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ABSTRACT

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Harold D. Wallace, Jr., PhD, August 2018

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Federal policies have targeted electric lighting since the 1880s with varying success. This dissertation examines the history of those policies to understand policy makers' intent and how their decisions affected the course of events. This qualitative study poses three research questions: How have changes in lamp efficacy affected policy development? How and why have federal policies targeted electric lighting? How have private sector actors adapted public policy to further their own goals? The analysis uses an interdisciplinary approach taking advantage of overlapping methodologies drawn from policy and political sciences, economics, and the history of technology. The concepts of path dependency, context, and actor networks are especially important.

Adoption of electric lighting spurred the construction of complex and capital intensive infrastructures now considered indispensable, and lighting always consumed a significant fraction of US electric power. Engineers and scientists created many lamps over the decades, in part to meet a growing demand for energy efficient products. Invention and diffusion of those lamps occurred amid changing standards and definitions of efficiency, shifting relations between network actors, and the development of path dependencies that

constrained efforts to affect change. Federal actors typically used lighting policy to conserve resources, promote national security, or to symbolically emphasize the onset of a national crisis.

The study shows that after an initial introductory phase, lighting-specific policies developed during two distinct periods. The earlier period consisted of intermittent, crisis-driven federal interventions of mixed success. The later period featured a sustained engagement between public and private sectors wherein incremental adjustments achieved policy goals. A time of transition occurred between the two main periods during which technical, economic, and political contexts changed, while several core social values remained constant. In both early and later periods, private sector actors used policy opportunities to further commercial goals, a practice that public sector actors in the later period used to promote policy acceptance. Recently enacted energy standards removing ordinary incandescent lamps in favor of high efficiency lamps mark the end of the later period. Apparent success means that policy makers should reconsider how they use lighting to achieve future goals.

ELECTRIC LIGHTING POLICY IN THE FEDERAL GOVERNMENT, 1880-2016

By

Harold Duane Wallace, Jr.

Dissertation submitted to the Faculty of the Graduate School of the
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Theodor Mommsen noted that the core of the craft lay in the individual historian's encounter with the sources. Thus, the interpretations expressed in this dissertation are my own, as is the responsibility for errors.

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Abbreviations

ac	alternating current
AEIC	Association of Edison Illuminating Companies
APA	Administrative Procedure Act of 1946
APD	American Political Development
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BLBS	Better Light Better Sight Bureau
cd	candela
CFL	compact fluorescent lamp
cp	candlepower
dc	direct current
DOE	Department of Energy
DSM	demand side management
EEI	Edison Electric Institute
EELB	Energy Efficient Light Bulb program
EISA07	Energy Independence and Security Act of 2007
EPAct92	Energy Policy Act of 1992
EPAct05	Energy Policy Act of 2005
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration

FCC	Federal Communications Commission
FEA	Federal Energy Administration
GE	General Electric Company (US)
GEC	General Electric Company (UK)
HID	high intensity discharge
HPS	high pressure sodium
HSUS	Historical Statistics of the United States
HVAC	heating, ventilating, and air conditioning
ICC	Interstate Commerce Commission
IES	Illuminating Engineering Society
kWh	kilowatt-hour
LBL	Lawrence Berkeley National Laboratory
LED	light emitting diode
lm	lumen
LPS	low pressure sodium
lpW	lumens per watt
NAECA88	National Appliance Energy Conservation Amendments of 1988
NBS	National Bureau of Standards
NEA	National Energy Act
NELA	National Electric Light Association
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Standards and Technology

NMAH	National Museum of American History
OLED	organic light emitting diode
OPEC	Organization of Petroleum Exporting Countries
PCB	polychlorinated biphenyls
PTO	Patent and Trademark Office
PURPA	Public Utility Regulatory Policies Act of 1978
REA	Rural Electrification Administration
SSEB	Solid State Electronic Ballast program
USFA	United States Fuel Administration
V	volt
W	watt
W/cp	watts per candlepower
WPB	War Production Board

Chapter One: Policy History and Electric Lighting

Now I know light bulbs may not seem sexy, but this simple action holds enormous promise because 7 percent of all the energy consumed in America is used to light our homes and our businesses.

—Barack Obama, 29 June 2009[1]

Light is a fundamental human need. People devised many different types of lamps to provide that light before turning to electricity in the latter nineteenth century. In announcing new standards for electric lamps, Barack Obama followed a path taken by federal policy actors since Woodrow Wilson's administration who used electric lighting to advance energy, national security, and economic goals. Electric lighting—popular, flexible, a symbol of modernity—has been an attractive policy tool for several reasons. Measurable energy savings were plausible since the most widely adopted technology, incandescent lamps, exhibited poor energy efficiency compared to other electric lamps.[2] Few companies produced electric lamps, making it easier to enforce regulations aimed at producers. Market differentiation permitted policy makers to design highly specific

1. Barack Obama, "Remarks on Energy," *Public Papers of the Presidents of the United States: Barack Obama, 2009* (Washington, DC: Government Printing Office, 29 June 2009), 1:921, https://www.gpo.gov. For the 7% figure see: Mary Ashe et al., *2010 U.S. Lighting Market Characterization* (US Department of Energy, Office of Energy Efficiency and Renewable Energy, January 2012), 63, http://apps1.eere.energy.gov. Government Printing Office hereafter cited as GPO.

2. *Lamp* refers to the radiating device itself (colloquially called a light bulb or tube) while *luminaire* refers to the fixture that holds the lamp and distributes the light (often confusingly referred to as a lamp). Alvin L. Powell and H. A. Smith, *Lighting Data Bulletin LD 137: Residence Lighting* (Harrison, NJ: Edison Lamp Works, General Electric Company, February 1922), 2.

interventions that affected distinct user groups, allowing for incremental progress toward goals. Significantly, the highly visible nature of electric lighting provided symbolic utility for politicians who not only needed to act in times of crisis but also to be seen by constituents as taking action. Policy actors typically made lighting one part of larger responses to critical events such as fuel shortages, within the limits of contemporary technological development, market realities, and public willingness to accept government involvement in their affairs.

This dissertation examines the history of federal lighting policies from 1880 to 2016, a period that began with the introduction of commercially practical incandescent lamps and concluded with the phase out of the modern version of that lamp.[3] The goals are to understand the decisions people made regarding electric lighting, how those decisions affected the course of events, and if lessons exist for future policy makers. Over time, government involvement with lighting has changed dramatically. Federal officials initially acted only as consumers of products and services but later expanded their involvement with lighting in response to specific national events such as the onset of wars. At first, that involvement was intermittent as events warranted, but by the late twentieth century federal lighting policy became continuous. Sequential policy interventions sought to address long-term national problems, and federal actors became product promoters, standards setters, market regulators, and research investors.

3. Energy Independence and Security Act of 2007, 42 U.S.C. § 17001 (2007). Hereafter EISA07. For debate on the incandescent standards, *Energy Efficiency Standards: Hearing to Receive Testimony on S. 398, a Bill to Amend the Energy Policy and Conservation Act to Improve Energy Efficiency of Certain Appliance and Equipment, and for Other Purposes, and S. 395, the Better Use of Light Bulbs Act: Hearing before the Committee on Energy and Natural Resources*, 112st Cong., 1st sess., March 10, 2011.

The shift occurred as Americans revised the context of national politics, enabling a more assertive federal policy apparatus that sought to manage an industrial economy while taking a more active role in international affairs. Economic depressions and wars created or exacerbated problems that, in several cases, resulted in federal policies that restricted the production and use of lighting devices. Generally the government's protective function justified policy intervention. Aside from blackouts during war, that function included addressing real market failures such as General Electric's stranglehold on domestic lamp production and perceived failures such as residential consumers' refusal to abandon incandescent lamps.[4] Sometimes policy goals were met and other times not, but implementing the policies always presented private sector actors with an opportunity to advance their own goals.

In the chapters that follow, I show the origin of the situation now facing policy makers and provide a larger context in which to place recent developments.[5] I define context as that set of relevant events and circumstances that affect the social environment within which a technology is developed and operated. I pose three research questions (detailed below) that explore federal lighting policy, private sector use of those policies, and the role of efficacy improvements in public and private sector actions. A range of primary and secondary sources ground this historical narrative and include reports, hearing transcripts, trade literature, artifacts, and journal and newspaper articles. The qualitative

4. Leonard S. Reich, "Lighting the Path to Profit: GE's Control of the Electric Lamp Industry, 1892-1941," *Business History Review* 66 (Summer 1992): 305-34. Alan H. Sanstad and Richard B. Howarth, "Consumer Rationality and Energy Efficiency," *Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings 1: Human Dimensions* (Washington, DC: American Council for an Energy-Efficient Environment): http://enduse.lbl.gov, for a discussion of consumer choice failure.

5. Thomas Edison Bulb Act of 2014, H.R. 3818, 113th Cong. (8 January 2014), for one example.

analysis is informed by methods drawn from the history of technology, policy history, economics, and political science. Common methodological concepts that emerged from this interdisciplinary approach help in understanding past events and the significance of those events for policy makers today. The resulting narrative contributes to each discipline's literature and provides a case study useful to all.

This dissertation emphases energy because energy problems underlie most recent lighting policy activities, and have drawn significant public attention with the phase out of general purpose incandescent lamps. In considering the wide range of federal policies that affected electric lighting, I identified two general policy types that allow me to focus on energy issues while avoiding duplication of prior scholars' work. The first type consisted of broadly applicable policies that affected most industries, such as antitrust laws, patents, and government purchases. These broad policies treated lighting as just another technology, and much of their history has been detailed elsewhere, as discussed in the literature review (chapter two).[6] Their details are typically less important that the fact that the actions occurred and resulted in consequences that shaped larger contexts within which policy makers worked to craft the second type of lighting policies. Broad policies are discussed in this study as needed to establish those contexts. The main focus of this study is policies specifically directed at electric lighting, such as fuel use prohibitions and minimum energy-efficiency standards, which may have affected other technologies but

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6. Arthur A. Bright, Jr., *The Electric Lamp Industry: Technological Change and Economic Development from 1800 to 1947* (New York: MacMillan Co., 1949), examined patent cases and antitrust decisions in close detail as did Reich, "Lighting the Path." Wiebe E. Bijker, "The Majesty of Daylight: The Social Construction of Fluorescent Lighting," in *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, MA: The MIT Press, 1995), examined Congressional hearings about fluorescent lamps.

were more selective than the broadly applicable policies. Some of these lighting specific policies have been mentioned in previous work but they have not been examined in a holistic manner.

Throughout this study, I present the lighting industry in terms of producers (who invent and manufacture devices), consumers (who use lighting), and conveyors (who act as intermediaries between the others). These differentiations and some of the groups that comprise them are seen in table 1.1. Policy makers (who are typically outside the industry in any role other than as consumers) must take into account the views and activities of all three groups, while recognizing complications that arise from internal differences within each group, such as consumer groups who adopt specific types of lamps.

Table 1.1: Lighting industry participation groups

Industry groups	Examples of industry group participants
Producers	Lamp manufacturer; Component manufacturer; Lamp Engineer; Lighting Scientist; Inventor
Conveyors	Wholesaler; Retailer; Marketer; Lighting Designer; Specifier / Electrician Electric utility
Consumers	Residential; Commercial / Institutional; Industrial; Municipal / Public space; Theatrical; Architectural

Over fourteen decades, scientists and engineers developed sophisticated ways to make and use electric light, while entrepreneurs and managers built huge industries to supply an ever increasing demand for the product. Researchers improved lamps' energy efficiency (or efficacy) and such improvements often motivated policy actors to use lighting as a means of saving energy on a national scale. Producers repeatedly participated in these policies in order to replace older products with newer lamps of higher efficacy and higher cost. Efficacy often served as the point where policy, technical development, and business goals intersected in the context of larger events. This remains true today as very high efficacy lamps enter the market, changing the direction of research and calling into question previously valid ideas about using lighting to achieve energy goals.

The role of efficacy in electric lighting policy

The first research question asks: How have changes in lamp efficacy affected the development of electric lighting policy? This question looks at the relationship between lighting policy and technology by focusing on energy efficiency. Illuminating engineers use the term *efficacy* to describe the energy efficiency of a given light source. Efficacy represents the light output of the source in lumens divided by the energy input in watts, expressed as lu/W (usually written as lpW). This should not be confused with their use of the term *efficiency*, which refers to how well a lamp produces a given color.[7] Energy, not spectral, efficiency is important for this study so hereafter the term efficiency is used in the common, generic sense. Engineers increased lamp efficacy throughout the timeframe under study, disrupting markets and forcing network actors to accommodate change. Policy makers in several cases sought to address national problems related to fuel supplies and energy consumption by promoting new lamps that gave higher efficacy than existing devices. By doing so they needed to engage with lighting producers, conveyors, and consumers in unexpected ways, because they found the seemingly straightforward technical definition of efficacy open to socially constructed interpretations, not all of which

7. John E. Kaufman and Jack F. Christensen, eds., *The IESNA Lighting Handbook: Reference & Application*, 7th ed. (New York: Illuminating Engineering Society of North America, 1984).

prioritized energy savings.

Like the miles per gallon fuel efficiency ratings of automobiles, lumens per watt efficacy ratings are a major lighting industry standard, yet professionals debated the meaning of the term and their interpretations shifted over time. Many lighting researchers stressed increasing light output while holding energy input constant, while others worked instead to maintain light output while lowering input energy. The former view held sway for most of the twentieth century and the latter came to dominate after the 1970s. For policy makers who wanted to reduce the energy used for lighting, the differing emphasis carried significant ramifications such as increased resistance from certain stakeholders. In addition, many in lighting actor networks placed technical efficacy within larger definitions of energy or economic efficiency, considering lpW simply one among many coequal factors that should not be given preference. As we understand from social constructivist thought, definitions and standards convey power; to implement successful policies, policy actors needed to work within the constraints of predominant definitions, or work to change them. Understanding how the concept of efficacy developed and was incorporated into larger definitions of efficiency improves historical knowledge and provides essential background for new policies intended to address energy issues.

As seen in table 1.2, many ways to make electric light have been invented over the years, and several will be discussed in the chapters that follow. They can be grouped into categories based on operating principles with the most pertinent being incandescent, fluorescent, discharge, and solid state. The incandescent lamps developed by Thomas

Table 1.2: Lamp types by general categories[8]

Technology	Incandescent	Fluorescent	Discharge	Solid State
Specific type	Carbon filament Tungsten filament Tungsten halogen	Linear Circular Compact (CFL)	Low pressure sodium Mercury vapor (HgV) Metal halide (MH) High pressure sodium (HPS)	Light emitting diode (LED)
Approximate Efficacy range (lumens/watt)	2-35	35-120	30-200	3-120 Laboratory units >300
Date of commercial introduction or *major advance	1880 (carbon) *1910 (tungsten) *1913 (tungsten) 1964 (halogen)	1939 (linear) 1946 (circular) 1981 (CFL) *1984 (linear)	1932 (LPS, HgV) 1964 (MH) 1966 (HPS) *1994 (MH, HPS)	1968 *1993

Edison and others in the 1880s revolutionized the way people illuminated their environs.[9]

Incandescent lighting was controllable, scalable, versatile in application, and safer than previous open-flame light sources. Those advantages outweighed incandescent lamps' poor efficacy; they emitted much more heat than light. In the late nineteenth and early twentieth centuries, American engineers and inventors, little concerned with minimizing energy consumption, focused on raising light levels. They were supported by electrical utility managers anxious to boost loads, who even argued that the correct term for energy efficiency should be watts per candlepower rather than candlepower or lumens per watt (discussed in chapter five). Europeans, however, faced higher energy costs and more actively attended to both sides of the lpW energy efficiency figure, developing new incandescent lamps, and then discharge sources like fluorescent lamps that exhibited substantially higher efficacy than incandescents. These European developments put

8. Bright, *Electric Lamp Industry*. Trade literature and subject files, Lighting Research Files, National Museum of American History, Electricity Collections (hereafter NMAH EC-LRF).

9. Bright, *Electric Lamp Industry*, 35-104.

pressure on US lamp makers to produce higher efficiency devices, which they often promoted as giving higher light output rather than using less energy. As producers commercialized these lamps, the improved efficacy gave policy advocates new choices as they advanced energy and environmental goals.[10]

The longevity of incandescent lamps in US homes despite more efficient options is bound up with consumer preferences but also reflects conflicted views on conservation among consumers and producers. The seemingly limitless energy resources available during much of the nation's history meant that most people cared little about energy efficiency.[11] Not until the mid-1910s when the newly industrialized US faced a coal shortage did efficient use of energy become a goal and ideas of conservation begin to take hold. People debated the meaning of conservation, however. Some people argued that conservation called for minimal use of natural resources while others held that the term meant rationally managed use of a resource to minimize waste.[12] That mirrored debates about efficacy: minimized use of energy or increased light levels that enhanced economic productivity and general health.

The first instance of policy makers engaging with the lighting industry to advance energy goals occurred during World War I. Understanding policy change in that and subsequent episodes, consistent with American Political Development methods (APD,

10. Bright, *Electric Lamp Industry*, 368-398. A. A. Bergh and P. J. Dean, *Light-Emitting Diodes* (Oxford: Clarendon Press, 1976), 6-8.

11. David E. Nye, *Consuming Power: a Social History of American Energies* (Cambridge, MA: MIT Press, 1998), 250-251.

12. David E. Nye, *America as Second Creation: Technology and Narratives of New Beginnings* (Cambridge, MA: The MIT Press, 2004), 294-301.

described below), requires placing social views about energy and conservation within the shifting national contexts of fourteen decades. In stages, each lighting market sector moved away from incandescents to higher efficacy lamps until only residential users remained. Now, as federal action eliminates incandescent lamps, lighting researchers interested in higher efficacy are discussing diminishing returns. Achieving further energy gains will therefore require policy actors to view efficacy in another way, perhaps by considering holistic lighting systems rather than just individual component like lamps.[13]

Federal policy and electric lighting

The second research question focuses on federal policies pertaining to electric lighting: How and why have federal policies targeted electric lighting through time? Policy makers have used electric lighting in various ways, often in times of national crisis, demonstrating a range of success and failure. Legislation has mandated efficient products and restricted applications, regulations limited energy use and market power, funding promoted research and development, and the exercise of purchasing power supported markets for new products. As citizens' views on the role of government shifted during the twentieth century, the ability of federal actors to pursue lighting policy changed significantly.[14] Federal lighting interventions went from temporary and limited early in the

13. I thank Robert Horner of the Illuminating Engineering Society for calling my attention to this difference. Personal conversation, 3 March 2016.

