Ballonoff, p. 21.
  25. Robert L. Bradley Jr., *The Mirage of Oil Protection* (Lanham, Md.: University Press of America, 1989), pp. 129–39.
  26. Robert L. Bradley Jr., “What Now for U.S. Energy Policy? A Free-Market Perspective,” Cato Institute Policy Analysis no. 145, January 29, 1991.
  27. Bradley, *The Mirage of Oil Protection*, pp. 139–66.
  28. Douglas Bohi and Michael Toman, *The Economics of Energy Security* (Boston: Kluwer Academic Publishers, 1996), pp. 124–29.
  29. Environmental Protection Agency, *National Air Quality Emissions Trends Report*, 1997 (Washington: EPA, 1999), [www.epa.gov/ttn/chieftrends97/emtrnd.html](http://www.epa.gov/ttn/chieftrends97/emtrnd.html); and David Mintz, statistician, Environmental Protection Agency, communication with the author, February 16, 1999.
  30. Available at [www.epa.gov/airprog/oar/aqtrnd97/trendsfs.html](http://www.epa.gov/airprog/oar/aqtrnd97/trendsfs.html).
  31. Ibid.
  32. Ben Lieberman, “Air Pollution—The Inside Story,” *Regulation*, Spring 1998, pp. 12–13.
  33. Quoted in *ibid.* See also Ben Lieberman, “The First Family’s Asthma Problems,” *CEI on Point*, February 26, 1999.
  34. EIA, *Annual Energy Review 1997* (Washington: Department of Energy, 1998), pp. 211, 313.
  35. *Ibid.*, p. 9.
  36. *Ibid.*, p. 315.
  37. Data Resource International, *Energy Choices in a Competitive Era* (Alexandria, Va.: Center for Energy and Economic Development, 1995), p. 3-3.
  38. Natural gas combined-cycle units emit between 50 percent and 100 percent less pollutants than a similarly sized coal plant with today’s best technologies. Bradley, “Renewable Energy,” pp. 50–52.
  39. Christopher Flavin and Nicholas Lenssen, *Power Surge: Guide to the Coming Energy Revolution* (New York: W. W. Norton, 1994), pp. 91–92; and Ross Gelbspan, *The Heat Is On* (New York: Addison-Wesley, 1997), pp. 8, 187–89.
  40. Robert L. Bradley Jr., “Defining Renewables as ‘Green’ Not Necessarily Final Verdict,” *Natural Gas Week*, September 15, 1997, p. 2.
  41. Christopher Flavin, Comments at a conference on the Department of Energy National Energy Modeling System, March 30, 1998, Washington, D.C. Flavin would prefer distributed solar to distributed natural gas, however.
  42. James Flink, *The Automobile Age* (Cambridge, Mass.: MIT Press, 1988), p. 136.
  43. American Automobile Manufacturers Association, “Automakers Have Made Great Strides in Reducing Emissions,” [www.aama.com/environmental/autoemissions3.html](http://www.aama.com/environmental/autoemissions3.html).