14. David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (Oxford, Oxford University Press, 1979); Stephen Skowronek, *Building a New American State: The Expansion of National Administrative Capacities, 1877-1920* (Cambridge: Cambridge University Press, 1982); and Louis Galambos, ed., *The New American State: Bureaucracies and Policies since World War II* (Baltimore, MD.: The Johns Hopkins University Press, 1987).

century to continuous involvement on a much wider scale later on. Many Americans' fundamental distrust of government translated into difficulty obtaining their cooperation in implementing policies, even during times of recognized national emergency. Table 1.3 provides an overview of some of the pertinent national events that proved context and motivation for subsequent policies. Substantive lighting policies, as opposed to purely symbolic initiatives, remained largely invisible to most of the polity, only occasionally reaching the level of serious national discourse, as seen with recent energy standards.[15]

Table 1.3: Selected electric lighting policies and events in US history, 1880-2016

Chapter	Dates	Pertinent national events	Policies affecting lighting
4	1880-1900	Industrialization; civil service reform; Panic of '96	Purchasing lighting systems; DC electrification
5	1900-1920	McKinley assassination; urban electrification; WWI	Standards; lightless nights; advertisement & exterior lighting ban
6	1920-1945	Great Depression; WWII; rural electrification	Blackouts; rural electrification; advertisement & exterior lighting ban; ration materials
7	1945-1973	Cold War; 1965 New York blackout; environmental awareness	Antitrust settlement; research; Air Pollution Control Act, Clean Air Act, Clean Water Act
8	1973-1992	Oil embargoes; environmental awareness; Gulf War	Advertisement & exterior lighting ban; Windows & Lighting Project; TSCA76; CAA90;
9	1992-2016	Electric power restructuring; 9-11; Middle-east wars	Green Lights program; NAECA88; EPAct92; EPAct05; EISA07

As noted above, this dissertation separates federal policies into two types: broadly applicable policies and lighting specific policies. During the first half of the twentieth century broadly applicable policies included the Justice Department's antitrust case that sought to end General Electric's domination of the US lighting market and the National

15. Carroll Pursell, "Seeing the Invisible: New Perceptions in the History of Technology," *Icon* 1, no. 1 (1995): 9-15. This volume includes several different takes on the concept of invisible technology.

Bureau of Standards work with industry to establish illumination standards.[16] Lighting specific policies, the focus of this study, included major initiatives undertaken throughout the period. In both First and Second World Wars, the federal government encouraged "Lightless Nights" and the curtailment of "frivolous" lighting to conserve fuel.[17] New Dealers used electric lighting as one way to encourage participation in electrical cooperatives funded by Rural Electrification Administration loans.[18] During the 1970s the Energy Research and Development Administration (ERDA) sponsored research aimed at pushing new lighting technologies to market, and those programs continued when ERDA was merged into the Department of Energy.[19] Congress passed a series of laws beginning in the late 1980s that affected all sectors of the lighting industry in the name of making the nation more energy efficient. The need to cut pollution as well as address problems in the electric power infrastructure by reducing peak loads and easing strains on over-burdened transmission lines brought minimum efficacy standards that effectively banned the most

16. Reich, "Lighting the Path." Accession 1992.0342, Electricity Collections, National Museum of American History, Smithsonian Institution, an assortment of thirty-one incandescent lamps used in tests at the NBS includes products of at least six different manufacturers.

17. "Sundays and Thursdays Set Aside as 'Lightless Nights'," *Electrical Merchandising* (January 1918): 43. United States Fuel Administration, *General Orders, Regulations and Rulings of the United States Fuel Administration: August 10, 1917-December 31, 1918* (Washington, DC: US GPO, 1919), 532, for a 9 November 1917 order, "restricting the consumption of coal for generating electricity for use in operating illuminated advertisements, notices, signs, etc." "Electric Light Bulbs and Lamps," *Electrical Merchandising* (January 1943): 7, for an example of materials rationing in World War II.

18. Mary Ellen Romeo, *Darkness to Daylight: An Oral History of Rural Electrification in Pennsylvania and New Jersey* (Harrisburg, PA.: Pennsylvania Rural Electric Association, 1986), 59, includes a photo of a symbolic tombstone marking the burial place of an oil lamp.

19. Lawrence Berkeley Laboratory, "A National Plan for Energy Conservation Research and Development Related to Windows and Lighting," 27 August 1976, Energy Research and Development Administration, NMAH EC-LRF.

common incandescent lamps.[20]

Federal legislators and regulators repeatedly adopted policy alternatives aimed at lighting and may continue to do so in the future. Like technologies, policies can display path dependencies (described below) wherein early policy decisions influence later decisions by enabling some options, placing limits on others, or foreclosing some entirely. A policy that removes a product from the market, incandescent lamps for example, makes subsequent policies to revive that product less attractive if producers have ceased making the product. Placing past policies into their respective historical contexts allows one to see the influence of larger national events, and links each policy to the ones that followed. Perhaps most important, reviewing these actions provides insight into policy makers' intent, and how successful they may or may not have been in achieving their goals. While the definition of success varied according to circumstance and the policy actors involved, clearly some policies succeeded and others failed to accomplish stated goals. For example, cajoling the public to curtail exterior lighting proved more difficult than requiring efficient ballasts for fluorescent luminaires.[21] In a larger sense, the adoption of laws and regulations, as well as professional standards, codes, and operating procedures all represent systematized means of social control.[22] Learning how those means of control have changed over time, who changed them and why, provides insight into the interplay of

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20. EISA07.

21. Marilyn A. Brown, Linda G. Berry and Rajeev K. Goel, *Commercializing Government-Sponsored Innovations: Twelve Successful Buildings Case Studies* (Springfield, VA: National Technical Information Service, January 1989), 40.

22. Amy Slaton and Janet Abbate, "The Hidden Lives of Standards," in *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes*, ed. Michael Thad Allen and Gabrielle Hecht (Cambridge, MA: MIT Press, 2001), 95-143.

technology, economics, and politics that continue to affect the development of both lighting technology and policy today.

Private sector utilization of lighting policy

The third research question focuses on a particular consequence of lighting policy that often lies beyond the control of policy makers: How have private sector actors involved with electric lighting adapted public policy to further their own goals? Enacting a law or regulation gives private sector actors an opportunity to undertake activities they might otherwise be unwilling or unable to pursue. Sometimes those activities align with the goals of policy makers, promoting new energy-efficient lamps in the face of market resistance, for example. Other times activities may be at odds with policy makers' goals, such as suppressing a competing technology. Policy actors alert to the opportunities that their alternatives present can use those opportunities to enlist the support of various issue networks as well as forestall negative consequences.[23]

The fact that legislators and regulators can be influenced while crafting laws and regulations is well known and not necessarily harmful. Obtaining expert information and listening to affected groups is essential when designing policies in a pluralistic democracy. Recent work has pointed out the multifaceted and sometimes "paradoxical" practice of standardization in the American state, for example. Technical standardization as negotiated between the private and public sectors is an example of one type of social construct that can serve many purposes. To stay within accepted political bounds, federal actors must work

23. Hugh Heclo, "Interest Networks and the Executive Establishment," in *Public Policy, Theories, Models, and Concepts*, ed. Daniel C. McCool, 262-87 (Upper Saddle River, NJ: Prentice Hall, 1995).

with private actors to promote the standards needed to meet economic or social goals.[24] Understanding how private sector actors have provided input to the policy process is important, but so is understanding the motives that underlie that input. This is important for lighting since policy makers have long sought the input of professional organizations like the Illuminating Engineering Society that are dominated by private sector members.

During each episode of government intervention with lighting, various private stakeholders attempted to adapt the given policy to meet their own needs. Lamp makers repeatedly took opportunities provided by federal policy to replace popular, inexpensive products with newer, more expensive devices in the face of resistance from various groups. In the late 1910s, General Electric used a war emergency to begin phasing out an inexpensive type of incandescent lamp in favor of a more expensive model.[25] Twenty years later GE and Westinghouse used another impending war to push fluorescent lamps onto the market over the objections of electric utilities fearful of reduced power sales, while working to suppress a competing device they did not control.[26] In these and other cases detailed in chapters four through nine, events created opportunities for private sector actors to use federal policies for goals apart from those of policy makers.

Understanding the historical context of different policy episodes is essential in avoiding simplistic notions of cyclical history, and coming to grips with questions of cause

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24. Desmond King and Marc Stears, "How the U.S. State Works: A Theory of Standardization," *Perspectives on Politics* 9, no. 3 (September 2011): 505-518.

25 "United States Fuel Administration's Program for Abolishing Inefficient Types of Incandescent Lamps," *General Electric Review* 21, no. 10 (October 1918): 685.

26. Willard C. Brown, "America is at Work Tonight," *Magazine of Light* 10, no. 6 (August 1941): 4. This issue's cover shows fluorescent lamps lighting a Bell Aircraft Company assembly line.

and effect. In some cases public and private goals were closely aligned, albeit for differing reasons. In other cases, the goals were disparate with both sets of actors taking opportunistic advantage offered by circumstance. Context is not all, however. It is created by and in turn shapes individuals who act in idiosyncratic ways with some acting more effectively than others. Whether they are policy entrepreneurs promoting agendas or policy advocates concerned with implementation, individuals influence the course of history, leading to the need for policy makers to "place" individuals, as Richard Neustadt and Ernest May argue.[27] The situation of corporate actors such as GE, partaking of both public and private sectors, plays a distinct but similar role.[28] Understanding the motivations of interest networks, individuals, and corporate actors provides significant insight into the decisions that affected lighting policy development.

Methodological overview

Technology and policy historians, economists, and political and policy scientists use a variety of methodological approaches as they gather and analyze information, build models, and frame understanding of events. Certain concepts pertaining to time, the roles of individual and group action, and the influence of past events on present options recur when comparing the disciplines' methodologies. Precise definitions vary due to the

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27. John Kingdon, *Agendas, Alternatives and Public Policies*, 2nd ed. (New York: Addison-Wesley Educational Publishers, Inc., 2003), 179-83; Jeffrey L. Pressman and Aaron Wildavsky, *Implementation: How Great Expectations in Washington are Dashed in Oakland* (Boston: Little, Brown 1984), 116-118; and Richard Neustadt and Ernest R. May, *Thinking in Time: The Uses of History for Decision Makers* (New York: Free Press, 1986), 157-195.

28. David Ciepley, "Between Public and Private: Toward a Political Theory of the Corporation," *American Political Science Review* 107, no. 1 (February 2013): 139-158.

differing questions each discipline seeks to answer, but the conceptual overlap creates an interdisciplinary framework for lighting policy. This overview briefly introduces the concepts and notes the intersections. A more detailed methodological review appears in chapter three.

Social constructivism heavily influences current practice in the history of technology, holding that technologies are shaped by the social dynamics within which they exist.[29] People interact with technologies like electric lighting in many ways, adapting to and molding those technologies to meet specific needs. Thomas Hughes's systems approach refined social constructivist thought and presented technological systems as dynamic constructs that exhibited various phases: invention and development, technology transfer, growth, and technological momentum, culminating with the rise of problem solvers.[30] Electric lighting is as such a system and exists within the context of larger technical, political, commercial, and social systems. Actor network theory, a variant of social constructivism, describes interactions between and within groups of participants who must negotiate to attain their goals. The theory helps to define various lighting networks and to understand the internal and external dynamics of network functions within larger socially constructed systems.[31]

Policy and political history methods that view historical concepts such as change

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29. Wiebe E. Bijker, Thomas Hughes and Trevor Pinch, *The Social Construction of Technological Systems* (Cambridge, MA: The MIT Press, 1987).

30. Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: The Johns Hopkins University Press, 1983).

31. Michel Callon, John Law and Arie Rip, *Mapping the Dynamics of Science and Technology* (London: MacMillan Press, Ltd, 1986).

through time as critical factors contribute important insights to this dissertation. The American Political Development school, for example, looks to the state or polity for the locus of policy change rather than focusing on elite politicians.[32] While not dismissing the individual's ability to initiate change, the approach helps account for systemic change that comes from groups within the state, bureaucratic agencies for example, or within the polity, such as corporations and professional societies. A refinement of APD, historical institutionalism, relies even more explicitly on historical perspective including the role of context and path dependence. Context shapes, enables, and constrains actors' capabilities to perceive events and define policies.[33] Marc Eisner, for example, posited a sequence of regulatory regimes that have existed in the US and serve as contexts for policies enacted within those eras. Though his regimes differ in detail from those evident in lighting, the idea of periodization in general provides a useful way to understand how lighting policies differ in scope and success over time.[34]

John Kingdon described a model of policy formation and agenda setting he called the Garbage Can approach to account for instances of sudden, unexpected policy shifts that neither rationalist models nor Charles Lindblom's theory of incrementalism could adequately explain. Kingdon's theory, a form of punctuated equilibrium, to borrow a term from the physical sciences, will be detailed in chapter three. Suffice here to say that his model provides for the interaction of differing groups of policy actors each having their

32. Karen Orren and Stephen Skowronek, *The Search for American Political Development* (New York: Cambridge University Press, 2004).

33. Orren and Skowronek, *Search*, 113.

34. Marc Allen Eisner, "Discovering Patterns in Regulatory History: Continuity, Change, and Regulatory Regimes," *Journal of Policy History* 6, no. 2 (1994): 157-87.

special roles, and accounts for the unpredictability of real world events.[35]

Economic concepts are central to this qualitative policy study as electric lamps exist as a private good sold in domestic and international markets. Accounting for government intervention in these markets requires addressing the rationale for that intervention, whether that be redressing market failures like a monopoly, or promoting economic productivity through better use of energy. Standards, for example, can be used to wield political and economic power, hence the importance of examining efficacy ratings and their use in developing energy regulations.[36] The role of markets in determining demand for lighting products and moving those products into particular applications at once constrained and enabled policy makers. Monopoly and cartel behavior, entrepreneurial activity, and externalities such as light pollution are all economic issues affecting the context within which lighting policies have been developed. Nathan Rosenberg examined how technological change occurs, the way historical sequence shapes that process, and the role economic factors play in subsequent developments such as diffusing technologies into markets. He assigned a significant role to path dependence and temporal sequencing for economic theory.[37]

Positive feedback refers to a process by which later decisions are influenced by, and tend to reinforce, the effects of earlier decisions. Early events in a sequence matter a great deal, so knowing how and why lighting regulations enacted in 1988 succeeded helps

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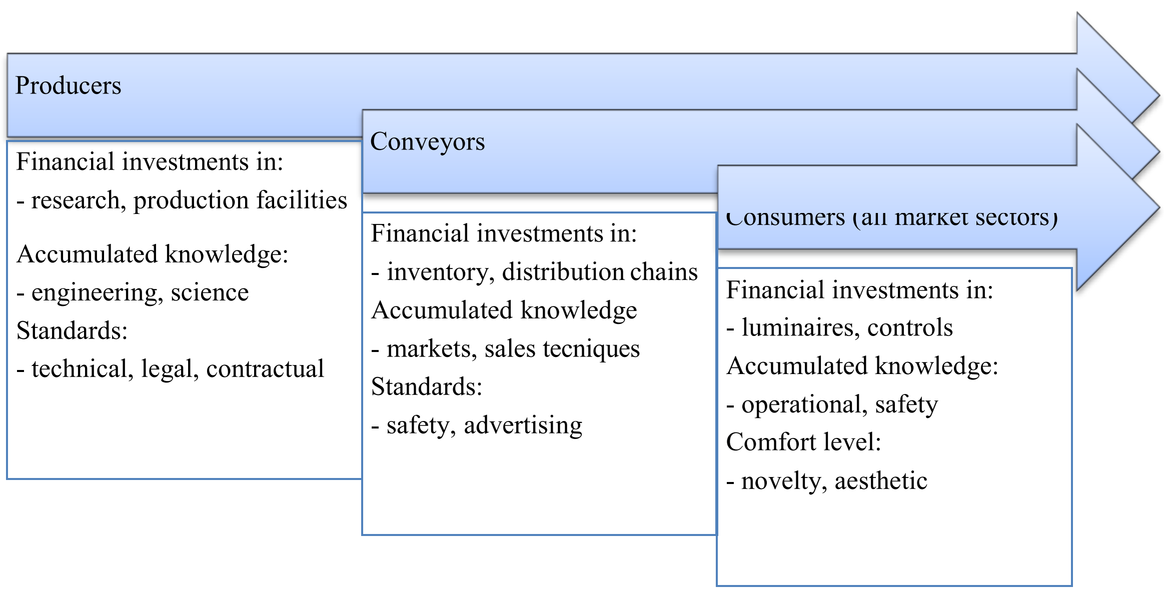
35. John Kingdon, *Agendas.*

36. Slaton and Abbate, "Hidden Lives."

37. Nathan Rosenberg, *Exploring the Black Box: Technology, Economics, and History* (New York: Cambridge University Press, 1994).

one understand subsequent lighting policies. Feedback fuels the process of path dependence; the idea being that choices become progressively more difficult to reverse as the effects of investments, standards, procedures, and other actions become more firmly ingrained within a system. Figure 1.1 provides examples of decisions that would be expected to influence path dependencies in lighting. As time goes on some courses of action, like retaining incandescent lamps despite poor energy efficiency, become more probable than others because the political, economic, and social costs of shifting from one path to another grow steadily higher. Path dependence is not inherently deterministic; actors can and sometimes do choose to change paths. The further along a path one goes however, the more difficult and hence the more improbable shifting to an alternate path

Figure 1.1: Factors contributing to lighting path dependencies



These are selected examples of factors that began influencing electric lighting technology and markets when Edison introduced a practical system in 1880. Some factors are economic and others are cultural. All represent decisions that constrained policy makers' attempts to use lighting to advance their goals.

becomes, complicating policy actors' goals.[38]

Overlapping methodological concepts form the interdisciplinary core upon which this dissertation is constructed. These include role of the contexts within which decisions are made, path dependence and sequencing, and the social dynamics of policy actors, whether individuals or groups. Although the concepts may differ in detail, they all apply to policies affecting electric lighting.

Chapter overview

The literature review and the discussion of methodologies appear as chapters two and three, respectively. Chapters four through nine each detail a successive period in US history from 1880 through 2016, generally bounded by momentous national and international events, as briefly outlined below. In all but the first period, these events led federal actors to develop policies that used lighting to address problems, often related to energy. In each period, important developments in technology raised lamp efficacy and gave policy makers new options to consider. Focusing on lighting-specific policies allows comparison of decisions taken in different circumstances, while the chronological structure helps to show the path dependencies that developed as technical and economic structures matured. Each substantive chapter is organized in five sections: an introduction to the period, a discussion of pertinent technology, two segments in chronological order that present the history, and a conclusion that summarizes the events and policies presented in that chapter. Chapter ten reviews the research questions, presents findings, and suggests

38. Paul Pierson, *Politics in Time: History, Institutions, and Social Analysis* (Princeton, NJ: Princeton University Press, 2004).

possibilities for future research.

Chapter four covers the years 1880 to 1900, during which several firms introduced electric lighting systems based on carbon filament incandescent lamps. Standards set in that period continue in use today, and economic decisions made by managers and investors founded path dependencies that shaped markets for lighting and electricity. Local and state governments rather than federal officials enacted lighting policy during this era and the private sector focused their activities on those levels. Most federal involvement with lighting lay in purchasing equipment for government buildings and the District of Columbia. Stephen Skowronek called the political system of this era, a "state of courts and parties." That situation began to change in the 1890s, as advocates for a professional rather than a patronage system of governance started to reorganize the federal policy apparatus.[39] The background for those changes included economic turmoil stemming from industrialization and urbanization, the growing political influence of Progressives, and a more assertive American presence in the world. Amid those changes the lighting industry consolidated; investors created General Electric (GE) in 1892.