44. American Automobile Manufacturers Association, "Super Clean Cars Are Coming to Houston," Press release, April 28, 1998; and Traci Watson and James Healey, "Clean Cars Out Sooner, Say Big 3," *USA Today*, February 5, 1998, p. 1A.
45. Kevin Cleary, staff engineer, Fuels Section, California Air Resources Board, communication with the author, March 4, 1999.
46. Caleb Solomon, "Clean Gasoline Makes Debut This Weekend," *Wall Street Journal*, October 30, 1992, pp. B1, B14; and California Energy Commission, *Fuels Report 1995* (Sacramento: CEC, 1995), p. 24.
47. *Ibid.*, pp. 24–26; California Air Resources Board, "Comparison of Federal and California Reformulated Gasoline," Fact Sheet 3, February 1996; and CARB, *California RFG Forum*, February 1995, p. 1.
48. Quoted in CARB, *California RFG Forum* August 1995, p. 3.
49. CARB, "Comparison of Federal and California Reformulated Gasoline," p. 1.
50. Kevin Cleary, communication with the author, March 8, 1999.
51. Sam Atwood, spokesperson, South Coast Air Quality Management District, California Environmental Protection Agency, communication with the author, March 4, 1999.
52. CEC, *Fuels Report 1993* (Sacramento: CEC, 1994), pp. 24, 32.
53. Tony Brasil, air resources engineer, CARB, communication with the author, September 4, 1998. Combined with the EPA requirement, the California standard reduced particulate matter an extra 5 percent.
54. "Diesel Will Continue to Be Heavy-Duty Fuel of Choice, House Told," *New Fuels & Vehicles Report*, March 27, 1998, p. 9.
55. Rebecca Blumenstein, "GM and Amoco Expected to Unveil Clean-Fuel Effort," *Wall Street Journal*, February 4, 1998, p. A10; Gregory White, "GM, Isuzu Investing \$320 Million to Build Advanced Diesel Engines for GM Pickups," *Wall Street Journal*, September 9, 1998; and "Diesel Will Continue to Be Heavy-Duty Fuel of Choice," p. A4.
56. EIA, *International Energy Outlook 1998*, pp. 40–47.
57. American Petroleum Institute, *Petroleum Industry Environmental Performance, 6th Annual Report* (Washington: API, 1998), pp. 34, 37; and Environmental Protection Agency, *Understanding Oil Spills and Response* (Washington: EPA, 1993).
58. Steering Committee Report, *Recommendations on the Implementation of PIRO*, January 5, 1990.
59. Robert Aldag, president, Marine Preservation Association, conversation with the author, October 8, 1998.
60. Timothy Egan, "An Alaskan Paradise Regained," *New York Times*, August 9, 1998, pp. 13, 23.
61. Henry Linden, "Operational, Technological and Economic Drivers for Convergence of the Electric Power and Gas Industries," *Electricity Journal*, May 1997, p. 18; and Johannes Pfeifenberger et al., "What's in the Cards for Distributed Generation," *Energy Journal*, Special Issue, 1998, p. 4.
62. A study by Data Resource International estimated that technological trends would result in an optimum size for gas plants of 150 megawatts. DRI, *Convergence of Gas & Power: Causes and Consequences* (Boulder, Colo.: DRI, 1997), p. 3-40.
63. Gerald Cler and Nicholas Lenssen, *Distributed Generation: Markets and Technologies in Transition* (Boulder, Colo.: E Source, 1997), pp. 10, 19.
64. Clyde Wayne Crews, "Electric Avenues: Why 'Open Access' Can't Compete," Cato Institute Policy Analysis no. 301, April 13, 1998, pp. 10–11. The ability of residential and small commercial users to profitably utilize microturbines is more distant than that of larger users owing to remaining scale diseconomies and sunk costs enjoyed by the incumbent provider.
65. Kenneth Lay, "Change and Innovation: The Evolving Energy Industry," Division 3 keynote address, World Energy Congress, September 14, 1998, Houston, Tex.
66. Bradley, "Renewable Energy," pp. 50–52.
67. *Ibid.*, pp. 53–55.
68. Jason Makansi, "Advanced Coal Systems Face Stiff Barriers to Application," *Electric Power International*, December 1997, pp. 27–34. On the improving retrofits of existing gas turbine technology, see CarolAnn Giovando, "Explore Opportunities for Today's Steam Turbine," *Power*, July–August 1998, pp. 28–39.

69. Judah Rose, "Comparative Costs of New Powerplants—Overseas Economics," Presentation by ICF Resources, April 1997; and Josh Spencer, ICF Resources, communication with the author, February 18, 1998. A 1995 study by DRI estimated the cost of electricity from new coal plants (in 1993 dollars) at between 4.3 cents and 5.1 cents per kWh. DRI, *Energy Choices in a Competitive Era*, p. TA-15.
70. J. Santucci and G. Sliter, "Ensuring the Economic Competitiveness of Advanced Light Water Reactors," Paper presented at TOPNUX '96, Paris, September 1996, p. 1. Copy in author's files.
71. Arlon Tussing and Bob Tippee, *The Natural Gas Industry* (Tulsa: PennWell Books, 1995), p. 54.
72. Makansi, pp. 27–28.
73. Enron Corp., *The Natural Gas Advantage: Strategies for Electric Utilities in the 1990s* (Houston: Enron, 1992), pp. 2–8.
74. This could be true if for no other reason than the "act of God" limitations of wind and solar—intermittent stillness for wind and darkness and intermittent cloudiness for solar.
75. World Association of Nuclear Operators, "1998 Performance Indicators for the U.S. Nuclear Utility Industry," <http://www.nei.org/library/tmiframe.html>.
76. EIA, *Annual Energy Review 1997*, pp. 7, 241, 243.
77. Nuclear Energy Institute, *Strategic Plan for Building New Nuclear Power Plants* (Washington: Nuclear Energy Institute, 1998), pp. III-4 and III-5.
78. EIA, *Annual Energy Outlook 1998*, p. 54.
79. Nuclear Energy Institute, *Nuclear Energy*, fourth quarter 1994; and Nuclear Energy Institute, *Nuclear Energy Insight 1996*, February 1996, pp. 1–2.
80. "EPRI Unveils New Reactor Design Standardization to Improve Safety," *Electric Power Alert*, July 1, 1998, pp. 27–28. A natural gas combined-cycle plant of the same size can still be built in two-thirds of this time.
81. As the Department of Energy has noted, "Without [the Price-Anderson Act of 1957], the nuclear power industry would not have developed or grown." U.S. Department of Energy, *United States Energy Policy: 1980–1988* (Washington: DOE, 1988), p. 105.
82. For a description of the environmental and economic features of a modern coal plant available to the international market, see Cat Jones, "Shinchi Leads Way for Large Advanced Coal-Fired Units," *Electric Power International*, September 1997, pp. 36–41.
83. Deren Zhu and Yuzhuo Zhang, "Major Trends of New Technologies for Coal Mining and Utilization beyond 2000—Technical Scenario of the Chinese Coal Industry," *Proceedings: 17th Congress of the World Energy Council* (London: World Energy Council, 1998), vol. 5, p. 93.
84. EIA, *International Energy Outlook 1998*, p. 78.
85. DRI, *Energy Choices in a Competitive Era*, p. 4-3.
86. Chinese and Indian energy planners provide an example of energy exploitation. They made wind and solar investments that had high capacity ratings but produced little energy. See EIA, *International Energy Outlook 1998*, pp. 103–4.
87. Roger Fouquet and Peter Pearson, "A Thousand Years of Energy Use in the United Kingdom," *Energy Journal* 19, no. 4 (1998): 7.
88. Carlo LaPorta, "Renewable Energy: Recent Commercial Performance in the USA as an Index of Future Prospects," in *Global Warming: The Greenpeace Report*, ed. Jeremy Leggett (Oxford: Oxford University Press, 1990), pp. 235, 242–43.
89. Flavin and Lenssen, p. 189.
90. Paul Druger and Carel Otte, eds., *Geothermal Energy: Resources, Production, Stimulation* (Stanford, Calif.: Stanford University Press, 1973), pp. 21–58.
91. "Shell Gets Serious about Alternative Power," *Petroleum Economist*, December 1997, p. 38; and Kimberly Music, "Shell Pledges to Focus on Renewable Energy," *Oil Daily*, October 17, 1997, p. 1.
92. John Browne, *Climate Change: The New Agenda* (London: British Petroleum Company, 1997).
93. Enron Corp., "Enron Forms Enron Renewable Energy Corp.; Acquires Zond Corporation, Leading Developer of Wind Energy Power," Press release, January 6, 1997.
94. Total international energy investment, estimated by the World Energy Council to be \$1 trillion annually, would make planned investments in wind, solar, geothermal, and biopower minuscule. Commercial energy financing only, estimated to be around \$150 billion in 1995 alone, would put nonhydro renewable investment at a fraction

of 1 percent, comparable to the world market share of wind, solar, and geothermal combined. Martin Daniel, "Finance for Energy," *FT Energy World*, Summer 1997, p. 5; and EIA, *International Energy Annual 1996*, p. 20.

95. Shell International Limited, "Shell Invests US\$0.5 Billion in Renewables," Press release, October 16, 1997; and Sam Fletcher, "Shell to Spend \$1 Billion on 3 Deep Gulf Fields," *Oil Daily*, March 20, 1998, p. 1.

96. Quoted in Amal Nag, "Big Oil's Push into Solar Irks Independents," *Wall Street Journal*, December 8, 1980, p. 31.

97. Charles Burck, "Solar Comes Out of the Shadows," *Fortune*, September 24, 1979, p. 75.

98. Paul Gipe, "Removal and Restoration Costs: Who Will Pay?" *Wind Stats Newsletter*, Spring 1997, p. 1. See also Bradley, "Renewable Energy," pp. 20-22.