Chapter five discusses the years 1900 through 1920, when the federal government showed more interest in energy matters and electric lighting. Progressive philosophy brought a scientific approach to governance that influenced federal planning and laid the groundwork for policy interventions when the nation entered World War I.[40] Two federal agencies were especially important for lighting: the National Bureau of Standards (NBS)

39. Skowronek, *Building*, 165-166.

40. Michael McGerr, *A Fierce Discontent: The Rise and Fall of the Progressive Movement in America* (New York: The Free Press, 2003).

and the US Fuel Administration (USFA). NBS promoted standardization and research as the industry professionalized and GE established dominance in lighting markets. Heated debates between scientists and engineers about the meanings of efficacy and efficiency began during this period, setting the tone for such discussions for the rest of the century. Ongoing coal shortages due to labor unrest and railroad chaos provoked fears of shuttered factories and freezing homes that focused federal attention on fuel policy. The USFA enacted "lightless nights" and other wartime restrictions to shift coal from lighting to other uses, and supported an industry proposal to ban carbon incandescent lamps in favor of tungsten lamps that gave thrice the energy efficiency. GE used the opportunity to rationalize production lines and phase out the popular carbon lamps, extracting itself from a marketing bind of its own making that interfered with product diffusion.[41]

Chapter six presents the years from 1920 through 1945, when the government at first dropped lighting regulations, and then revived those policies during the Great Depression and World War II. At first, efforts to recover from the Depression followed Herbert Hoover's ideas about volunteerism in which the government facilitated but did not mandate beneficial policies, but those efforts fell short. Many citizens' desire for an active federal response brought Franklin Roosevelt to the presidency, and a program of rural electrification that used electric lighting to encourage people to form electric cooperatives. New lamps that emitted light from energized gases became commercially practical during this era. Fluorescent lamps in particular raised efficacy levels such that electric utilities

41. "Sundays and Thursdays Set Aside," 43. "United States Fuel Administration's Program for Abolishing Inefficient Types of Incandescent Lamps," 685-688.

exerted pressure on lamp producers to suppress white light lamps.[42] As they had 20 years before, those producers used an impending war emergency to push an efficient but expensive technology onto the market. Government policy makers anxious to speed industrial recovery and prepare for war accepted fluorescents as a way of conserving energy. The War Production Board promoted one type of fluorescent lamp when the US entered WWII, but worked to suppress a competing type not under GE's control. As in WWI, military authorities struggled to enforce blackouts and outdoor lighting bans in the face of public resistance.

Chapter seven reviews political and economic changes that affected electric lighting from 1946 through 1973, and that period represents a key transition for lighting policy and the industry as a whole. Legislators passed the Administrative Procedure Act in 1946 that revamped the context within which federal policy actors worked by giving executive agencies a formal structure within which to regulate affairs in their purview. A booming economy, fueled by optimistic consumers and Cold War military spending, created a growing demand for energy. GE lost control of the domestic lighting market in 1953, while international markets adjusted to the demise of an international cartel that had controlled the lamp trade.[43] The onset of competition led GE to develop several novel light sources for niche markets that later helped meet demand for high efficacy lamps. During the 1960s the cost of electricity began rising, and the power industry struggled to meet

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42. Bijker, "Majesty of Daylight".

43. Reich, "Lighting the Path," 305-34, 331-332. Robert Jones and Oliver Marriott, *Anatomy of a Merger: A History of G.E.C., A.E.I., and English Electric* (London: Jonathan Cape Ltd., 1970), for a detailed account of the Phoebus cartel.

surging demand as technological stasis hindered their ability to grow through the introduction of new technology.[44] At the same time, public concern about pollution brought a new set of actors to lighting policy, especially the Environmental Protection Agency. The emergence of environmental awareness among the polity and the end of declining electric rates set the stage for a new era in federal lighting policies aimed at improving the efficacy of lamps and regulating lighting design.

Chapter eight looks at federal policies enacted between the 1973 oil embargo and the early 1990s, a period that began with consumers hastily removing lamps from sockets to save energy. Twenty percent of US electric power was generated with oil in 1973 and rising fuel costs prompted policies such as Richard Nixon's call to reduce "wasteful lighting." Lamp makers rushed to market with old ideas to improve efficacy and accelerated research on new ideas. Illuminating engineers adopted a new approach to lighting recommendations, reversing decades of support for ever higher light levels. Two government led projects, one to produce an efficient fluorescent lamp ballast and the other to design an efficient replacement for incandescent lamps, helped push the lighting market in new directions.[45] During the 1980s oil prices dropped but electricity prices remained high, and the electric infrastructure grew increasingly stressed.[46] To cope, many utilities

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44. Richard F. Hirsh, *Technology and Transformation in the American Electric Utility Industry* (London: Cambridge University Press, 1989), 2-3 for technological stasis.

45. Rudolph Verderber, David Cooper and Donald K. Ross, "Testing of Energy Conservation ofElectronic Ballasts for Fluorescent Lighting: Review of Recent Results & Recommendations for Design Goals," (project report, Department of Energy, circa 1980). "Should DOE Pursue Further Development and Commercialization of the Electrodeless Fluorescent Lamp?," (internal report, Department of Energy, September 1978).

46. Barry M. Casper and Paul D. Wellstone, *Powerline: The First Battle of America's Energy War* (Amherst, MA: University of Massachusetts Press, 1981).

enacted demand side management programs that included subsidizing consumer purchases of compact fluorescent lamps (CFLs).[47] An unexpected need to remediate a hazardous substance and high electricity prices led many commercial users to replace old fluorescent fixtures, boosting demand for new energy efficient ballasts. Political compromise resulted in energy standards for a few lighting devices in 1988, setting the stage for incremental expansion of those policies in the coming decades.

Chapter nine examines policies from 1990 to 2016, focusing primarily on three pieces of legislation: the Energy Policy Acts of 1992 and 2005 (EPAct92, EPAct05), and the Energy Independence and Security Act of 2007 (EISA). These laws represent a continuous dialog between legislative, executive, and private sector actors. The context for that dialog included state level restructuring of electric power markets, presidential agendas that alternated between energy and environmental concerns, and the aftermath of the September 11th crimes. The global lighting market consolidated when Philips, Osram, and GE purchased companies in each other's territories. EPAct92 enacted standards that cleared the market of inexpensive fluorescent lamps in favor of expensive, efficient lamps, followed by standards in EPAct05 and EISA07 affecting other lamps.[48] A new generation of engineers and designers entered practice viewing lighting as a holistic system within a building's total energy budget.[49] A breakthrough in material science led to light emitting

47. "Commercial-Sector Demand-Side Management Activities," *EPRI Journal* 10 (November 1985): 63.

48. Jack Lindsey, "Green Lights + EPACT = Increased Business Opportunities," *Electrical Contractor* 60, no. 4 (April 1995): 11.

49. R. Clear and S. Berman, "Economics and Lighting Level Recommendations," *Journal of the Illuminating Engineering Society* 22, no. 2 (Summer 1993): 77-86. Kathryn M. Conway, "Lighting Makeovers: The Best is not Always the Brightest," *Home Energy* 11, no. 6 (November/December 1994): 20-25.

diodes (LEDs) that could produce white light at unprecedented efficacy levels, triggering a technological revolution.[50] Lamp makers again took advantage of policy opportunities to retire old equipment and push expensive new lamps, while policy makers finally succeeded in retiring the descendant of Edison's incandescent lamp.

Significance of lighting policy

Illumination has always been a fundamental human need and policies that affect lighting, like policies affecting food and water, take on special significance. Torches, oil lamps, and candles date to ancient times, while nineteenth century gas lighting taught people early lessons about networked systems.[51] Demand for better lighting motivated inventors and investors to design and market practical electric lighting systems in the late nineteenth century.[52] Widespread acceptance of their work generated profits and spurred development of other applications for electricity, promoting the growth of power networks. Electric lighting came to be a visible metaphor for invention, progress, and modernity.[53] Yet this inherently visible technology has become largely invisible as today's users casually flip a switch to obtain light but take conscious note of the system only if it fails to

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50. Bob Johnstone, *Brilliant! Shuji Nakamura and the Revolution in Lighting Technology* (Amherst, N.Y.: Prometheus Books, 2007).

51. Leslie Tomory, *Progressive Enlightenment: The Origins of the Gaslight Industry, 1780-1820* (Cambridge, MA: The MIT Press, 2012).

52. Harold L. Platt, *The Electric City: Energy and the Growth of the Chicago Area, 1880-1930* (Chicago, IL: University of Chicago Press, 1991).

53. William J. Hausman, Peter Hertner and Mira Wilkens, *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878-2007* (New York: Cambridge University Press, 2008), 1-8.

function.[54] The failure might simply be a burned-out lamp, but often indicates some electrical malfunction not caused by lighting. Regardless of the cause, the sudden loss of light angers and inconveniences people; a reaction that policy makers ignore at their professional peril. Given the profound effects, few events rouse the American polity as predictably as a blackout.

The effects of a blackout are profound because the infrastructure that supports electric lighting is critically important for America's technology-dependent society, so policies affecting that infrastructure are equally critical. Today's continental system of generating plants, substations, and wires started as a few scattered electric lighting systems in the years around 1880. As engineers and investors expanded the systems, they cultivated additional uses for the power they generated and the percentage of electricity used for lighting declined, although lighting retained its symbolic stature.[55] Being able to "keep the lights on" provides an important marker for tracking the technical health of an electrical system, and by extension the functional health of its society.[56] When power systems reached technical limits or external factors like fuel shortages impacted operations, lighting not only provided a visible indication of a problem but also a visible target for policy intervention. Outdoor advertising is a prime example of a lighting application repeatedly

54. Pursell, "Seeing the Invisible."

55. US Department of Energy, Energy Information Agency, "Electricity Net Generation: Electric Power Sector by Plant Type, 1989-2009," *Annual Energy Review 2009* (Washington DC: Department of Energy, 2009), 232, http://www.eia.gov. For the symbolism of lighting see Bernard S. Finn, "The Incandescent Electric Light," in "Bridge to the Future," ed. Margaret Latimer, Brooke Hindle and Melvin Kranzberg, *Annals of the New York Academy of Sciences* 424 (1984): 247-263.

56. Michael E. O'Hanlon and Ian Livingston, "Electricity," *Iraq Index: Tracking Variables of Reconstruction & Security in Iraq* (Washington, DC.: Brookings Institution, July 2012), 10, http://www.brookings.edu. A criticism of the US reconstruction effort in Iraq was that reliable electricity production did not exceed prewar levels until four years after the 2003 invasion.

targeted by federal policy makers seeking to conserve energy. During much of the twentieth century lighting consumed about 20 percent of the electricity generated in the US annually, so lighting restrictions seemed a reasonable alternative for policy makers to consider.[57]

Lighting policy thus became important within larger policies related to national energy efficiency and several actions, EPAct92 for example, promoted new, high efficacy lamps as one step to address energy problems. However, views within the lighting industry of energy efficiency in general and technical efficacy (lumens per watt) in particular shifted over time; a shift in line with social constructivist thought. Many people involved with lighting defined higher efficacy as providing more light per given unit of energy, while others sought to provide a constant level of light using less energy; a subtle but significant difference. Additionally, technical efficacy was initially one among several equally important criteria used to evaluate competing electric lamps but later became the primary focus in efforts to advance larger goals of lighting system efficiency. In the past, policy makers needed to deal with this shifting definition in order to achieve their goals of reducing energy consumption. Future policy makers will need to reevaluate the applicability of efficacy for new energy policy alternatives since the definition seems to be shifting again. Lamp efficacy has been discussed from an engineering perspective in technical publications but understanding lighting policy requires a focused treatment examining the socially constructed nature of the term within its historical context. That approach to efficacy is currently lacking in the extant literature.

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57. Ashe et al., *2010 U.S. Lighting Market Characterization*, 63. The 18% is lighting's share of US electrical energy; the 7% figure cited by President Obama is lighting's share of total US energy use.

Lighting policy is significant in part because lighting affects everyone, but in differing ways. Lighting applications for residential, commercial, industrial, and municipal sectors present differing technical, economic, and political opportunities as well as differing challenges. Policies to influence energy efficiency in or with lighting must be nuanced and take those different markets into account. A policy to promote energy efficiency in commercial buildings by upgrading luminaires, for example, may be more politically palatable than a similar policy aimed at residential users since the affected group is accustomed to making cost-benefit decisions about lighting. Yet a policy aimed at home owners may result in lower national energy consumption due to the higher level of energy wasted in incandescent lamps. Making choices about policies like these requires input from those well-versed in the details of lighting technology and economics. However, illuminating engineers, the technical experts to whom policy makers should look for advice, can and have disagreed, like any other group of people. The issue of how much light constituted too much, for example, generated debate within lighting actor networks in the 1970s just as a policy window opened and policy makers needed their advice. The internal professional debate became public, resulting in confusion about how or even whether to make specific policy recommendations. Policy makers should thus consider the social dynamics of the lighting profession when crafting policies, especially as individuals and organizations enter and exit actor networks.

In 1993, Hugh Davis Graham discussed two types of policy history: the history *of* policy, and the use of history *in* policy.[58] This dissertation is intended to provide the

58. Hugh Davis Graham, "The Stunted Career of Policy History: A Critique and an Agenda," *Public Historian* 15 (Spring, 1993): 21.

former but, given the significant consequences of lighting policy, it should also be useful for that latter. An examination of lighting-specific policies spanning the electrical era and emphasizing energy efficiency fills gaps in the existing literature useful for historians in several fields including policy, economics, technology, and the environment. While the importance of electrification has been well recognized by historians, fewer works have dealt with the history of electric lighting and seldom in a comprehensive manner. The actions of various lighting companies and organizations reveal economic and political relationships as various actors took advantage of political windows of opportunity to advance their goals. Most importantly, this dissertation shows the long relationship between national energy policy and electric lighting development.

Significance of policy history

The chapters that follow place electric lighting policies in the context of US energy policy and the nation's electrical infrastructure. For policy participants, the significance lies in reviewing how specific policies targeted the same energy-using technology, lighting, with varying degrees of success. This includes understanding the larger technical, economic, and political contexts within which decisions were made in a given era; information useful in thinking about ideas for future policy alternatives. As John Kingdon noted when discussing the role of ideas in policy making, "the content of the ideas themselves, far from being mere smokescreens or rationalizations, are integral parts of decision making in and around government. ...Government officials often judge the merits of a case as well as its political costs and benefits."[59] While he does not mention historians, history does play a role in informing ideas if the history is deemed pertinent by policy actors. More than mere window-dressing, clearly and concisely presented history can be useful in public policy discourse to reveal past trends, prior attempts to address problems, and changes in contexts that may enable new alternatives.[60]

As Otis Graham wrote, problems of analysis and implementation have arisen not because policy makers failed to use history but because they often used it poorly. "Policy error comes often in the form of a surprise from some impinging factor or factors whose bearing upon one's own narrower plans, indeed whose very existence, was often screened out of the analysis."[61] Richard Neustadt and Ernest May noted that policy makers who looked for lessons in the past often accepted analogies uncritically, heedless of changed circumstances. They failed to appreciate the unique nature of historical events that arise from shifting contexts and changing personalities and abhorred the ambiguity that arose from incomplete historical data.[62] Neustadt and May discussed how policy makers could profit from historical perspective and proposed generalizable ways "to get more history used better." Building on several of their suggestions, this dissertation gives those considering lighting policies useful information for avoiding false analogies as well as a

59. Kingdon, *Agendas*, 125.

60."Social science evaluations of [federal] research projects are virtually non-existent or, worse yet, are window-dressings for decisions already made." John Cloud, "Discerning the Relation Between American Science and American Democracy," review of *Science in the Federal Government*, by A. Hunter Dupree, *Technology and Culture* 48, no. 3 (July 2007): 593.

61. Otis L. Graham, Jr., "The Uses and Misuses of History: Roles in Policymaking," *Public Historian* 5 (1983): 11.

62. Neustadt and May, *Thinking In Time*.

better understanding of the relationships between the people, technology and institutions of the lighting industry.[63]

True, Hugh Davis Graham cautioned that claiming utility of any historical treatment for policy makers represented a "plausible generalization" given that:

> Historians, [compared to "lawyers and 'hard' social scientists, or to policy analysts"] are cautionary and seem more comfortable with negative advice. [We] are quickest to see what's wrong with politically tempting analogies. You can never step in the same river twice, we say. We refuse to predict.[64]

Indeed this dissertation predicts but little; historians deal in the past and the present, linking the two and leaving the future to others until it becomes the past. However, as Neustadt and May wrote, "[seeing] the past can help one envision the future."[65] The usefulness of a historical study in the policy realm lies in showing how a situation came to be, identifying critical factors and trends, and preparing policy makers to address problems. Andrew Achenbaum wrote that historians can be useful to policy makers,

> by discussing alternatives to the status quo that have been previously proposed but ignored or rejected, and those that have been attempted but failed, applied histories reduce the temptation to pretend that public policies evolve in a predictable or inevitable manner. ... Historical analysis does not resolve the dilemmas caused by competing goals and incompatible priorities, but it does underscore the need to keep perennial value conflicts and enduring social tensions in mind.[66]

Private sector actors have often complained about real or imagined negative

63. Neustadt and May, *Thinking in Time*, 34-90 for the problems of analogy; 157-231 for placing people and organizations; xii for quote.

64. Hugh Davis Graham, "The Stunted Career," 19-20.

65. Neustadt and May, *Thinking in Time*, xv.

66. W. Andrew Achenbaum, "The Making of an Applied Historian: Stage Two," *Public Historian*, 5 (Spring 1983): 45.

consequences of federal policy interventions. In some cases, however, those same companies have remained silent and advanced their own interests, as with energy standards enacted over the past thirty years. Understanding how various participants have used federal interventions to their own ends helps policy actors design palatable alternatives and better balance the interests of business and society in future policies. The recent debate over the incandescent lighting standards is an example of why this study is relevant and timely.[67] That policy was met with derision and resistance by some citizens, a reaction not unprecedented, but most people have moved on to other issues.[68] High efficacy LEDs are rapidly displacing other types of lamps in almost all applications.

The successful result of thirty years' sustained effort means that energy policy must now change to account for that success. That there will be future policies seems clear as policy actors seek ensure energy supplies for twenty-first century America while managing the nation's electrical infrastructure. As policy actors craft those future alternatives, they will likely follow in the footsteps of those whom Otis Graham referred to when he wrote, "[policy makers] were not good at utilizing history, but they were hopelessly addicted to doing so."[69] Policy makers would be well served by learning a few details of lighting history, especially pertaining to previous interactions between producers, conveyors, consumers, and federal policy actors. This dissertation will enable policy makers to use the past well as they contemplate adapting electric lighting to new energy plans.

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67. EISA07, title III, subtitle B.

68. Better Use of Light Bulbs Act of 2011, S. 395, 112th Cong., 1st sess., (2011), http://www.gpo.gov. See also, Diane Cardwell, "Vintage Light Bulbs Are Hot, but Ignite a Debate," *New York Times*, June 7, 2010.

69. Otis Graham, "Uses," 7.

Chapter Two: Literature Review

This interdisciplinary dissertation contributes to bodies of literature that often overlap: political and policy sciences, economics, historical scholarship in those fields, and the history of technology. This chapter reviews literature in those areas as they relate to the electric lighting policy, discusses how those works informed this dissertation, and where the dissertation fits into the literatures. Work that informs my understanding of methodologies is discussed in chapter three. The first section in this chapter examines political and policy history, including specific works of environmental and energy policy. The second section looks at economic literature pertaining to electric lighting as well as economic history. The final section reviews histories written about lighting technology. All three bodies of literature discuss issues pertinent to the three research questions, but in a fragmented fashion. None provide a holistic treatment of lighting specific policies involving energy efficiency and public-private sector interactions. This dissertation provides that treatment, placing those policies in historical context.