99. John Berger, *Charging Ahead: The Business of Renewable Energy and What It Means for America* (New York: Henry Holt, 1997), pp. 4-5. This book provides an in-depth look at the personal hardships, financial precariousness, shifting government subsidies, and occasional environmental degradation associated with unconventional energy development in this period.

100. Flavin and Lenssen, pp. 176-77. Biopower can be carbon neutral if its inputs are replanted to create sinks (a "closed loop" system), leaving cost and quantity as the major issues.

101. EIA, *Renewable Energy Annual 1995* (Washington: U.S. Department of Energy, 1995), p. 78; and Bradley, "Renewable Energy," pp. 33-34.

102. *Ibid.*, pp. 26-28.

103. See, for example, Rebecca Stanfield, "Lethal Loophole: A Comprehensive Report on America's Dirtiest Power Plants and the Loophole That Allows Them to Pollute" United States Public Interest Research Group, Washington, June 1998, p. 11.

104. Kenneth Lay, "The Energy Industry in the Next Century: Opportunities and Constraints," in *Energy after 2000*, ed. Irwin Stelzer (Seville, Spain: Fundacion Repsol, 1998), p. 23.

105. Expenditures of the Department of Energy, since its creation, on wind and solar energy have averaged, respectively, nearly 4 cents and 23 cents per kWh produced. Other renewable and fossil-fuel technologies for electricity generation have averaged less than 1 cent per kWh. Bradley,

"Renewable Energy," pp. 55, 63.

106. M. L. Legerton et al., "Exchange of Availability/Performance Data and Information on Renewable Energy Plant: Wind Power Plants," Paper presented to the 17th Congress of the World Energy Council, September 15, 1998, pp. 5-6. This cost estimate is exclusive of major tax preferences.

107. Bradley, "Renewable Energy," pp. 7-12.

108. Adolf Huitti, "Challenges of the Power Plant Market," in *World Energy* (New York: McGraw-Hill, 1998), p. 55.

109. Alliance to Save Energy et al., *Energy Innovations: A Prosperous Path to a Clean Environment* (Washington: ASE, June 1997), p. 37. See also Adam Serchuk and Robert Means, "Natural Gas: Bridge to a Renewable Energy Future," REPP Issue Brief, May 1997. The Department of Energy in its most recent 20-year forecast states, "Low fossil fuel prices are expected to continue to hamper the development of renewable energy sources." EIA, *International Energy Outlook 1998*, p. 5.

110. In 1996 wind and solar plants operated at 22 percent and 31 percent capacity factors, respectively. EIA, *Renewable Energy Annual 1997* (Washington: Government Printing Office, 1998), p. 12.

111. The lower energy loss of natural gas transportation relative to electricity transmission dictates that gas power plants be located close to their market. Wind and solar farms, on the other hand, often have to be away from their market centers and must have their transmission lines sized at peak output despite their low average capacity factor. Ballonoff, p. 47.

112. U.S. Department of Energy and Electric Power Research Institute (EPRI), *Renewable Energy Technology Characterizations* (Pleasant Hill, Calif.: EPRI, 1997), p. 2-1.

113. *Ibid.*

114. The biopower cost estimate is the bottom of the range for existing plants given by DOE and EPRI and a current estimate by the EIA. *Ibid.*; and Roger Diedrich, industry analyst, EIA, conversation with the author, September 1, 1998. For wind and solar estimates, see Pfeifenberger et al., p. 4. See also Bradley, "Renewable Energy," p. 11, for wind power; and Solarex, "Everything You Always Wanted to Know about Solar Power," Company pamphlet, March 1997, p. 3, for solar power. The 6 cents per kWh for wind at ideal U.S. sites with scale economies is exclusive not