Political and policy history

Policy makers in different eras of the twentieth century used electric lighting to advance their goals. How they did so changed during that time due to a variety of factors as will be discussed in the body of this dissertation. Because policy makers in the near future seem likely to continue to use electric lighting, a study of that long history makes an important contribution to the literature. In reviewing the extant literature on political and policy histories, some works used specific episodes in electric lighting to examine larger themes such as environmental policy.[1] A few program reviews also appear that examine specific programs, such as EPA's Green Lights initiative.[2] There is no holistic work that examines the political or policy history of electric lighting, however; nothing that connects the various episodes and puts them in context. This dissertation provides that holistic overview for lighting specific policies.

The role of history in informing and explaining policy development has changed since the mid nineteenth century. Political history once dominated historical studies, but as Karl Marx and others focused on economic causes for historical change, and still others examined social and ethnic groups ignored by prior studies, historians' interest in politics waned. History became an analysis of various groups' experiences rather than a chronicle of elite leaders' decisions.[3] Methodological changes such as social constructivism, gendered studies, and post-colonial approaches widened the scope of historical activities. By the last decade of the 1900s some scholars worried about fragmentation and sought shared spaces in which groups and individuals interacted.[4] Policy history and a revamped political history provided such spaces.

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1. Marc Allen Eisner, *Governing the Environment: The Transformation of Environmental Regulation* (Boulder, CO: Lynne Reinner Publishers, Inc., 2007), for environmental policy.

2. Gilbert E. Metcalf and Donald Rosenthal, "The 'New' View of Investment Decisions and Public Policy Analysis: An Application to Green Lights and Cold Refrigerators," *Journal of Policy Analysis and Management* 14, no. 4 (1995): 517-531.

3. Ernst Breisach, *Historiography: Ancient, Medieval and Modern* (Chicago: University of Chicago Press, 1983); Anna Green and Kathleen Troup, *The Houses of History: A Critical Reader in Twentieth-Century History and Theory* (Washington Square, NY: New York University Press, 1999); John Tosh, *The Pursuit of History* (New York: Pearson Education Ltd., 2010).

4. Mark H. Leff, "Revisioning U.S. Political History," *American Historical Review* 100, no. 3 (June 1995): 853.

Several historical readings inform methodological approaches as well as help establish the context for the events and decisions presented in the following chapters. Stephen Skowronek's *Building a New American State* is one such example. Skowronek developed his ideas about American Political Development (discussed in chapter three) while arguing that the modern American state arose from a fundamental shift in the late nineteenth and early twentieth centuries.[5] He called the US of the former era "a state of courts and parties" in which an active judiciary and locally-based political machines controlled the federal government. Actors who sought to address problems rooted in industrialization worked to create a merit-based bureaucracy.

> Proponents of administrative expansion spoke to all who were fearful of socialists and agrarian radicals but were, at the same time, uncomfortable with making stark choices between support for industrial capitalism and support for democracy. Constructing a national administrative apparatus held the dual potential for promoting the further development of the private economy and providing new rights and guarantees to the average citizen.[6]

Along with growing industrial capacity after the Civil War, Skowronek noted the,

> ...general reorganization of American professional life..... New communities of intellectual competence, socially differentiated and internally ordered, ... [established] formal professional associations, to upgrade standards of professional recruitment and practice, and to build universities that would train specialists and define expertise.[7]

Electrical and lighting specialists were among those new professional communities and interacted with the professional bureaucrats later involved with federal lighting policies. The establishment of professional associations and a professional civil service added to the

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5. Skowronek, *Building*.

6. Skowronek, *Building*, 165-166.

7. Skowronek, *Building*, 43.

context within which federal actors later made policy.

Barry Karl discussed the effect of an evolving American national identity in, *The Uneasy State*.[8] In particular, Karl identified as a "flaw ...our commitment to the autonomous individual as the fundamental element in American democracy." That ideal of individualism placed limits on Progressives, industrialists, and New Dealers and became another part of the national political context. Tensions created by that idealized national identity resonate to this day as seen in recurring friction between large, technical and economic infrastructures and the nation's individualist self-identity. Fundamental distrust of large centralized institutions lay behind many Americans' calls for return to normalcy after both world wars as well as support for antitrust activities to regulate large businesses.[9] Lighting policy is one more example of how the tension between nation and individual manifests, as recently seen by resistance to eliminating incandescent lamps.

Like Skowronek, Ballard Campbell in *The Growth of American Government* also placed the beginning of the transformation of the federal government in the 1880s.[10] He described "polities" that define successive eras: a "Republican Polity" prior to the 1880s, which gave way to a "Transitional Polity" in response to problems of industrialization. A "Claimant Polity" of the mid-twentieth century used government as a positive tool to address national issues, followed by a conservative "Restrained Polity" late in the century that sought to reverse federal growth. Campbell recognized changes in the opportunities

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8. Barry D. Karl, *The Uneasy State: The United States from 1915 to 1945* (Chicago: University of Chicago Press, 1983).

9. Karl, *Uneasy State*, 235-236.

10. Ballard C. Campbell, *The Growth of American Government: Governance from the Cleveland Era to the Present* (Bloomington: Indiana University Press, 1995).

and limits of federal power, and Americans' shifting comfort levels with that power, and those provide context for lighting policy. The types of policy interventions that were possible, and even the basic definition of a given situation as problem or condition, depended on the national political environment. Another shift in political eras, from a Restrained Polity to something else, would affect options for future lighting policies.[11]

Louis Galambos's selection of essays for *The New American State* focused on the growth and operation of federal bureaucracies after World War II.[12] Galambos, like others, attributed expansion of government domestic interventions to industrialization and urbanization. WWII and the Cold War brought further expansion, while the enactment of measures like the Administrative Procedures Act of 1946 sought to keep the bureaucracy "on a short political leash."[13] The essays provided case studies of several post-WWII episodes. Samuel Hays's "The Politics of Environmental Administration," for example, argued that environmental policy represents "a new stage in the evolution of government agencies."[14] Lighting policy occurred in two distinct periods, one before and one after WWII. The essays Galambos selected give insight into the contextual differences between those eras, especially as they pertain to the changing bureaucratic structures.

Reducing lighting's impact on the natural environment, one rationale for recent electric lighting regulations, makes environmental policy literature relevant. Samuel Hays

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11. Some observers speculate that a shift may now be ongoing. David Frum, "The Great Republican Revolt," and Peter Beinart, "Why America is Moving Left," *Atlantic* (January / February 2016), 48-69.

12. Galambos, *New American State*.

13. Galambos, *New American State*, 18.

14. Samuel P. Hays, "The Politics of Environmental Administration," in Galambos, *New American State*, 25.

provided insight into federal policy in *The History of Environmental Politics Since 1945*. This overview of US environmental policy included a look at various policy actors, scientific and economic issues, and the politics involved with defining problems and designing alternatives. Rather than give a chronological review of specific disasters and policies, Hays delved into the changing values that enabled incremental policy interventions that people previously might have rejected,. Hays acknowledged the importance of the "single event," but argued, "the social, economic, scientific and professional context is more far-reaching ... and the event cannot be understood outside that context." Understanding context is essential since, "much that happens today is both closely rooted in what happened yesterday and ... will shape most of what happens tomorrow."[15] Hays did not discuss lighting but his coverage of changing values, tied to energy as a necessary part of urban development, provided valuable perspective.[16]

Environmental policy, generally made by state and local governments before WWII, shifted to the federal level in the postwar period. Joel Tarr's *Search For the Ultimate Sink* described that shift as rooted in technological change that generated too much waste for local disposal methods, becoming regional problems beyond the ability or will of local actors to address.[17] Medical, engineering, and scientific knowledge about long term effects and waste disposal methods developed at different rates, resulting in contradictory expert advice. The interplay between competing experts, local policy actors,

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15. Samuel P. Hays, *The History of Environmental Politics Since 1945* (Pittsburgh: University ofPittsburgh Press, 2000), 3.

16. Hays, *Environmental Politics*, 18.

17. Joel Tarr, *The Search For The Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, OH: University of Akron Press, 1996).

and vested interests motivated federal intervention. Lighting experts experienced a similar contentious period in the 1960s and 1970s when changing beliefs about light levels and energy use hindered their ability to advise policy makers. Simultaneously, issues like light pollution grew important locally and then moved to federal agendas.

Marc A. Eisner's *Governing the Environment* described the establishment of environmental regulation as a command and control activity in the 1970s, based largely in the activities of the Environmental Protection Agency.[18] He then explored the changes in federal approaches in view of regulatory reform efforts made during subsequent years that included inclusion of cost-benefit analyses, and voluntary programs to encourage public-private sector cooperation. One such approach, the reinventing government initiative of the 1990s included voluntary programs important to lighting policy such as Green Lights and Energy Star. Although Eisner concentrated on environmental policy, his approach informed the larger context for cooperative programs between the Department of Energy and lighting companies during the administrations of Bill Clinton and George W. Bush. Eisner reminded readers that, "policy outcomes are the product of a complex set of political-institutional forces."[19] Those forces are seen in the sustained policy engagement between lighting network actors; a key factor in incrementally strengthening energy standards during that time.

Hugh S. Gorman's *Redefining Efficiency* gives an example of how changing

18. Eisner, *Governing*.

19. Eisner, *Governing*, 49.

definitions of efficiency can influence an industry, in this case the US petroleum industry.[20] Gorman argued that pollution, defined by technocrats and engineers as a waste to be eliminated through higher efficiency, became defined after WWII era as a problem in accounting. That shift took place as Americans' grew averse to environmental degradation caused by industrial activity and recognized that greater engineering efficiency did not lead to reduced pollution. The need to internalize a negative externality and to meet government standards led the oil industry to make environmental activities part of their standard operating procedures. That change occurred as illuminating engineers debated their own redefinition of efficiency for different reasons; making a new definition part of their standard procedures. Gorman also described how postwar social and economic changes intruded into arenas previously considered engineers' domain.

Lighting sometimes appears in environmental policy studies about hazardous materials or light pollution, and this dissertation expands that presence by covering the influence of environmental awareness on the formation of lighting policies.[21] Likewise, the history of energy policy covers lighting only in a limited fashion. While definitions of energy policy changed from "fuel policy" to today's meaning in the twentieth century, lighting has been used in such policies throughout.[22] When coal shortages threatened to stall mobilization for WWI, close factories, and freeze city dwellers, federal actors

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20. Hugh S. Gorman, *Redefining Efficiency: Pollution Concerns, Regulatory Mechanisms, and Technological Change in the U.S. Petroleum Industry* (Akron, OH: University of Akron Press, 2001).

21. For example, John M. Chilcott, "Disposal Dilemma," *Lighting Design & Applications* 25, no. 10 (October 1995): 29-31; D. M. Finch, "Atmospheric Light Pollution," *Journal of the Illuminating Engineering Society* 7, no. 2 (January 1978): 105-117.

22. Robert W. Rycroft and others, *Energy Policy-making: A Selected Bibliography* (Norman: University of Oklahoma Press, 1977), 6.

implemented policies that included lighting regulations to save coal for other uses. That and other examples discussed in the following chapters add to energy policy literature.

Literature focused on electrical policy typically discusses lighting in the context of electrification. For example, historian David Nye's *Consuming Power* compared different forms of power that Americans have used, including electricity, but mentions lighting only within that context. Nye compared water and steam power, electric power, the internal combustion engine, atomic energy, and computers to learn how the US "became the greatest power consuming nation in history."[23] For Nye, the social consequences of electrification as conveyed by centralized power were bound-up with other energy systems. "The energy systems a society adopts create the structures that underlie personal expectations and assumptions about what is normal and possible."[24] Policy is one aspect of social interaction with technology and the social nature of policy formation and implementation certainly pertains to lighting policies.

In *When the Lights Went Out*, Nye looked at the social history of blackouts, and the book's title and much of its content refer to the symbolic importance of lighting.[25] While a blackout disrupts routines involving all the electrical devices we rely upon, the loss of lighting evokes fear and awe. The transformation of familiar nocturnal spaces into unfamiliar and often threatening spaces can draw people together (New York, 1965) or unleash pent up anger (New York, 1977). Either way, a blackout means trouble; a sign of

23. Nye, *Consuming Power*, 5.

24. Nye, *Consuming Power*, 7.

25. David E. Nye, *When The Lights Went Out: A History of Blackouts in America* (Cambridge: The MIT Press, 2010).

war during the early twentieth century, a sign of system malfunction more recently. Symbolic “Greenouts” such as Earth Hour call attention to environmental problems. Policy makers have often used light’s symbolism to gain the public’s attention.

In recent times political history and policy history often merged as Campbell noted, “the goal of tracking the history of political power naturally leads to public policy, which refers to the ways that authority and influence were used.”[26] Political actors make policy decisions within their capabilities and are affected by past decisions made by their predecessors. This dissertation shows how changing administrative contexts, as well as interactions of overlapping generations of public and private sector actors, affected policy making in the area of electric lighting.

Economics and technology history

The interplay of economic factors and technological change seen in the history of efficient lighting has been dealt with in a fragmented way in existing literature. Various episodes in lighting history provide examples within larger works, such as in Stocking and Watkins’s examination of cartels.[27] Occasionally a specific episode has been examined in depth from either a historical or a technical standpoint.[28] Much of the existing literature that examines the intersection of economics and technology simply does not treat electric

26. Campbell, *Growth*, 5.

27. George W. Stocking and Myron W. Watkins, *Cartels in Action: Case Studies in International Business Diplomacy* (New York: The Twentieth Century Fund, 1949).

28. Reich, “Lighting the Path,” is an example of the former; Jonathan G. Koomey, Alan H. Sanstad, and Leslie J. Shown, “Energy-Efficient Lighting: Market Data, Market Imperfections, and Policy Success,” *Contemporary Economic Policy* 14, no. 3 (1996): 98–111, http://web.a.ebscohost.com. is an example of the latter.

lighting at all. This dissertation adds to that literature by looking in a holistic fashion at how the public and private sectors have interacted in the area of lighting specific policies, especially as they pertain to energy efficiency. This allows changes to be seen over time within broader contexts of nationally significant events.

There are many ways to approach the economics of electric lighting policies. This study focuses on technology, especially as it pertains to energy efficiency and the choices available to actors in policy networks. The intersection of technology and economics has long been explored; Adam Smith in *Wealth of Nations* wrote of the effects of technology on economics and discussed political ramifications of capitalism.[29] The works of Karl Marx and Friedrich Engels, as much economic history as political tracts, sought to explain the effects of industrialization and capitalism on nineteenth century society. As the consequences of technical change influenced larger national contexts, historians integrated economic thought into their work while economists looked to history for case studies. Economist Nathan Rosenberg understood the need for both, writing that "present activities are powerfully shaped by technological knowledge inherited from the past."[30]

Rosenberg and co-author David Mowery, for example, reviewed how effectively research results were applied to commercial purposes in *Technology and the Pursuit of Economic Growth*. Research is often characterized as basic, a scientific inquiry to reveal fundamental principles, or applied, an engineering activity to resolve specific problems.

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29. Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Roy H. Campbell and Andrew S. Skinner, eds. (Oxford: Oxford University Press, 1976. Reprint, Indianapolis, IN: LibertyFund Inc., 1981).

30. Rosenberg, *Exploring*, 14.

The authors found the actual differences between basic and applied research murky, and rejected the traditional notion of a linear relationship in which the former preceded and fed the latter. The process that links research and commercial utilization is critical and they argued that the institutional structure of the "U.S. R&D 'system'" must be better understood, particularly how it changed relative to shifting national conditions.[31] They held, for example, that neoclassical economic theory underestimated private incentive to invest in basic research by failing to appreciate the costs involved in adapting knowledge for practical use, thus mischaracterizing basic research as a public good. Much of the book reviewed the history of research and development in the US, and they presented the changing place of corporate research labs in competitive industries, the influence of government research, and the role of international partnerships. They did not discuss lighting, but comprehending how invention and innovation happens is important for the history of lighting policies, such as awarding prizes for technical advances. The economic theories they use were grounded in historical context, a necessity for this dissertation.

Paul David and Mark Thomas in *Economic Future in Historical Perspective* intended their edited volume to establish the value of history for economists' and policy actors' everyday practice.[32] They selected short case studies written mostly by economic historians and economists that recount historical episodes to inform issues of interest to policy makers and the public. Three sections examined mechanisms of long term growth,

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31. David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth* (New York: Cambridge University Press, 1991), 3-4.

32. Paul A. David and Mark Thomas, eds., *Economic Future in Historical Perspective* (New York: Oxford University Press, 2003).

the effects of economic regime change, and issues affecting human capital development. Many of those case studies involve technologies, their economic connotations, and the effect of governmental policies. David and Thomas stated a "conviction that it is not just useful but truly vital to think historically about the economic future," and explained that conviction in their largely methodological introduction that includes an economic review of path dependence (covered below in chapter 3).[33] The essays they selected demonstrated a narrative approach to analyzing historical events in the context of economic principles, the type of narrative this dissertation seeks to provide.

One essay, coauthored by Gavin Wight and David, looked at the economic effects of the electric dynamo as a "general purpose technology," and extended that analysis to future productivity growth in information and communications technology (ICT).[34] They noted that the expected economic benefits of an electrically powered factory could not be realized until plant owners retired old equipment. In the US, that did not occur until the 1920s, decades after the introduction of commercially practical dynamos. The delay deferred most economic and societal benefits beyond the horizons of initial investors, and the authors projected similar deferrals for ICT investments. High efficiency lighting is also a technology investment with a deferred payoff given that the current stock of lighting equipment will not be economical to replace until end of service life. Lighting as a general purpose technology shows an inherent combination of budgetary and personal values that policy actors must take into consideration.

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33. David and Thomas, *Economic Future*, 8.

34. Paul A. David and Gavin Wright, "General Purpose Technologies and surges in Productivity: Historical Reflections on the Future of the ICT Revolution," in David and Thomas, *Economic Future*, 135-166.

The history of electric lighting in the US has been deeply affected by a domestic de facto monopoly and an international cartel. Economists George Stocking and Myron Watkins's *Cartels in Action*, provided an in-depth study of how monopolies and cartels worked.[35] They presented nine case studies looking at the production of different goods such as sugar, nitrogen, and steel. One case study centered on the "aggressive" incandescent lamp cartel, an industry described as, "'born with a silver spoon in its mouth'—and reaching always for a bigger ladle."[36] The work explained how GE controlled the US lighting market with restrictive licensing agreements that featured production quotas, predatory pricing, and retail price fixing. They also discussed the international Phoebus Cartel that facilitated the global flow of lighting information while protecting members' domestic markets. "Proponents of the cartel highlight the former [function] and dim the latter."[37] The book was written in the wake of WWII as the cartel was being dismantled and the GE's domestic market control was about to end. Those arrangements, in force for many decades, contributed to the path dependencies evident in the lighting industry. Their removal aided policy makers in shifting that path to one that emphasized energy efficiency as a policy goal.

Another examination of GE's de facto monopoly, Leonard Reich's "Lighting the Path to Profit" is more recent and focused than Stocking and Watkins's work.[38] Reich, a professor of administrative science, described the actions GE took to establish and defend

35. Stocking and Watkins, *Cartels*, 3.

36. Stocking and Watkins, *Cartels*, 8.

37. Stocking and Watkins, *Cartels*, 335.

38. Reich, "Lighting the Path," 305-334.

their market control. Writing in the early 1990s gave him access to materials unavailable in the 1940s and permitted him to assess the effect of the 1953 consent decree. His well-researched article did not discuss federal lighting policy in general, only the antitrust actions. The article provides economic context for this dissertation and a detailed look at the major private sector player during the early twentieth century.