- only of the 10-year federal tax credit (approximately 1.7 cents per kWh today) but also of accelerated depreciation (a 5-year rather than a 20-year write-off of capital costs).
115. Flavin and Lenssen, pp. 101-2; and Nelson Hay, ed., *Guide to New Natural Gas Utilization Technologies* (Atlanta: Fairmont, 1985), pp. 323-31.
116. Cler and Lenssen, pp. 13, 28; Gerald Cler and Michael Shepard, "Distributed Generation: Good Things Are Coming in Small Packages," *Tech Update*, November 1996, pp. 14-16; and "Utilities Benefit in DOE Grants for Fuel Cells," *Gas Daily*, August 23, 1996, p. 6.
117. Cler and Lenssen, p. 27.
118. Battery storage devices to hold electricity from ten seconds to two hours cost between \$400 and \$1,000 per kilowatt. DOE and EPRI, p. A-4. Battery costs alone are as much as or more than the installment cost of distributed oil and gas generation, making the competitive viability of intermittent energies decades away at best.
119. Yves Smeers and Adonis Yatchew, "Introduction, Distributed Resources: Toward a New Paradigm of the Electricity Business," *Energy Journal*, Special Issue, 1998, p. vii. See also Robert Swanekamp, "Distributed Generation: Options Advance, But toward What Pot of Gold?" *Power*, September-October 1997, pp. 43-52.
120. Nancy Rader and William Short, "Competitive Retail Markets: Tenuous Ground for Renewable Energy," *Electricity Journal*, April 1998, pp. 72-80.
121. EIA, *Annual Energy Outlook 1998*, p. 57.
122. Of the 17 states that had announced a restructuring of their electric industry as of early 1998, 8 had a renewable quota requirement, 3 had financial subsidies in addition to a quota requirement, and 5 had financial incentives for renewables only. For a list of those states and programs, see Bentham Paulos, "Legislative Help Grows at State and Federal Level," *Windpower Monthly*, April 1998, p. 52, 54.
123. American Automobile Manufacturers Association, *Motor Vehicle Facts & Figures, 1997* (Washington: AAMA, 1997), p. 44.
124. American Petroleum Institute, *How Much We Pay for Gasoline: 1997 Annual Review* (Washington: API, April 1998), p. i.
125. Ibid., pp. ii-iii; and EIA, *Monthly Energy Review*, February 1999, p. 114. In a free-market system, electronic road billing would replace pump taxation as the primary incremental cost of driving, outside of vehicle costs and (free-market) fuel costs. See generally, Gabriel Roth, *Roads in a Market Economy* (United Kingdom: Avebury Technical, 1996).
126. See, for example, a spot check of 25 liquid products at a Philadelphia grocery store in Interfaith Coalition on Energy, "The Cost of a Gallon of Gasoline," *Comfort & Light Newsletter*, Spring 1998, p. 2.
127. A recent advertisement by Mobil described the goal of new-generation refineries as producing "a new breed of fuels that burn cleaner and more efficiently, lubricants that last longer and chemicals that are recyclable" from advanced compositional modeling and molecular engineering (membrane and catalyst technologies). Mobil, "Technology: Transforming Tomorrow's Refineries," *New York Times*, September 17, 1998, p. A31.
128. W. Michael Cox and Richard Alm, "Time Well Spent: The Declining Real Cost of Living in America," in Federal Reserve Bank of Dallas, *1997 Annual Report* (Dallas: Federal Reserve Bank of Dallas, 1998), p. 11.
129. Ibid.
130. See, for example, *New York Times* reprint, "Ford Motor Co. Plans to Reduce Average Price on '99 Cars, Trucks," *Houston Chronicle*, August 11, 1998, p. 4C.
131. Cox and Alm, p. 11.
132. Arthur Cummins, "Diesel Vehicles, in Greener Mode, May Stage Comeback," *Wall Street Journal*, April 9, 1998, p. B4. Mainstream environmentalists overrate the environmental potential of diesel relative to gasoline, citing the lower CO<sub>2</sub> emissions of the former. Carbon dioxide, as will be discussed, is not a pollutant, compared with other emissions that are greater with diesel technology.
133. "Diesel Will Continue to be Heavy-Duty Fuel of Choice," p. 9.
134. Robert L. Bradley Jr., *Oil, Gas, and Government: The U.S. Experience*, (Lanham, Md.: Rowman & Littlefield, 1996), pp. 1744-45.
135. Public Law 96-294, 94 Stat. 611 (1980).
136. EIA, *Annual Energy Review 1997*, pp. 37, 251.
137. American Petroleum Institute, "Alternative Fuels," p. 2.