In the *Economics of Regulation* Alfred E. Kahn, reminded readers that, "Regulation, deregulation, competition and various combinations of them are not good and bad in the abstract .....They are merely different ways of organizing economic activity to achieve certain ends. They are all imperfect."[39] As a young PhD economist at Yale, he assisted Stocking and Watkins in the production of *Cartels in Action*. Interested in regulations that affected pricing and service for networked infrastructures like electric power, trucking, and telecommunications, Kahn's discussion informed my views of the interactions between public and private sector actors. For example his, "view of regulation as a sort of a collective bargaining process with the commission mediating between investors and consumers. " if one substitutes legislature or bureaucracy for "commission."[40] Though he did not refer to lighting, the policy actors crafting regulations to enact higher efficacy standards for lamps were in engaged in economic negotiations with producers, conveyors, and consumers alike.

The issue of standards is of long recognized importance, especially when looking at networked technologies like electric power, and devices such as lamps that must function

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39. Alfred Kahn, *The Economics of Regulation: Principles and Institutions* (Cambridge, MA: The M.I.T. Press, 1988), xiv.

40. Kahn, *Economics*, 43.

within such networks. Standards can have a long lasting effect, contributing to path dependency and technological momentum. Electric power and lighting standards have been intertwined from the start; the US voltage standard is 120 volts because of a decision made by Edison in 1879. The frequency standard of 60 hertz was set in part to prevent visibly perceptible flickering in the light from incandescent lamps.[41] Lamp efficacy standards, once solely the concern of lighting engineers and business people, became the concern of policy actors in the mid-twentieth century and later entered public consciousness. Works that examined economic and policy roles played by standards are therefore pertinent to this dissertation.

Historian Ronald Tobey's *Technology as Freedom* described the ways New Dealers hoped to use electric technologies to improve living standards in the course of promoting better housing. He argued "the appropriate historical context for understanding the electrical modernization of American homes is the political history of the nation's housing."[42] Tobey rejected a "consumerism thesis" that ascribed electrical modernization of the home to a series of rational choices made by individuals in private markets while denying the importance of public discourse and progressive policy decisions.[43] Though he did not discuss lighting in great detail, lighting was deliberately used to help sell people on the idea of electrical modernization. His study of how private markets failed to understand and meet the needs of many potential consumers helps inform my understanding of the

41. Hughes, *Networks of Power*, 127-128.

42. Ronald C. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home* (Berkeley: University of California Press, 1996), 6.

43. Tobey, *Technology as Freedom*, 2-5.

rationale behind New Deal market interventions, and those that came later. Modernization of lighting in the US stemmed as much from policy driven market interventions as from individual choices to adopt more efficient lamps. Enactment of minimum lamp efficacy standards in the 2000s, in part to cut pollution from power plants, affected product choices regardless of consumer demand.[44] Tobey's work shows that such recent use of lighting to promote social standards and political agendas has historical precedent.[45]

Historian Janet Abbate's overview of another networked technology in *Inventing the Internet* included a review of how internet standards originated.[46] She demonstrated that defining and adopting standards constitutes an act of social control, empowering those whose standards prevail. Engineers needed to develop standardized hardware and software to allow early mainframe computers to communicate with each other, technically complex additions that required reallocation of resources. Adopting the standards required users, prodded by federal funders, to relinquish some control to gain the benefits of interconnection achieved with the ARPANet, forerunner of the Internet.[47] Abbate describes a similarly contentious development of international standards, as well as the debate over whether standards should be public or proprietary. The issue of who controls standards is important in this dissertation. In order to reduce lighting energy use, policy makers in the latter twentieth century needed to overcome lighting standards that

44. Jackie Olson, "Energy-Efficient Program Surpasses Demand Management Goals," *Home Energy* 7, no. 5 (September/Autumn 1990): 42-43.

45. David E. Nye, *American Technological Sublime* (Cambridge: MIT Press, 1994), 32-43, for one example.

46. Janet Abbate, *Inventing the Internet* (Cambridge: MIT Press, 1999).

47. ARPA: the Advanced Research Projects Agency.

emphasized high light output and power input, standards long accepted by industry as promoting productivity, safety, and profit. Lighting network actors debated who should be allowed to craft standards incorporated into mandatory building energy codes.[48] Tobey's and Abbate's works provided context for the discussion of lighting standards and show one aspect of how policy actors can influence technological development.

Economist Joseph Schumpeter studied how technological innovation influenced economic development, believing that "innovative activities...are the primary generator of economic change."[49] There is little question that electric lighting has significantly affected US economic development and that the reverse is true as well. For example, better lighting conditions led to higher productivity and greater workplace safety, if not to the extent claimed by lamp makers.[50] Another economist, Arthur Bright published two early articles on the economics of fluorescent lighting and considered their high efficacy a negative economic factor, an insight into general thinking at that time.[51] Bright saw fluorescents' lower electricity consumption as an economic loss; rather than meeting "a previously unsatisfied need [the new lamp] is merely a substitute for another product in satisfying an old need. .. A fluorescent installation requires more lamps than an incandescent installation of equal total wattage ... " This view makes sense if one sees power consumption as

48. Stanley H. Pansky, "Lighting standards," *Lighting Design & Application* 15, no. 2 (February 1985): 46-48.

49. Rosenberg, "Joseph Schumpeter: Radical Economist," *Exploring*, 49.

50. Willard C. Brown and Dean M. Warren, *Lighting for Seeing in the Office* (Cleveland: General Electric Company, Nela Park Engineering Department, 1936). One example of claims about increased productivity.

51. Arthur A. Bright, Jr., "Some Broad Economic Implications of the Introduction of Hot-Cathode Fluorescent Lighting," *Transactions of the Electrochemical Society* 87 (1945): 367; and Bright and W. Rupert MacLaurin, "Economic Factors Influencing the Development and Introduction of The Fluorescent Lamp," *Journal of Political Economy* 51, no. 5 (October 1943): 429-450.

positively related to economic growth, and presumes that designers will seek to maintain power consumption rather than lighting levels.[52]

As with the political and policy history literature, the economics literature deals with electric lighting in a very focused way, typically by using specific examples to explore larger arguments. The one work that provides a longer historical overview, Arthur Bright's, *Electric Lamp Industry*, is dated. This dissertation provides a holistic view that places lighting in larger national economic contexts, and shows the development and evolution of path dependencies in the lighting industry.

Electric lighting history and technology

This dissertation provides an account of how policy makers adopted and adapted to changes in lighting technology, and how constructed definitions of energy efficiency affected their policies. The focus on energy efficiency through time does not appear in other lighting histories. Overall, the existing historical literature on electric lighting is sporadic in theme and content, tending to emphasize the late nineteenth century and the work of Thomas A. Edison and his Menlo Park team. Some literature covers the early twentieth century but usually in a narrowly defined way, except for one detailed treatment of the lighting industry published in 1949 and therefore limited. The few works covering the mid and late 1900s tend to be technical chronologies lacking historical context.[53] Unlike most of the works that seek to cover the full run of electric lighting history, this

52. Bright and MacLaurin, "Economic Factors," 429.

53. Raymond Kane and Heinz Sell, eds., *Revolution in Lamps: A Chronicle of 50 Years of Progress* (New York: Upword Publishing Co., 1997), is an example.

study takes a critical rather than a monumental or antiquarian approach. Only one recent scholarly work has attempted to cover the entire period's history but does not specifically treat lighting policy or details of energy efficiency. Several corporate sponsored histories lack critical perspective and generally serve as public relations vehicles.[54]

The most important extant work on electric lighting is Arthur Bright's *The Electric Lamp Industry*.[55] An economist and historian at MIT, Bright covered the industry's origins and its technical and business development in a deeply detailed manner. He included topics such as the effect of new production equipment on productivity, and the relation of scientific research to commercial innovation. European and Asian lighting developments appear only as they influenced the US industry. His deep and well researched treatment of politics and policy focused on patents, tariffs, and antitrust enforcement. Bright detailed the then-ongoing antitrust action against General Electric using publically available sources such as Congressional hearings and court records, but paid little attention to the social consequences of lighting nor lighting design and illuminating engineering as emerging professions. Bright touched on energy efficiency only as one issue among many for engineers, as indeed it was in his time. He mentioned the effects of lighting policies during the World Wars but not how they were crafted or implemented. Bright's work is invaluable for this dissertation as an expert secondary source that covers the broadly based policies, like patents, that help form the context for later policy actions.

No one has attempted to bring Bright's detailed work up to date, but Brian Bowers's *Lengthening the Day* covers the entire period of electric lighting including

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54. James A. Cox, *A Century of Light* (New York: Benjamin Co., 1979), one such corporate sponsored work.

55. Bright, *Electric Lamp Industry*.

developments of the late twentieth century.[56] Bowers, emeritus curator at the London Science Museum, focused mainly on how lamps operate, compared developments in the field, and described the impact of science on research. He discussed inventors and engineers, and how lighting helped influence changes in society, but only touched on the business history and economics. Bowers's earlier book, *A History of Electric Light and Power*, likewise covered technical details but placed lighting development within a chronology of other electrical devices rather than providing an extensive investigation of influences and consequences.[57] Bowers's intended a general overview that called attention to important electric lighting developments and on that level he succeeded, but his wide overview unavoidably lacks depth. He mentioned the Phoebus cartel, for example, but did not explore its influence. Like Bright, Bowers's discussion of energy efficiency is not a central focus but simply one aspect of lamp development. He does not discuss the energy problems of the 1970s in any detail nor talk about lighting policies.

Edison's Electric Lamp: Biography of an Invention detailed the events leading up to and immediately following the demonstration of a successful incandescent lighting system by the Menlo Park team.[58] Technology historians Robert Friedel and Paul Israel made extensive use of original papers and notebooks from Edison's lab to document the inventor's research and attempt to reconstruct this much mythologized event. Their study looked at the technical and social environment of the Menlo Park lab, where Edison and his

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56. Brian Bowers, *Lengthening the Day* (New York: Oxford University Press, 1998).

57. Brian Bowers, *A History of Electric Light & Power* (New York: Peter Peregrinus Ltd., 1982).

58. Robert Friedel and Paul Israel with Bernard S. Finn, *Edison's Electric Light: Biography of an Invention* (New Brunswick: Rutgers University Press, 1986).

team balanced work on a new light and power system with work on telephones and phonographs, among other inventions. They did not discuss policy as indeed, except for interactions with local New York City officials, there was little to discuss. They used Thomas Hughes's systems approach in presenting the lighting development, an approach that influences this dissertation.

Another excellent work that speaks to lighting history and historical methodology was Wiebe Bijker's chapter on the introduction of fluorescent lighting in, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*.[59] Telling the history of lighting was not the intent of the book; the story of fluorescent lamps was used as a case study to show how technical and non-technical issues can influence the invention and diffusion of a device. In this case, electrical utilities concerned about the effect of fluorescents on their equipment and sales figures pressured lamp makers to sell only colored lamps. Utilities deliberately downplayed promoting fluorescent lamps as more efficient than incandescent lamps, fearing that widespread adoption of an efficient lamp would reduce power sales. Bijker, a historian, pointed out that different groups having differing needs constructed conflicting definitions of this product. The role of efficacy lay behind the conflict and Bijker's work served as a guide to this episode (in chapter six).

David Nye wrote *Electrifying America* to discuss social ramifications of electrification, including but not limited to lighting. "In the United States electrification was not a 'thing' that came from outside society and had an 'impact'; rather, it was an

59. Bijker, "Majesty of Daylight," 199-267.

internal development shaped by its social context."[60] Nye discussed how Americans adopted electric lighting and transportation, and how those adoptions led to changes in society. The development of Great White Ways and uses of exterior lighting radically altered the appearance and expectations of nightscapes, for example, especially when linked to commercial applications.[61] The use of lighting by Edison and by the Rural Electrification Administration as an inducement to promote electric power plays on socially accepted symbolism of light. Nye's views on the social context of electrification helps to explain the relationship between electricity and lighting that made such uses effective, an important point for this dissertation.

Specific case studies of electrification such as historian Harold Platt's *The Electric City*, discuss aspects of lighting history as pertinent to the early adoption of electricity.[62] Platt explored the growth of American energy use by looking at the example of Chicago, beginning with competition between established gas lighting companies and new electric lighting companies, and then competition between electric lighting entrepreneurs seeking contracts in the city. Similarly, historian Mark Rose in *Cities of Heat and Light* looked at how gas and electric infrastructures affected the development of Kansas City and Denver.[63] Rose's very first sentence described the first demonstration of electric lighting in Kansas City, and like others he recognized the role of lighting as the introductory electrical service.

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60. David E. Nye, *Electrifying America: Social Meanings of a New Technology* (Cambridge: The MIT Press, 1995), ix.

61. Nye, *Electrifying America*, 29-84.

62. Platt, *The Electric City*.

63. Mark H. Rose, *Cities of Light and Heat: Domesticating Gas and Electricity in Urban America* (University Park: The Pennsylvania State University Press, 1995).

Both authors touched on federal policy in that context and also on issues of efficiency but mainly explored business and social effects of adopting modern energy sources. These works are not intended as lighting histories but show the practical and symbolic importance of electric lighting in the larger social context of electrification. Lighting's symbolic importance went beyond electrification; policy actors' repeated used lighting to promote energy conservation.

Several books on lighting fall into the categories of monumental and antiquarian histories. Often written by engineers or scientists, these works usually provide minute technical details and describe how innovation affected development of a given device. The authors typically make a point of recognizing principle researchers, being sensitive to documenting inventive priority. Works of these types can be important sources of basic information and provide interesting anecdotes but typically lack the contextual background and scope found in critical histories. They are often constrained by personal or professional bias, rarely discussing the failures and dissentions that occur during any development process. Focused on project leaders and individual accomplishments they can overlook institutional and social factors that contributed to making an invention possible.[64] This dissertation in contrast, takes a critical approach to history that asks why events happened and what they meant to the society in which they occurred.

John Howell and Henry Schroeder's *History of the Incandescent Lamp* is an example of the antiquarian model.[65] The authors, lighting engineers at General Electric,

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64. I acknowledge former UMBC history professor GaryBrowne for the differentiation of monumental, antiquarian, and critical modes of history, presented in his Hist723 class on material culture studies.

65. John Howell and Henry Schroeder, *History of the Incandescent Lamp* (Schenectady: Maqua Co., 1927).

wrote a detailed, evolutionary account of Edison's incandescent lamp and the GE products that followed. They mentioned a few of Edison's early competitors, but said little about inventions that did not emerge from the GE research. They discussed efficacy solely in technological terms, how many watts were needed to generate one candlepower. Their work is valuable for technical insight into production equipment and the progress of manufacturing techniques; detailed expert knowledge that would otherwise be lost. These details were not set in larger context nor did the authors discuss non-technical consequences, such as the displacement of labor by improved production equipment.

A more recent example is *Revolution in Lamps* by engineers Raymond Kane and Heinz Sell.[66] Organized taxonomically, the book delves into the technical minutia of each lamp type, carefully credits the innovators, and relies mostly on published technical papers for source material. The role of efficacy is covered as a technical requirement. Documenting this type of information is essential so that the technical knowledge is preserved, and their work is valuable for any researcher looking deeply into lighting technology. However, it lacks the historical scope that asks why a certain invention was made at a given time, as well as the attention to social and economic consequences that a critical history requires.

Francis Jehl's three volume *Menlo Park Reminiscences* is a prime example of a monumental account of early lighting history.[67] Written by a technician who worked for Edison during the incandescent lamp project, the unfinished trilogy paid glowing tribute to

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66. Kane and Sell, *Revolution in Lamps*.

67. Francis Jehl, *Menlo Park Reminiscences*, 3 volumes, (Dearborn: Edison Institute, 1936-1941).

Edison. Jehl was one of the Edison Pioneers, a social organization dedicated to ensuring recognition for the inventor and his accomplishments. The author's biases prevent much of *Reminiscences* from being accepted without significant confirmation from other sources, but the work does have uses. The technical details of experiments and equipment can be considered accurate, eyewitness accounts. Anecdotes of the social life in and around the Menlo Park lab also can be informative. However, normal memory loss and selective editing must be taken into consideration when approaching this work. Like many monumental and corporate historical accounts, *Reminiscences* was intended to commemorate and inspire, and thus avoided asking difficult questions.

Missing from the extant historical literature is a detailed examination of electric lighting policy, particularly as it pertains to energy efficiency. This dissertation is intended to fill that gap. Extant literature discussing energy efficiency in lighting does so from a technical standpoint, namely the concept of efficacy. Literature that presents economic costs and benefits of lighting also tends to be technically oriented, often built on quantitative analyses. Very little policy literature discusses lighting, except for the occasional review of a given program like EPA's Green Lights.[68] Few of these works contain comprehensive historical analysis looking at how and why change occurred over time, and what that change meant. This dissertation relates the history of how different groups perceived and constructed the idea of efficiency, how that constructed idea affected the course of federal lighting policy, and how the private sector made use of those policies. Changes in technology and standards are placed within broader contexts, namely the trends and events that motivated federal efforts to include lighting in national energy policies.

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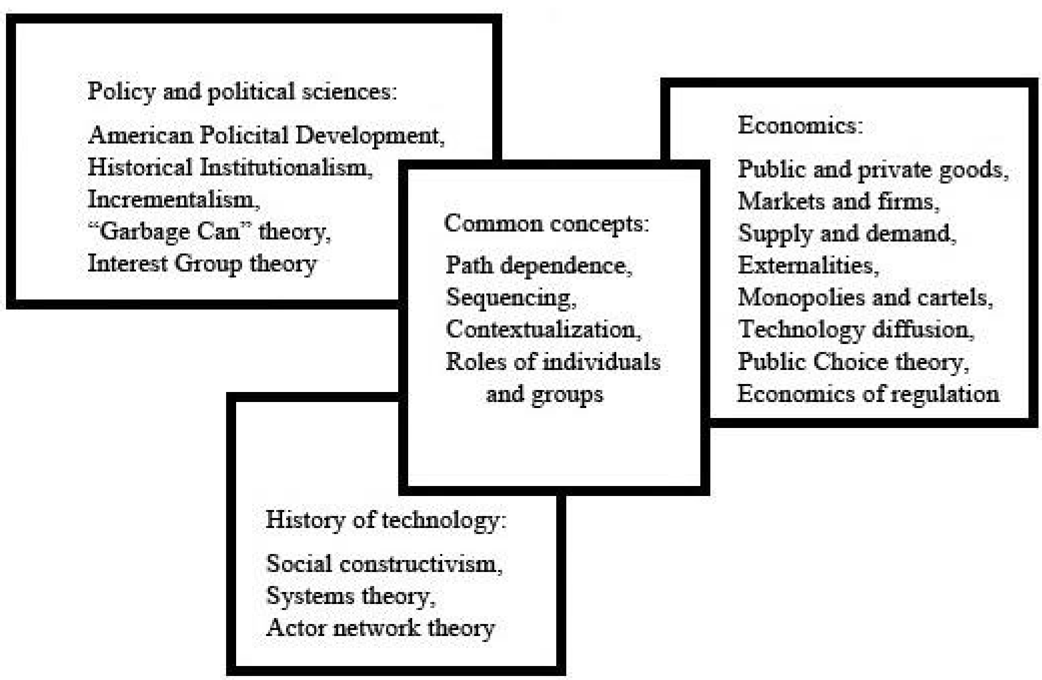
68. Metcalf and Rosenthal, "'New' View," 517-531.