138. Auto/Oil Air Quality Improvement Research Program, *Final Report*, January 1997, pp. 4, 26–27.
139. Complained Daniel Becker of the Sierra Club, “Ford’s announcement about making cars for which there is not fuel is a cynical ploy to avoid violating a law.” Quoted in Keith Bradsher, “Ford to Raise Output Sharply of Vehicles That Use Ethanol,” *New York Times*, June 4, 1997, p. A1.
140. EIA, *Renewable Energy Annual 1997*, p. 13.
141. National Academy of Sciences, *Policy Implications of Greenhouse Warming* (Washington: National Academy Press, 1992), p. 342.
142. Cannon, p. 2. Farm equipment uses diesel fuel.
143. Public Law 105-78, 112 Stat. 107 at 502 (1998).
144. See, for example, Matthew Wald, “It Burns More Cleanly, but Ethanol Still Raises Air-Quality Concerns,” *New York Times*, August 3, 1992, p. D1.
145. *Methanol: Fuel of the Future, Hearing before the Subcommittee on Fossil and Synthetic Fuels*, 99th Cong., 1st sess. (Washington: Government Printing Office, 1986), pp. 43, 80, 114.
146. *Ibid.*, pp. 52–53; and “Methanol: Alcohol-Based Fuel Has Powerful Ally,” *Houston Post*, September 17, 1989, p. A-14.
147. Charles Imbrecht, Statement, in *Alternative Automotive Fuels: Hearings before the Subcommittee on Energy and Power of the House Committee on Energy and Commerce*, 100th Cong., 1st sess. (Washington: Government Printing Office, 1988), pp. 336–46.
148. American Petroleum Institute, “Methanol Vehicles,” GSA Response no. 464, August 23, 1991, p. 1. Methanol-flexible vehicles would register 40 percent less fuel economy than vehicles using CARB Phase 2 reformulated gasoline.
149. Matthew Trask, “Methanol Power Experiment Called a Failure,” *California Energy Markets*, December 23, 1993, p. 2.
150. CEC, *California Oxygenate Outlook* (Sacramento: CEC, 1993), pp. 19, 65; and CEC, *The California Energy Plan 1997* (Sacramento: CEC, 1998), pp. 18–19, 32–33. The CEC’s first step in abandoning methanol was to state in a December 1995 study that natural gas was overtaking methanol as the alternate fuel of choice in California and elsewhere in the country.
151. Cannon, p. 3-4.
152. Flavin and Lenssen, p. 200.
153. American Petroleum Institute, “Alternative Fuels: Myths and Facts,” August 8, 1995, p. 4.
154. Andrea Adelson, “Not One of Your Big Jump-Starts,” *New York Times*, May 7, 1997, p. C1; Rebecca Blumenstein, “Electric Car Drives Factory Innovations,” *Wall Street Journal*, February 27, 1997, B1; and Rebecca Blumenstein, “GM to Put New Batteries in Electric Cars to Increase Per-Charge Driving Range,” *Wall Street Journal*, November 10, 1997, p. A13. As of 1996, the cumulative private and public investment in electric vehicles was nearly \$1 billion, “roughly equal to half of the National Science Foundation’s entire research budget.” Richard de Neufville et al., “The Electric Car Unplugged,” *Technology Review*, January 1996, p. 32.
155. Peter Passell, “Economic Scene,” *New York Times*, August 29, 1996, p. C2.
156. Quoted in American Petroleum Institute, “Alternative Fuels,” p. 3.
157. Neufville et al., p. 33.
158. Quoted in Dan Carney, “Once on Fast Track to Future, Electric Cars Take Wrong Turn,” *Houston Post*, December 12, 1993, p. A17.
159. Timothy Henderson and Michael Rusin, *Electric Vehicles: Their Technical and Economic Status* (Washington: American Petroleum Institute, 1994), chapter 2.
160. Michael McKenna, “Electric Avenue,” *National Review*, May 29, 1995, p. 38.
161. K. H. Jones and Jonathan Adler, “Time to Reopen the Clean Air Act: Clearing Away the Regulatory Smog,” Cato Institute Policy Analysis no. 233, July 11, 1995, p. 18.
162. Cited in “Science Panel Knocks Hybrid-Electric Cars,” *Oil Daily*, April 20, 1998, p. 1.
163. Internationally, “operating experience with cars using [compressed natural gas] is fairly extensive, going back to the 1920s in Italy.” Robert Saunders and Rene Moreno, “Natural Gas as a Transportation Fuel,” in *Natural Gas: Its Role and Potential in Economic Development*, ed. Walter Vergara (Boulder, Colo.: Westview, 1990), p. 251.
164. Reported one leading company in the effort: “[Natural gas vehicle conversions in the 1970s] died due to . . . oil carry over into the fuel systems and the difficulties of trying to get a mechanically ignited carbureted engine to run on dual fuels acceptably.” Eric Heim, “Pacific Gas &