Chapter Three: Methodologies

Scholars use methodologies as intellectual guides to analyze and interpret data. This interdisciplinary dissertation merges methods from political and policy scientists, economists, and historians. History examines change over time, and several inherently historical concepts appear in each discipline, as seen in figure 3.1. These concepts include temporal sequencing, path dependencies, contextualization, and the ability of individuals and institutions to affect change. Though concepts' names and precise definitions vary subtly in each field, they share common ideas. That commonality provides an opportunity to present a history of lighting policy useful to different groups. Pertinent methodological approaches from each discipline that highlight the common concepts are discussed below.

Figure 3.1: Methodologies and concepts showing disciplinary overlaps



Political and policy sciences

This dissertation is influenced by methodological approaches in policy and political sciences that contain important historical concepts. Those approaches highlight the role of people, individually or collectively, in shaping choices and events. They place their subjects within a social context, allowing one to see events as emerging from the social structures and norms within which they exist. Most importantly, they incorporate a dynamic view of change over time, something fundamental for historical understanding and for political and policy studies as well.

Authors of the American Political Development (APD) school relied on history to study groups within the state or a polity as the focus of political change rather than individual leaders. Anne Schneider and Helen Ingram pointed out that groups may be defined in differing ways and these differences can be reflected in policies adopted by a society.[1] Professionals and consumers comprise only two groups important for lighting policy. Karren Orren and Stephen Skowronek's *The Search for American Political Development* described the APD school's approach to historical perspective, noting that "because a polity in all its different parts is constructed historically, over time, the nature and prospects of any single part will be best understood within the long course of political formation."[2] A group such as the Better Light Better Sight Bureau for example, was created, modified, and disbanded within the contexts of events that occurred during its

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1. Anne Schneider and Helen Ingram, "How the Social Construction of Target Populations Contribute to Problems in Policy Design," *Policy Currents* 3, no. 1 (February 1993): 1-4.

2. Orren and Skowronek, *Search*, 1.

existence. The idea of social construction also applies to how those groups are defined by others, as Deborah Stone noted. Such constructed definitions are a part of lighting policy history, as seen by competing definitions of the term conservation and the varying portrayals of groups that hold differing definitions of that term.[3]

A group within the APD school, historical institutionalists, gave special attention to context and the cumulative nature of events. Public and private institutions arise at different times and their functional policies, standards, and rules overlap resulting in friction. The authors referred to this overlap as intercurrence, a cumulative process of layering they called, "pervasive and inescapable."[4] Intercurrence occurred in lighting policy when public agencies' agendas conflicted, as when FCC and DOE views of electrodeless lamps differed, and between private groups as when lighting designers and illuminating engineers disagreed about energy conservation. Ellen Immergut, a professor of comparative politics, described historical institutionalists' view of "causality as being contextual," i.e. a product of interacting events of unclear priority requiring one to understand the environment in which decisions are made. That includes "the large role played by chance" in the course of events, an "accidental combinations of factors that may nevertheless have lasting effects."[5]

Public policy professor Marc Eisner's characterization of "regulatory regimes"

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3. Deborah Stone, "Causal Stories and Formation of Policy Agendas," *Political Science Quarterly* 104 (1989): 2: 281-300.

4. Orren and Skowronek, *Search*, 113.

5. Ellen M. Immergut, "The Theoretical Core of the New Institutionalism," *Politics & Society* 26 (March 1998): 19.

serves as a way of viewing periods within which lighting policy. Eisner compared policy change and institutional evolution during the Progressive Era (that featured a market regime), the New Deal (an associational regime), the early 1970s (a societal regime), and the 1980s and early 1990s (an efficiency regime). These regimes featured diverse political views of government capabilities, problem definition, and agenda setting.

> One can analyze each expansion of regulatory authority as an independent event. However, one can bring order to the history of regulation by identifying particular regimes that have emerged during critical periods in U.S. history. [A regime can be defined as] "a set of principles, norms, rules, and procedures around which actors' expectations converge." ...[and] a regulatory regime [as] *a linked set of policies and institutions that condition the relationship between social interests, the state, and economic actors in multiple sectors of the economy*.[6]

The periodization that emerged from my study of lighting policy differs from these regimes, but his analysis of policy development and change that relies in part on understanding how context constrains and enables political actors was influential.

In *Politics in Time*, political scientist Paul Pierson pointed out that sequencing of events and their duration have a profound impact on real world policies and decisions. "We turn to an examination of history because social life unfolds over time. Real social processes have distinctly temporal dimensions."[7] He presented several concepts for understanding the history's role in explaining policy, including positive feedback and path dependence, both of which I found useful. Positive feedback refers to a process by which later decisions are influenced by and tend to reinforce the effects of earlier decisions. Early

6. Eisner, "Discovering Patterns," 157, emphasis in original.

7. Pierson, *Politics in Time*, 5.

events in a sequence matter a great deal, the success of DOE's solid-state ballast program, for example, influenced subsequent energy standards in EPAct92.

Pierson defines path dependencies as "dynamic processes involving positive feedback, which generate multiple possible outcomes depending on the particular sequence in which events unfold."[8] Defining good lighting as a high light level constituted one important path for lighting. Influenced by technology development and economic circumstances in the early twentieth century, subsequent developments fed that path and could have led in many directions. Path dependence is a probabilistic way of viewing human activities that helps address unpredictability, but is not an inherently deterministic concept. Alternate paths exist that actors do sometimes choose. The further along a given path one travels though, the more difficult and hence the more improbable shifting to an alternate path becomes. The constraints on policy actors tighten as the existing path penetrates deeper into society, raising the costs of shifting paths.

Various models of policy processes developed over the years include the rational-comprehensive model, incrementalism, and a version of punctuated equilibrium called the "garbage can theory." The latter two were especially useful for understanding lighting policy, the former less so. While theoretically sound, rational-comprehensive models presume policy actors have more knowledge, time, and resources than typically available, and fail to account for interactions among policy actors and differing values within the polity.[9] As just one example, technological change in lighting has not occurred

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8. Pierson, *Politics in Time*, 20.

9. Charles E. Lindblom, "The Science of Muddling Through," in Daniel C. McCool, ed., *Public Policy* on a regular, linear basis, and unexpected breakthroughs such as that made in LED technology in 1993 (chapter nine) affected everyone involved with lighting. As will be detailed in chapter six, policy makers knew little of fluorescent lamp development until GE gave the Navy a private demonstration. To push use of the lamp in new defense plants, they needed to overcome resistance from electrical utilities.[10] Examining the course of lighting policy requires a researcher to account for varying rates of change over time, the non-linearity of policy processes, and input from a multiplicity of policy actors.

Incrementalism provides one such potentially useful model. As described by political scientist Charles Lindblom, incrementalism accounts for the observed actions of administrators, the modest rate of most policy change, and allows for the input of many actors. His paper, "The Science of Muddling Through," described the way most policy administrators function as "successive limited comparisons."[11] Lindblom argued that in the workaday world policy actors "expect to achieve their goals only partially," making it unnecessary to absorb all knowledge and consider all options about a given problem.[12] They build upon past decisions and experiences, having learned what is politically and practically feasible, and also knowing that by taking small steps, they can correct errors and refine alternatives over time. All of these factors help to explain the sustained engagement between policy makers and the lighting industry in the latter twentieth

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Theories, Models, and Concepts (Englewood Cliffs, NJ: Prentice Hall, 1995), 144-147, table 3-1.

10. Bijker, "Majesty of Daylight," 199-267.

11. Lindblom, "Science," 142-157.

12. Lindblom, "Science," 143.

century. Yet more is needed since Lindblom's model fails to account for instances of sudden, unexpected change, such as the sudden elevation of energy efficiency on political agendas after the 1973 oil embargo.

Political scientist John Kingdon's garbage can model of agenda setting and policy formation accounts for such sudden change.[13] Based on earlier work that investigated so-called organized anarchies, Kingdon proposed three parallel streams that he labeled problem, policy, and political, respectively.[14] The streams consist of many ideas, actors, and conditions; the content of a given stream varying based on how actors construct definitions.

> Each of these streams has a life of its own, and runs along without a lot of regard to happenings in the other streams. Proposals are hatched in the policy stream whether or not they are solving a given problem; politics has its own dynamics independent of the policy proposals being developed by specialists.[15]

Actors work within the context of their streams, moving in ways that depend on their inherent capabilities within the political system and interacting with others as they go about their business. For example, political appointees can set agendas but need bureaucrats with technical knowledge to design and implement policies. The streams can converge via a policy window that may open for a number of reasons, like a triggering event. Out of that convergence can emerge a new or a significantly revised policy.

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13. Kingdon, *Agendas*.

14. Michael Cohen, James March and Johan Olsen, "A Garbage Can Model of Organizational Choice," *Administrative Science Quarterly* 17 (March 1972): 1-25. Their model recognized the importance of timing in making choices, that solutions can precede problems, and that institutional structure influences decisions.

15. Kingdon, *Agendas*, 227.

The garbage can model lends itself well to the social constructivist approach in the history of technology (defined below). For example, identifying a problem that requires policy intervention depends on constructed definitions. As Kingdon points out, conditions differ from problems. The energy inefficiency of incandescent lamps may be seen as an inherent condition that simply exists until an individual or group redefines it as a problem in need of solution.[16] Kingdon also called attention to the importance of individuals as policy entrepreneurs and as members of interest networks. Such actors play a significant role because historical events are the result of decisions made by people in the context of the institutions in which they operate. Some have objected to various parts of the garbage can model, its lack of predictivness for example, but I found it a useful tool for thinking about differing types of change over time and the role of people in promoting and adapting to changes in their social environments.[17] The differentiation between actors' routine spheres of activity (their streams) aligns well with observed interactions between groups involved with lighting policy, particularly when the streams converged.

The historical sensitivity seen in the writings of the APD school, especially by the historical institutionalists, meshes well with Lindblom's incrementalist and Kingdon's garbage can models. The ideas of sequencing, path dependence, contextualization, and the roles of group and individual actors all appear in these works, and in the history of lighting policy as will be noted in the chapters that follow.

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16. Kingdon, *Agendas,* 109-110.

17. Kingdon, *Agendas*.

Economics

This dissertation uses a qualitative approach to inform a complex topic of electric lighting policy.[18] The qualitative approach serves well for a case study that ideally will complement quantitative approaches that use statistical tools.[19] As Jennifer Platt argued, case studies have rhetorical and logical functions in the social sciences that can work in concert with quantitative investigations. For example, case studies can "aid in understanding by offering an [illustrative] example," reveal "phenomena which would otherwise be cut off from the [target] audience," and "show the effects of a social context... "[20]

Basic economic concepts inform this analysis and connect to other disciplines' methodologies. Electric lamps are a private good traditionally supplied by for-profit companies in ostensibly competitive markets. Consumers in different market sectors adopted lamps most appropriate for their needs, and those lamps demonstrated cost structures reflecting separate research and production investments and levels of demand. Real and perceived market failures such as negative externalities and a de facto monopoly provided one set of reasons for government intervention in lighting markets.

In *Exploring the Black Box*, economist Nathan Rosenberg examined how technological change occurs, the way historical sequence shapes that process, and the role

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18. Earl R. Babbie, *The Practice of Social Research*, 10th ed. (Belmont, CA: Thomson/Wadsworth, 2004).

19. Henry E. Brady and Jason Seawright, "Outdated Views of Qualitative Methods: Time to Move On," *Political Analysis* 18, no. 4 (Autumn 2010): 506-513, http://www.jstor.org. Breisach, *Historiography*, 355-360.

20. Jennifer Platt, "What can case studies do?" *Studies in Qualitative Methodology* 1 (1988): 6, 9.

economic factors play in subsequent developments. Rosenberg saw “a strong degree of path dependence” in the growth of technological knowledge and recognized the need to understand the “sequence of events” when considering economic issues. For Rosenberg, “path-dependent processes are those phenomena whose outcomes can only be understood as part of a historical process” and his views complement the work of policy theorists (like Pierson) and historians (Hughes) discussed elsewhere in this chapter.[21] Rosenberg also discussed economic factors surrounding adoption of energy efficient technologies, particularly in the post-1973 era. He argued that adopting efficient and/or renewable technologies solely for the sake of using less energy per unit output may be counterproductive for a variety of reasons, many of which are historical in nature. For example, because “energy-efficient systems are embedded in expensive and long-lived assets,” one could expect slower adoption rates that otherwise might be seen.[22]

Technology diffusion is an important concept studied by economists and historians alike. In *Diffusion of Innovations*, communications scholar Everett Rogers defined diffusion as, “the process by which an innovation is communicated through certain channels over time among members of a social system.”[23] Rogers used examples including electrical communication media and electric appliances to examine different aspects of diffusion such as the role of time, rates of adoption, and types of adopters. He then explored what he called diffusion networks, paths of communications that spread

21. Rosenberg, *Exploring*, 205.

22. Rosenberg, *Exploring*, 163. Timothy J. Brennan, “Energy Efficiency Policy Puzzles,” *Energy Journal* 34, no. 2 (2013): 1-25, makes a similar point looking at the substitutability of energy and energy efficiency.

23. Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: The Free Press, 1995), 5.

information about an innovation. He found that diffusion often does not proceed in a linear fashion from producer to consumer but can follow a “convergence model,” in which interaction occurs between participants in a diffusion network. Negotiation between producers and consumers over a new lamp, for example, can lead to the invention being rejected, as with the Fusion sulfur lamp described in chapter nine. In this model, federal policy actors are another voice in the diffusion network, negotiating with producers (about efficiency standards) and with consumers (encouraging adoption.) Diffusion networks demonstrate another way that social influences affect technology, similar to actor networks (reviewed below), and interest networks (above.) These models all share an appreciation for information flows between network participants.

Economist Paul Stoneman and various coauthors offered other useful perspectives on technological diffusion. Discussing policies designed to promote diffusion, for example, Stoneman and Paul Diederen noted that “a useful typology of technological change is provided by the Schumpeterian trilogy: invention (the generation of new ideas), innovation (the development of those ideas through to the first marketing or use of a technology) and diffusion (the spread of new technology across its potential market).”[24] These distinctions help frame the discussion even though lighting is a mature technology, not an invention by Schumpeter’s definition. The innovation aspect applies if we adopt a looser definition that includes developments that are not “first marketing or use” but rather later improvements. That aligns better with my understanding of innovation as an adaptation or subsequent improvement of an invention that may refine or differ from the

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24. Paul Stoneman and Paul Diederen, “Technology Diffusion and Public Policy,” *Economic Journal* 104, no. 425 (July 1994): 918, http://www.jstor.org.

intent of the original inventor.

Stoneman and Diederen also call attention to the rate of a technology's diffusion:

> The idea of too fast a rate of diffusion for an economy often causes some consternation amongst policy makers for whom the principle that new technology should be introduced as quickly as possible is almost a statement of faith..... However, in the absence of significant differences between private and social costs and benefits, a rate of diffusion that is too fast could result in firms adopting a technology before it has become profitable to do so or adopting a less well developed or higher priced technology today at the expense of adopting a more developed or cheaper technology in the future.[25]

Lamps for different applications diffused into the economy at differing rates. Also, policy makers carefully designed legislation in 2007 to avoid suppressing light emitting diodes in favor of mature compact fluorescent lamps. Stoneman and Myung-Joong Kwon noted the effect of associated technologies on diffusion rates:

> ...most of the past literature on technological diffusion has been exclusively concerned with individual technologies considered in isolation from other technologies that may at the same time be either in use or on their own diffusion path. However, one may well expect that there exist interconnections between technologies such that the diffusion of any one technology is not independent of the diffusion of another technology.[26]

This effect has also been seen with energy efficient lighting. Diffusion of compact fluorescent lamps depended on reducing the cost of rare-earth phosphors also used in color television tubes, connecting the two technologies. Likewise, simultaneous adoption of power electronics by car makers, ballast makers, and others linked the rate at which those products diffused into markets by increasing demand and thus short-term prices (both

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25. Stoneman and Diederen, "Technology Diffusion," 919.

26. Paul Stoneman and Myung-Joong Kwon, "The Diffusion of Multiple Process Technologies," *Economic Journal* 106, No. 423 (July 1996): 420-431, http://www.jstor.org.

examples discussed in chapter eight).

Regulation of markets by government policy is central to this dissertation especially as it affected interactions between the public and private sectors. Economic historian Thomas McCraw wrote, “[regulation] in America has been a multi-functional pursuit ... Regulation is best understood as an institution capable of serving diverse, even contradictory ends, some economic, some political, some cultural.”[27] Economist George Stigler wrote that the state “is a potential resource or threat to every industry in the society,” through its power to tax and compel compliance with regulations.[28] His model of supply and demand for regulatory practices recalls the interplay between GE and federal policy actors during the twentieth century. GE several times contributed to demand for federal policy so as to aid in placing “substitute” lamps on the market. Ideas of regulatory capture seem not to apply well in the case of lighting, especially in the later period when policy actors sought input from firms yet pursued policies many of those firms wished to avoid. The often opportunistic nature of GE’s interaction with regulators, such as their attempt to gain a federal ban on a particular carbon filament lamp in 1918, suggests a more deliberative decision making process at work on both sides.

Electric lighting emerged from scientific research conducted in laboratories in the early nineteenth century, but by century’s end became a commodity controlled by entrepreneurs and businesses. That situation solidified during the twentieth century as

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27. Thomas K. McCraw, “Regulation in America: A Review,” *Business History Review* 49, no. 2 (Summer, 1975): 180, http://www.jstor.org.

28. George J. Stigler, “The Theory of Economic Regulation,” *Bell Journal of Economics and Management Science* 2, no. 1 (Spring 1971): 3, 8.

markets proliferated and electric lighting became so reliable and ubiquitous that it receded from the public's consciousness to become an invisible technology. Eventually lighting consumed enough energy in the US that policy makers felt compelled to intervene in those markets to control growth in usage by promoting efficient lamps. Whether one considers policies that influence efficacy, standards, competitive markets, or technology diffusion, the history of electric lighting is in large part an economics story.

History of technology

This dissertation utilizes historical methods refined during the past several decades. Where previously devices such as electric lamps might have been seen as an independent byproduct of human activity, historians came to realize that technologies could not be disconnected from larger issues of economy and society. Edison's work required access to capital, markets, and expert assistance. The relationship of science to technology, rather than linear and progressive as once characterized by the phrase "science discovers and technology applies," exhibited complexities that reflected the humans doing the research.[29] People adopted technology and adapted it to meet specific needs, creating a feedback loop that affected people and their devices. These connections are all apparent in reviewing the history of lighting. The affect different people have on lighting as producers, conveyors, consumers, and policy actors is reflected in the following chapters.

Thomas Kuhn's *The Structure of Scientific Revolutions* influenced much of the

29. Trevor Pinch and Wiebe Bijker, "The Social Construction of Facts and Artefacts: Or, How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," *Social Studies of Science* 14, no. 3 (1984): 403.

current intellectual framework in the field of technology history. Kuhn argued that knowledge develops within structures called paradigms, influenced by the societies that create them.[30] They attract adherents who use them to frame and answer questions that older, previously accepted paradigms answer less well if at all. When a new paradigm attracts enough adherents it supplants the older paradigm, resulting in a revolution. In lighting, a major paradigm emerged from corporate research in the early twentieth century that defined uniformly high light levels as good lighting. Later in the century, rising energy costs created problems for that paradigm and professionals argued over light levels, with many turning to new a paradigm that defined good lighting in other ways. These paradigms and definitions emerge from social interactions among the knowledge participants and can apply to technology as well as science.

Adapted to the history of technology, Kuhn's approach became social constructivism wherein technologies are understood as integral to the cultures and societies that create and use them. As will be seen in chapter six, the particular type of fluorescent lamp adopted in the US (called a hot cathode design) came to dominate due to business decisions rather than an inherent technical advantage. People shape and are shaped by the technologies they choose to adopt, often adapting those technologies for uses beyond the imagination of the inventors; witness the current convergence of lamps and WiFi devices (see chapter nine). Our technical environment is shaped as much by society as by individual choice. When a business owner decides to install energy efficient lighting, for

30. Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 3d ed. (Chicago: University of Chicago Press, 1996).
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example, that decision may be influenced by the legal availability of light sources, local building codes, and possibly by the availability of tax credits, all conditions outside that individual's control.[31]

A variant of social constructivism useful for this project appears in Thomas Hughes's *Networks of Power*. Hughes compared the development of power transmission grids in the US, UK, and Germany, and proposed a systems theory to account for the differences he found. [32] *Networks* presented technological systems as dynamic social constructs that exhibited growth and momentum, among other characteristics. In comparing the shift from local networks to regional grids Hughes wrote that:

> Electric power systems embody the physical, intellectual, and symbolic resources of the society that construct them. ... Electric power systems made in different societies—as well as in different times—involve certain basic technical components and connections, but variations in the basic essentials often reveal variations in resources, traditions, political arrangements, and economic practices from one society to another. In a sense, electric power systems, like so much other technology, are both causes and effects of social change.[33]

Electric lighting is a similar system. Development and diffusion of energy efficient lamps shows marked societal differences between Europe and the US, with higher efficacy devices typically appearing first in Europe due to higher energy costs. Lighting as a system diverged from electric power systems, yet electric lamps are components in power systems so utility operators retained influence over lamp adoption. Fluorescent lighting is a

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31. For additional discussions of social constructivism: David E. Nye, *Electrifying America*; Wiebe E. Bijker and John Law, *Shaping Technology / Building Society: Studies in Sociotechnical Change* (Cambridge: The MIT Press, 1992); Bijker, Hughes and Pinch, *Social Construction*.

32. Hughes, *Networks*.

33. Hughes, *Networks*, 2.

system-in-miniature wherein components (electrodes, gas fills, phosphors, reflectors) must function as a cohesive unit. Hughes did not limit his definition of system to "technical components" but included "centrally directed, interacting institutions." Institutionalized sales and marketing systems created difficulties for those advocating a policy of replacing incandescent lamps with other light sources.[34]

One additional approach from the history of technology, actor network theory, has proven useful for this dissertation. Actor networks, described by theorists such as Bruno Latour and Michel Callon, are constructs of "actants" that must be "enrolled" in order to achieve the "prime mover's" goals.[35] The theory's strength comes from examining relations between actors in the network and how these relations change and mesh. No actant operates unencumbered by ties to others so any attempt at translation, enrollment, or definition by any actant, even the prime mover, alters the structure of the network. Technologies are as much social as technical constructs; each actor network negotiates with others and they do not always cooperate. Utility operators who resisted energy efficient lamps represent one such example.

> The theory of the actor network assumes that there is no overall structure– that there is always a multiplicity of actor-networks each trying to impose its own structure on potentially unreliable entities and thereby borrow their forces and treat them as its own.[36]

This idea of unstructured multiplicity meshes well with Kingdon's streams although Callon, Rip, and Law fault "garbage can theories" for a "cynical resignation" stemming

34. Hughes, *Networks*, 6, 14-17.

35. Callon, Law and Rip, *Mapping*.

36. Callon, Rip and Law, *Mapping,* 70-71.

from reliance on “random forces.”[37] The theory is also useful here because it recognizes an inherent link between science, technology, and politics.[38]

The history of technology is the study of how people adopt technologies for use and adapt to the demands and constraints associated with those technologies. Historians of technology have refined strong methodological tools such as social constructivism, systems theory, and actor network theory to help explain how technologies affect and are affected by society. This dissertation adds to that literature by examining socially defined and constructed influences on the development of lighting policies involving energy efficient lamps. People make choices about the details and forms of their lighting systems. Those choices—made rationally or irrationally, consciously or by default—are shaped by the capabilities and limitations of lighting technology. Informing those choices helps policy makers recognize the benefits and risks of using technology in alternatives.

Common ideas: the center of the Venn

The methodologies reviewed above come from differing disciplines but contain overlapping concepts that form the interdisciplinary core upon which this dissertation is founded. As seen in figure 3.1 at the beginning of this chapter, these overlapping concepts include the role of historical context within which policy decisions are made and enacted, path dependence and sequencing, and the internal and external dynamics of policy actors

37. Callon, Rip and Law, *Mapping,* 224.

38. “It has been our contention that science should be viewed as politics pursued by other means.” Callon, Rip and Law, *Mapping,* 222.

whether groups or individuals. The past influences present and future, so understanding the context within which previous decisions were made is vital for crafting effective policies.

Path dependence is one example of overlap pertinent to the study of efficiency and lighting policy. The development of electric lighting exhibits evidence of positive feedback due to the cumulative nature of financial and political investments. The various light sources represent decades of engineering and scientific work based on decisions that extended earlier decisions, a situation Hughes defined as system momentum, a form of path dependence. Pierson noted that these issues, adapted from economic theories involving increasing returns, are often applicable to the study of technology.[39] Although some have criticized the concept, I find the path dependence and sequencing pertinent to lighting and the concepts' appearance in differing literatures significant.[40] Another example of interdisciplinary overlap includes Rogers's network concept that meshes well with Hugh Heclo's idea of interest networks pursuing policy adoption, Latour's actor networks, Hughes's cultural look at the technology of electrical networks, and David's views of network effects on market development. All describe interconnectedness and emphasize that changes in one network component affects others as well as the structure of the network itself.[41] In yet another example Neustadt and May discussed the need to place

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39. Rosenberg, *Exploring*, 205; Hughes, *Networks*, 15-16; Pierson, *Politics in Time*, 24. Pierson does note that "not all technologies are subject to increasing returns."

40. Stanley J. Liebowitz and Stephen E. Margolis, "Path Dependence, Lock-In, and History," *Journal of Law, Economics and Organization* 11, no. 1 (April 1995): 205-226, https://www.utdallas.edu.

41. Rogers *Diffusion*, 281-334; Heclo, "Interest Networks"; Bruno Latour, *Aramis, or, The Love of Technology*, trans. Catherine Porter (Cambridge: Harvard University Press, 1996), 41; Hughes, *Networks*; Paul A. David and Julie Ann Bunn, "The Economics of Gateway Technologies and Network Evolution: Lessons from Electricity Supply History," *Information Economics and Policy* 3 no. 2 (1988).

individuals; those include Kingdon's policy entrepreneurs, Hughes's inventor entrepreneurs, Sheingate's political entrepreneurs, and Schumpeter's capitalist entrepreneurs. These authors all describe individuals and groups who exert influence and affect a degree of change within a given system.[42]

As stated above, history is the study of change over time, and this dissertation traces interwoven changes in technology, policy, and economics over the course of a century. As Donna Gabaccia pointed out, time and temporality can be viewed in different ways by different disciplines and some (like many policy actors) do not share historians' horizontal view of time, or discount its influence on the future.[43] The lack of attention to history prompted historian Edward Berkowitz to explore why policy makers listen more to social scientists and less to historians. He ascribed their reticence to historians' lack of desire to operate in the future while other professionals have no such qualms, despite a poor record of making accurate predictions. Policy makers deal in futures and want predictions no matter how methodologically flimsy. Berkowitz argued that historians excel at understanding how the present came to be, and can explain constraints that the past places on the future. He acknowledged that recent source material may be wanting for a given topic, and that extant material may not pertain to the most important events or actors. However he argued that if a "realistic portrayal of the policy process" can be constructed,

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42. Neustadt and May, *Thinking in Time*, 157-195; Kingdon, *Agendas*, 179; Hughes, *Networks*, 14; Adam D. Sheingate, "Political Entrepreneurship, Institutional Change, and American Political Development," *Studies in American Political Development* 17 (Fall 2003): 185–203; Joseph A. Schumpeter, "The Creative Response in Economic History," *Journal of Economic History* 7, no. 2 (November 1947): 150-151.

43. Donna R. Gabaccia, "Is It About Time," *Social Science History* 34, no. 1 (Spring 2010): 1-12.

historians can make themselves heard.[44] A variety of policies promoting energy efficiency through regulation of electric lighting have been adopted over the past century; more such policies are being discussed by government and industry now. A historical overview that views past policies in terms of path dependence and historical context will aid those considering future alternatives affecting this critical and ubiquitous technology.

44. Edward D. Berkowitz, "History, Public Policy and Reality," *Journal of Social History* 18 (Fall 1984): 79-89.

Chapter Four: Carbon lamps in the Gilded Age, 1880-1900

There will be a great sensation when the light is made known to the world for it does so much more than anyone expects can be done.

—Francis R. Upton, 7 December 1879[1]

On 31 December 1879, Thomas A. Edison welcomed the public to his Menlo Park, New Jersey, laboratory to see the culmination of nearly two years' intensive research. Visitors arrived that New Year's Eve to find the laboratory, office building, grounds—and the homes of Edison, Francis Upton, and Sarah Jordan—illuminated by the glow from about eighty small glass globes. Each globe contained a horseshoe-shaped piece of Bristol-board that had been baked to remove all impurities so that only carbon remained. Those carbon filaments glowed warmly when heated to incandescence by the electric current supplied from a generator in the lab.[2] Edison, not the first to make a working incandescent lamp, demonstrated a commercially practical lighting system that included new electrical generation, distribution, and control equipment.[3] His lamp served as the visual centerpiece of an integrated system designed to function in a technically and

1. Francis Robbins Upton to Elijah Wood Upton, 12 /07/1879 [MU02] Special Collections Series -- Francis R. Upton Collection: Unbound Documents (1879) [MU038; TAEM 95:580], http://edison.rutgers.edu.

2. "Local Miscellany: Edison's Electric Light," *New York Tribune* (1 January 1880): 8, http://search .proquest.com. "Edison's Electric Light," *Scientific American* 42, no. 2 (10 January 1880): 19.

3. Joseph Swan of Great Britain publically demonstrated a lamp in February 1879. Bowers, *Lengthening*, 87-93. Bright, *Electric Lamp Industry*, 35-56, for other early lamp experimenters.

economically efficient manner.[4] Though skeptics remained, press and public alike agreed with Upton who wrote, “Mr. Edison has simply found one of the finest things of the age.”[5]

That age already astounded people with technical marvels. Less than twenty years after the Civil War, telegraph and railroad networks allowed rapid communication and transportation on a continental scale. Telephone systems based on Alexander Graham Bell’s work held the promise of voice communications on a similar scale. Those systems, along with developments in business management and finance that enabled and used them, gave people a palpable sense of change.[6] The Menlo Park lab itself, home to two of Edison’s most significant inventions—the phonograph and incandescent lamp—showed what an organized research facility dedicated to commercial gain could achieve. Maturing energy systems built around coal-fired steam engines provided scalable and controllable power that multiplied the productivity of workers, once factory owners learned how to use them.[7] The technical changes came within a larger context; the rural and agrarian United States’ transformation into an urban and industrial nation.

Federal government policy processes also began to reflect the new era. In 1883, in the wake of James Garfield’s assassination, the Pendleton Act began to change the old system of political patronage to a non-partisan civil service. Along with other goals, the

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4. Friedel, and Israel, *Edison’s Electric Light*.

5. Francis R. Upton to Elijah W. Upton, 28 December 1879, Thomas A. Edison Papers, Digital Edition, http://edison.rutgers.edu.

6. Alfred D. Chandler, Jr., *The Visible Hand: The Managerial Revolution in American Business*, 15th ed. (Cambridge, MA: Belknap Press, 1999).

7. Lindy Biggs, *The Rational Factory: Architecture, Technology, and Work in America’s Age ofMass Production* (Baltimore, MD: The Johns Hopkins University Press, 1996).

Act's advocates believed that the policy process would be more efficiently handled by experts rather than political appointees.[8] The state of US maritime lighthouses provided a good example of the old system's problems. A cozy relationship between the federal administrator and the contractor who built many lighthouses contributed to inferior quality and poor service prior to the Civil War.[9] Even the US Lighthouse Board, created in 1852, failed to speed adoption of new technology like Fresnel lenses and electric arc lamps.[10] For this introductory period of electric lighting, federal policies consisted of broadly-based actions such as patents and government purchases that affected most technologies, rather than interventions specifically directed at lighting. Decades in the making, electric lighting was simply one more novel technology with which policy makers of the late nineteenth century coped.

Technology: creating a new form of lighting

Work to create electric lights began soon after Alessandro Volta demonstrated the battery in 1800. By the late 1870s inventors in Europe and the US connected arc lights to dynamos, producing the first electric lighting systems. Arc lights passed an electric current between two electrodes, typically rods made of carbon, and generated tremendous amounts

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8. Campbell, *Growth*, 60; Rebecca Edwards, *New Spirits: Americans in the Gilded Age, 1865-1905* (New York: Oxford University Press, 2006), 75.

9. Francis R. Holland, Jr., *America's Lighthouses: An Illustrated History* (New York: Dover Publications Inc., 1972), 13-38.

10. Holland, 23. W. James King, *The Development of Electrical Technology in the 19th Century 3: The Early Arc Light and Generator* (Washington, DC: Smithsonian Institution, 1962), 352-362.

of light.[11] Ill-suited for indoor use, arc lights nevertheless inspired Edison and others who believed that a lighting system for interior spaces could be profitably developed. With the support of investors captivated by his phonograph and the assistance of his expert Menlo Park team, Edison developed an incandescent lamp that gave about 16 candlepower (cp) on 120 volt direct current. The incandescent lamps that awed crowds on New Year's Eve 1879 lasted for about 120 hours, not enough for a commercial product but sufficient to reassure investors. Edison deemed 16 cp vital to commercial success because his research showed the output of a typical gas burner in New York City to be about 15 cp; his cost calculations proceeded from that point. Edison's team soon produced a 16 cp lamp that lasted 600 hours and they began selling products and franchises.[12]

Edison's close study of gas lighting was a key factor in his success. Both inventor and entrepreneur, he looked to gas lighting as a model of how to design and make money with a lighting system. Established in Europe in the late eighteenth century, gas lighting systems first illuminated single buildings like factories. Companies then built networks that supplied gas to customers on a municipal scale. They generated gas in centrally-located plants, stored the gas in special tanks called gasometers, and fed pipes that ran under the streets and into buildings.[13] Gas lighting moved to the US in 1816 when Baltimore installed gas streetlights, and by 1880 gas companies were mature

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11. Bright, *Electric Lamp Industry*, 25-34.

12. *The Papers of Thomas A. Edison*, ed. Paul B. Israel, et al., vol. 6, *Electrifying New York and Abroad, April 1881-March 1883* (Baltimore, Md.: The Johns Hopkins University Press, 2007), 23n8. "Edison commonly used [15 cp] as his standard measurement for a gas lamp." These volumes cited hereafter as *Edison Papers*.

13. Tomory, *Progressive Enlightenment*.

establishments in many cities. Capital investments, technical knowledge, and political savvy accumulated during the intervening decades, creating path dependencies that electrical entrepreneurs needed to overcome.

Electrical system builders followed Edison's lead with the gas lighting model: central generating plants fed a distribution system (sometimes buried but more often above ground) that connected to customers' buildings. Entrepreneurs selling either arc or incandescent lamps in cities understood they were entering economically and politically competitive markets. Arc lamp companies promoted the fact that their product gave far more light than gas lamps; as Baltimore mayor Thomas Hayes noted after seeing arc lamps in Paris, "No language could describe the enchanting brilliancy of the scene."[14] In fact, some people objected to glaring arc lamps but complaints about poor service and high prices put gas companies on the defensive. Lamp lighters sometimes dawdled and company managers grew complacent about system maintenance and expansion.[15] The public welcomed the promise of competition for gas companies perceived as arrogant, greedy, and non-responsive.[16]

Incandescent lamp promoters also pointed to gas companies' deficiencies, though they sometimes used a grim approach in emphasizing the safety of incandescent lighting

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14. "First Annual Meeting of the National Electric Light Association," *Electrical World* 7 (20 February 1886): 79.

15. "Let There Be Light: A General Complaint Against the Present Dark Streets," *Washington Post* (11 February 1881): 4, http://search.proquest.com, for a conversation about gas company problems.

16. Jacob Harry Hollander, *The Financial History of Baltimore* (Baltimore, MD: The Johns Hopkins press, 1899), 112-114. In 1850, Baltimore mayor John Jerome described his city's gas light system as "of a defective character." The company complained of insufficient funds from the City while the City Council accused the company of charging exorbitant rates. Other cities experienced similar controversies.

over gas. Sales brochures reprinted newspaper accounts of gas-fueled fires and deaths due to asphyxiation.[17] While people did succumb in that way, less dramatic factors proved as important in promoting incandescent lamps. Without an open flame, the lamps gave off far less heat, consumed no oxygen, and emitted no fumes or soot at point of use. Easily controllable with a switch, they did not flicker like gas but glowed steadily. The 16 cp rating meant that electric suppliers could make direct comparisons to gas, leading them to tout electric lighting as more efficient than gas, economically and technically.

Technical efficiency was a work in progress, however, and physics stood in the way of obtaining much more light from carbon filaments. Although carbon's melting point is the highest of any element (3490º C), the filaments evaporated rapidly when operated above 1800º C.[18] Edison's commercial lamps of 1880 used a carbonized bamboo filament that gave about 1.7 lumens per watt (lpW), but some competitors tried different approaches. Britain's Joseph Swan had demonstrated an incandescent lamp in February 1879, but low electrical resistance made a system based on that lamp uneconomic to commercialize.[19] His strong patent position in Britain nevertheless forced a merger that created the Ediswan Company, for which Swan soon developed a filament that gave about 3 lpW. His cellulose filaments could be mass produced more easily than Edison's bamboo

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17. Edison Company for Isolated Lighting, Bulletin No. 6, "The Edison Electric Light in use in some of the Principal Hotels, Apartment Houses, &c." (New York: 25 July 1885), 20-25, for an extensive list of deaths, injuries, and fires attributed to gas lamps. This is just one sample of such advertising from that era.

18. Eugene W. Beggs, "The Operating Characteristics of Incandescent Lamps," *Journal of the Optical Society of America* 29 (March 1939): 117. Chester L. Dows and Willard C. Brown, "Incandescent Lamp Temperatures," Engineering Department Bulletin, no. 44 (Cleveland, OH.: General Electric Co., 15 December 1922), 3, in NMAH EC-LRF

19. Bowers, *History*, 113-116.

filaments and other makers soon adopted the design or made their own variants.[20] Modified cellulose filaments pushed carbon lamp efficacy to 3.6 lpW by the mid-1890s.[21] Aside from slow improvements in technical efficiency, other features that would enhance the commercial efficiency of electric lighting systems remained in flux for many years, including standardized lamp bases and voltage ratings.

Direct federal involvement with electric lighting began slowly and in limited ways. Mostly, the national government played the part of institutional consumer, evaluating electric lighting systems and debating whether to allocate funds to equip federal buildings, continuing along a path already established with gas lighting.[22] This role suited private sector actors who used early government installations partly as high-profile demonstrations and partly as research opportunities. An experimental system in the Capitol replaced 1300 gas jets that cost about $22 per hour to operate with four arc lamps costing 50¢ per hour.[23] Installed in the House of Representatives in 1879, the system drew praise but almost a decade passed before the Senate voted to install incandescent lamps on their side of the building. Even then, "the Architect states that he does not think it will be a matter of economy to substitute electric for gas lighting," though he supported limited adoption in parts of the building where incandescent lamps' lack of heat and smoke prevented

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20. Bowers, *History*, 123-124.