- Electric," in *Utility Strategies for Marketing Compressed Natural Gas: Proceedings* (Arlington, Va.: Natural Gas Vehicle Coalition, 1991).
165. CEC, *Fuels Report 1995*, p. 53.
166. "NGVs Seen as Average, or Worse, in FedEx Test," *Gas Daily*, April 17, 1995, p. 3. The test was done for 1992-model vehicles.
167. Natural Gas Vehicle Coalition et al., *NGV Industry Strategy*, May 1995, p. 16.
168. EIA, *Annual Energy Outlook 1998*, p. 46. The premium without subsidies is an estimate from Harry Chernoff, senior economist, Science Applications International Corporation, communication with the author, October 13, 1998.
169. Within the alternative-fuel-capable family, methanol (M85) has a 5 percent market share with 21,000 vehicles, ethanol a 3 percent share with 11,000 vehicles, and electricity a 1 percent share with 5,000 vehicles. EIA, *Alternatives to Traditional Transportation Fuels 1996* (Washington: Government Printing Office, 1997), p. 16.
170. *Report of the National Fuels and Energy Study Group*, pp. 297-98.
171. Cannon, pp. 9-10; Joseph Norbeck et al., *Hydrogen Fuel for Surface Transportation* (Warrendale, Pa: Society of Automotive Engineers, 1996), pp. 397-406.
172. C. E. Thomas et al., "Market Penetration Scenarios for Fuel Cell Vehicles," *International Journal of Hydrogen Energy* 23, no. 10 (1998): 949.
173. *Ibid.*
174. *Ibid.*, p. 957.
175. *Ibid.*, p. 949. The authors add, "Government alone has the charter to develop those technologies that will benefit society, including reduced environmental impact and reduced dependence on imported fossil fuels."
176. *Ibid.*, p. 963. This assumes that, on the basis of a 1995 actual 200 million fleet, the total U.S. fleet could be as high as 250 million vehicles in this period.
177. Alliance to Save Energy et al., p. 76.
178. Keith Naughton, "Detroit's Impossible Dream?" *Business Week*, March 2, 1998, p. 68.
179. Steve Plotkin, communication with the author, July 27, 1998.
180. Matthew Wald, "In a Step toward a Better Car, Company Uses Fuel Cell to Get Energy from Gasoline," *New York Times*, October 21, 1997, p. A10.
181. Rebecca Blumenstein, "Auto Industry Reaches Surprising Consensus: It Needs New Engines," *Wall Street Journal*, January 5, 1998, p. A1.
182. California Environmental Protection Agency, "Proposed Amendments to California Exhaust, Evaporative, and Onboard Refueling Vapor Recovery Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles," November 5, 1997, p. 11.
183. "The Third Age of Fuel," *The Economist*, October 25, 1997, p. 16. Optimistic forecasts for hydrogen vehicles have a long—and wrong—history. For example, a study by Frost and Sullivan in 1989 predicted "significant movement" away from fossil fuels to hydrogen by the year 2000. J. E. Sinor Consultants, *The Clean Fuels Report* (Niwot, Colo.: J. E. Sinor, 1990), pp. 102-3.
184. American Automobile Manufacturers Association, *World Motor Vehicle Data* (Washington: AAMA, 1997), pp. 3, 8.
185. EIA, *Annual Energy Review 1997*, pp. 177, 211.
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187. CEC, *California Energy Plan 1997*, p. 30.
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190. *Ibid.*, p. 12. The "sustainable changes" refer to open-access transmission under which customers can purchase their own electricity and outsource their entire energy function to energy service companies.
191. Paul Wuebben, Statement, in *Alternative Fuels: Hearing before the House Subcommittee on Energy and Commerce*, 103d Cong., 1st sess. (Washington: Government Printing Office, 1994), p. 7.

192. Bradley, *Oil, Gas, and Government*, pp. 569–75.
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