21. Bright, *Electric Lamp Industry*, 66 for Edison's use of bamboo, 166-169 for filament improvements.

22. For example, Samuel Gardiner, Jr. used electricity to light gas lamps in the Capitol's dome. Michael B. Schiffer, "A Cognitive Analysis of Component-Stimulated Invention: Electromagnet, Telegraph, and the Capitol Dome's Electric Gas-Lighter," *Technology and Culture* 49, no. 2 (2008): 376-98.

23. "Lighting the Capitol," *Washington Post*, 20 November 1878, 1, http://search.proquest.com. "Enter the Electric Light," *Washington Post*, 3 May 1879, 2, http://search.proquest.com.

“vitiation of atmosphere.”[24] Balls and presidential inaugurals provided opportunities to showcase the new technology. James Garfield’s inaugural featured older, non-electric calcium lamps and new electric arc lamps mounted on prominent buildings in the downtown area.[25] Federal officials may not have completely understood the technology but they were quick to use electric lights to symbolize the dawn of a new era.

1880s: establishing incandescent lighting systems

In general, state and local governments set lighting policies during the 1880s, not the federal government. Health and safety standards were only just becoming an area for federal intervention (in mines and on railroads), and electrical codes did not yet exist in any case. Electric lighting companies needed to win approval from local authorities to install wires and provide service, so that served as the most significant area of regulation and an important political opportunity. Edison recognized as much when he invited the aldermen of New York City to see the system, and then provided an extravagant dinner catered by Delmonico’s the evening before requesting a franchise agreement.[26]

Although they enacted no nationally-binding policies, Congress participated in the local government of the District of Columbia through the House and Senate Committees on the District. While District commissioners managed the local mechanisms of government on a workaday basis, Congress controlled the budget and reviewed major programs such as

24. “The District in Congress,” *Washington Post*, 27 April 1888, 6, http://search.proquest.com.

25. “The First Ball in the Capitol,” *Washington Post*, 21 November 1879, 1, http://search.proquest.com. “Illuminations,” *Washington Post*, 5 March 1881, 3, http://search.proquest.com.

26. Jehl, *Reminiscences*, 2:778-85.

installation of electrical infrastructures. Efforts to provide electric lighting for streets and residences began as early as 1879 when legislators introduced a bill to incorporate the National Electric Light Company of the District.[27] Then as now, such proposals could be contentious, as members of Congress often debated over several sessions the relative merits of technologies and the appropriateness of using federal funds. As late as 1894, local National Electric Light Association members resorted to general tourism to lure fellow members to DC for an annual convention. "While the electrical features of Washington are few, there is...much else of historical value and interest [to occupy visitors' spare time.]"[28]

A major part of the delay stemmed from the larger debate about forcing electric lines of all types into underground conduits. By the 1880s, overhead lines proliferated in the city. Public and private telegraph lines, fire and burglar alarm systems, telephone lines, and higher-voltage lines for light, power, and trolley-cars created dangerous and unsightly wired chaos. Residents, fire fighters, and civic-minded reformers wanted overhead wires buried; an idea the various companies' officials vigorously fought. This gave Congress a taste of raw local politics as the same heated debate raged in major cities across the nation. District Commissioners refused permits for new above-ground wires and Congress struck out amendments that required installing lines underground. The standoff resulted in a de facto moratorium that prohibited any "extension of electric lighting service" or opening any streets for that purpose "until specifically authorized by law."[29]

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27. "Local legislation," *Washington Post*, 29 April 1879, 1, http://search.proquest.com.

28. "Electricity in the Capitol City," *Electrical World* 23, no. 9 (3 March 1894): 295.

29. "To Buy Art Gallery," *Washington Post*, 26 February 1897, 4, http://search.proquest.com. When Rep. McComas was asked "if he had ever introduced a bill [to require undergrounding] to be referred to the [District Committee]," he answered "that was the last place in the world he would send such a bill he wanted

Existing gas light companies anxious to preserve their franchises to light DC streets also fought the commissioners on electrification. Stung by a sharp drop in stock prices when Edison commenced lighting research in 1878, gas companies did not sit idle when consumers began adopting electricity.[30] They cited their own grim anecdotes on the dangers of "the mystic nerve energy of electric wires," and adopted a three-fold response that provided an almost textbook example of the benefits of market competition.[31] They reduced prices, cultivated new markets in heating and cooking, and improved their lighting product in two ways. The improvements, higher quality illuminating gas and better burners, served to raise the energy efficiency of gas lighting. Carl Auer von Welsbach of Austria invented a practical gas mantle in the 1883 that gave a ten-fold increase in efficiency and kept gas lighting competitive with electric lighting for thirty years.[32] Many buildings in the District already took gas service—a mixed blessing. Gas company executives had long experience with policy makers and local reporters but the city had long experience with gas company shortcomings. Though Washington Gas Light Company promoted the Welsbach mantle, Congress authorized an electric lighting company and debated whether to establish a competing gas company or municipalize Washington Gas.[33]

[to pass]." "Not Quite as Reported," *Washington Post*, 9 January 1890, 6, http://search.proquest.com.

30. Friedel and Israel, *Edison's Electric Light*, 23.

31. Allen R. Foote, "The Dangers to Firemen of Electric Light Wires in Buildings," (paper read before the North Carolina State Firemen's Association, 20 May 1890, reprint), 1, in NMAH EC-LRF.

32. Bright, *Electric Lamp Industry*, 126-127, 211-213. Gas lamp efficiency ultimately rose from 4 to 6 candlepower per cubic foot of gas per hour to between 60 and 70 cp/cf/hr by feeding mantle-equipped burners better gas at higher pressures.

33. "The Welsbach Gas Burner," *Washington Post* (13 May 1888): 7, http://search.proquest.com; "Light for the City," *Washington Post* (13 February 1896): 4, http://search.proquest.com; "For the Public Good," *Washington Post* (26 October 1895): 2, http://search.proquest.com.

In addition to buying systems for buildings and the District, scientific research constituted another, albeit minimal, federal involvement with lighting at this time. The use of federal funds to promote research of almost any kind was controversial throughout most of the nineteenth century. Many in Congress considered using public money to support open-ended research inappropriate, believing such activities to be the province of private individuals and universities. Establishment of the Naval Observatory and the Coast and Geodetic Surveys that pursued projects with clear national benefit, came only after much political maneuvering. Even acceptance of the bequest that founded the Smithsonian Institution as a trust entity came only after a decade of contentious debate. However, as Hunter Dupree noted, most of the Framers during the Constitutional Convention "could agree that universities and learned societies were in fact internal improvements," thus making federal support constitutionally permissible, if no less controversial.[34]

Research into lighting received at least token federal support through the activities of the Lighthouse Board and to a lesser extent through the Smithsonian. Joseph Henry, first secretary of the Smithsonian sat on the Board and conducted research for that body. One of Henry's successors, Samuel Langley, conducted experiments on bioluminescence and declared it "the cheapest form of light" from both energy and economic standpoints.[35] But these projects were limited, and research perceived as duplicating private sector efforts would doubtless have drawn Congressional wrath. University laboratories devoted to

34. A. Hunter Dupree, *Science in the Federal Government: A History of Politics and Activities* (Baltimore, MD: The Johns Hopkins University Press, 1986), 5.

35. Samuel P. Langley and F. W. Very, "On the Cheapest Form of Light," *Smithsonian Miscellaneous Collections*, no. 1258 (Washington, DC: Smithsonian Institution, 1901), 3.

scientific research undertook investigations both into the fundamental nature of light and the basic engineering principals of converting energy into light.[36] The emerging electric lamp industry tested both lamps and lighting systems to determine optimum characteristics and improve commercial products.[37] Much about the new technology remained unknown and some cooperative research did occur. In 1883 for example, Secretary Spencer Baird allowed installation of a Brush-Swan arc lamp on the Smithsonian Castle by which "a newspaper was plainly read upon the [Capitol terrace]."[38]

Without doubt, the most important aspect of federal government involvement with electric lighting in the nineteenth century came through the granting of patents and adjudicating subsequent infringement suits. Patents are a legal monopoly granted an inventor for a period of time deemed sufficient to allow them to profit from their invention. In exchange they make detailed knowledge of the invention publically available for anyone to use after the patent expires. Seen as vital to economic progress by promoting individual initiative, the patent process involves multiple points of social negotiation and definition construction by various policy actors. Inventors and their attorneys must decide what exactly has been invented and how to translate that invention into approved patent language. Patent examiners, typically with less technical knowledge than the inventor, must determine novelty of the invention and decide if more has been claimed than is

36. John W. Howell, "Economy of Electric Lighting by Incandescence," *Van Nostrand's Engineering Magazine* 26, no. 1 (January 1882): 51-59.

37. John W. Howell, "New Lamp and High Efficiency Lamps in General," *The Association of Edison Illuminating Companies, Minutes of Semi-Annual Meeting, August 8 and 9, 1888* (New York: 1888): 18-32. Among the issues Howell discussed were variations in efficacy of 10, 13 and 16 cp lamps.

38. "The Wonders of Electricity," *Washington Post*, 6 December 1883, 4, http://search.proquest.com.

revealed. Once the negotiation between examiner and inventor has resulted in a patent grant, other inventors and their attorneys must decide if and how to challenge the claims. Finally, if a legal case ensues, courts at various levels—having even less technical knowledge—must interpret definitions, and give opinions on the veracity of competing claims and the validity of the process.[39] Patents can run the gamut from worthless to priceless depending on demand for an invention, so the resources invested in obtaining, challenging and defending them varies accordingly.

Thomas Edison actively filed for patents and aggressively defended them. He still holds the record for patents obtained by an individual but doubtless held special regard for US patent 223,898, an "electric lamp." His suit against Hiram Maxim's U.S. Electric Lighting Co. alleging infringement of that patent became a seven year saga and one of the most watched cases of its day. Judge William Wallace decided in Edison's favor in 1891, a ruling sustained on appeal the following year. The details of the case are less important here than the fact of the litigation and ramifications of the verdict. Wallace's decision effectively defined the new and thus patentable features of Edison's invention; one contemporary account of the case noted the importance of defining a filament and "the phraseology [as] the basis of contention."[40] While grounded in technology, Wallace's decision was constructed within the highly social setting of a legal proceeding in which personalities counted, and bounded by the politically defined nature of patent law which favored certain types of evidence. Wallace chided Edison at one point for "the haste which

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39. Charles Bazerman, "Patents as Speech Acts and Legal Objects," *The Languages of Edison's Light* (Cambridge, MA: The MIT Press, 1999), 85-109.

40. "The Edison Decision," *Electrical Review* 21, no.8 (15 October 1892): 85-86.

has always seemed to characterize [his] efforts to patent every improvement, real or imaginary, he made or hoped to make," a haste that led to the "perplexing" specification Wallace found crucial.[41] That specification disclosed a carbon filament of high resistance enclosed in a glass globe wherein all parts had been permanently sealed. Most incandescent systems used such a lamp so Wallace's definition shook the nascent industry.

This federal policy decision removed some players from the market and reinforced the ongoing industry consolidation but little affected the technology itself, mostly due to the simple fact that Edison's basic patent would soon expire. Edison's most significant rival by this time, George Westinghouse, had purchased Maxim's company in 1888 and planned shrewdly for an adverse decision. Purchasing a company embroiled in a key patent suit while the outcome was at best uncertain seems a curious investment, especially since the Edison interests wanted a decisive victory rather than a settlement. When the appellate court sustained Judge Wallace's decision in 1892, Westinghouse shifted production to a lamp based on earlier patents owned by the U.S. Electric Lighting and Sawyer-Man companies. That lamp differed in several minor ways from Edison's but also in one major way: a two-piece structure wherein the filament assembly was not permanently sealed in the glass envelope.[42] The design was not a single piece of sealed glass by the definition established in the court decision and thus legal. Westinghouse produced these two-piece

41. William J. Wallace, "The Edison Incandescent Lamp Case: Full text of Judge Wallace's Opinion, the Interlocutory Decree, the Injunction, and the Stay," 23 July 1891. Reprint, Circuit Court of the United States, for the Southern District of New York, The Edison Electric Light Company vs. The United States Electric Lighting Company, NMAH EC-LRF, 16 for chiding statement, 4 for description of specification.

42. "The New Westinghouse Lamp," *Electrical Review* 31, no. 782 (18 November 1893): 597-598. Westinghouse, stopper lamp, ca. 1894, NMAH-EC, catalog number 1997.0388.81, includes a Westinghouse socket adapter.

lamps for two years until the expiration of Edison's Canadian patent in late 1894 triggered the expiration of his US patent.[43] Westinghouse then resumed making Edison-style lamps. Edison by that point, tired of all the litigation, had moved on to other inventions.

1890s: founding an industry and defining markets

The 1880s had constituted a chaotic period for the electric lighting industry and the larger electrical industry it depended on. Once people grasped the technical fundamentals, dozens of lamp makers jumped into the market.[44] As the decade progressed many companies like Maxim's were acquired by competitors. By 1890 three major players emerged, each with its own strength. Edison General Electric (EGE) combined in one organization the separate companies that made components for Edison's lighting system and supported franchisees in many cities and towns. Devoted to direct current (dc) systems, EGE's most important asset lay in rights to Edison's patents. Westinghouse Electric promoted alternating current (ac) systems and sought to establish ac for industrial power as well as for long distance transmission. Thomson-Houston Electric, founded on the arc lamp and dynamo patents of Philadelphia high school teachers Elihu Thomson and Edwin Houston, sold an Edison-style incandescent lamp but focused mainly on arc lamp systems for municipalities. The company produced both dc and ac products and featured a strong

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43. Thomas A. Edison, Electric Lamp, US Patent 223,898, filed 4 November 1879, issued 27 January 1880. Edison's patent was only valid for 15 years, not the 17 one would expect. This quirk of US patent law was remedied in 1898 after "agitation" over the Edison patent and others. Bright, *Electric Lamp Industry*, 91, n29.

44. William J. Hammer, "The William J. Hammer Collection of Incandescent Lamps," *Transactions of the New York Electrical Society* (New Series, 1913, no. 4) : 15-30, lists over 200 different makes of incandescent lamps and conveys the scope of activities in the introductory era.

management team led by Charles Coffin.[45]

Expansion of manufacturing plants and sales distribution networks to supply a growing number of lighting franchises required significant capital investment. Financiers including J. P. Morgan began looking for merger opportunities and decided that the combination of EGE and Thomson-Houston made the most sense. The dc experience and strong patents of the former would complement the ac experience and professional managers of the latter. When EGE and Thomson-Houston merged to create General Electric (GE) in 1892, Coffin took the reins and instilled Thomson-Houston's culture in the new corporation.[46] Edison remained involved with the company for several years, lending his name to GE lighting products he had no hand in making, but for the most part he moved on to other inventions.

Coffin needed his team's management skills when the US economy went into a major depression just after GE's formation. The Panic of 1893 closed factories and shook the financial system for years, belying the later rosy moniker, "Gay Nineties." The social disruption caused by massive unemployment exacerbated labor strife and drove political activism led by populists in the West and South.[47] Attempting to end the crisis, Congress reduced import tariffs on raw materials including copper and some finished goods, while Morgan and other financiers worked with Grover Cleveland's administration to stabilize

45. W. Bernard Carlson, *Innovation as a Social Process, Elihu Thomson and the Rise of General Electric, 1870–1900* (Cambridge: Cambridge University Press, 1991).

46. Harold C. Passer, *The Electrical Manufacturers, 1875-1900* (Cambridge, MA: Harvard University Press, 1953), 321-329.

47. Edwards, *New Spirits*, 235-251.

gold reserves.[48] The depression made Coffin's task of merging two diverse organizations even more difficult when electrical franchisees cancelled orders and stock prices dived. GE's second annual report, praised by a trade journal for its "frankness," relayed the problems, but also noted that "incandescent lighting...has not suffered so severely."[49] The new, lower tariffs on incandescent lamps apparently had little effect on the industry, and expansion of lighting systems continued, albeit at a slower pace.

Aside from the tariff (a broadly applicable policy), federal policy makers took little specific note of electric lighting during the Panic. Some private sector actors came to the fore during the 1890s, however, making decisions that affected electric lighting more than public authorities. In particular, insurance underwriters used their ability to set premiums and estimate risks to push adoption of electric lighting and to maintain installations in good order. They encouraged policy holders to switch from open-flame light sources to electric lamps, especially in high risk locations like textile mills and other places where a flame could ignite airborne dust and cause an explosion. Underwriters supported development and adoption of codes to promote safe installation and operation of electrical installations. To help understand electrical systems—and lessen their dependence on corporate research—they established Underwriters Laboratories (UL) to test equipment and promote safety.[50] That research formed the basis for the first national electric codes, standards that

48. Edwards, *New Spirits*, 82-89, for Morgan; "The New Tariff Schedules and Electrical Manufacturers," *Electrical World* 24, no. 9 (1 September 1894): 198.

49. Charles A. Coffin, "Second Annual Report of the General Electric Company," *Electrical World* 23, no. 15 (14 April 1894): 513; editorial commentary, 514.

50. Norm Bezane, *This Inventive Century: The Incredible Journey of Underwriters Laboratories, 1894-1994* (Northbrook, IL: Underwriters Laboratories, 1994), 5-9. Prior to UL's establishment underwriters had to rely on company knowledge, a potential conflict of interest. For example, see Thomas Edison to Edward Johnson,

were sorely needed. Retrofitting a building for electricity meant installing panels, wires, switches, and sockets in structures never designed for such; many installers simply string wires wherever convenient to cut costs. Some installers used gas pipes as conduits for wires, supplying gas and electricity to combination lighting fixtures. Many local and state governments (and the federal government, acting for the District) adopted the privately developed electrical codes, giving them legal standing. These codes focused on safety, however, not energy efficiency.[51]

Whether influenced by insurance premiums or other factors, lighting often served as the main reason building owners installed an electric system. Once wired for electric lighting, a building's system could be used for other tasks and that created a market for appliances and demand for more electricity. Some businesses and a few wealthy individuals acquired isolated systems, but most people took service from centrally located power plants.[52] As service providers expanded networks and more customers electrified, economies of scale through the use of larger generating units became important. Larger central stations attained higher generating efficiencies and lighting became one application

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letter dated 23 January 1882: "I also enclose you several copies of the last rules adopted by the Board of Underwriters which rules were suggested by us and adopted by them after consultation with all the Light Companies and arguments before the National Board of Fire Underwriters." *Edison Papers* 6, 358.

51. "The Fire Question," *The Edison Electric Light Company* 1, January 26, 1882, http://edison.rutgers.edu. Commissioners of the District of Columbia, *Rules and Regulations of the District of Columbia for the Installation of Wires and Apparatus for Electric Light, Heat and Power*, 1st ed. (Washington, DC: 1904). "These rules are based, so far as is practicable, on the National Electric Code of the National Board of Fire Underwriters." Dana Pierce, *Underwriters' Requirements for Safe Electrical Installations* 2 vols. (Chicago: American School of Correspondence, 1911, 1915).

52. "Electricity in a Country House," *Electrical World* 55, no.3 (January 1910): 160-161, for the example of J. Ogden Armour's isolated plant.

among many.[53] Lighting franchises expanded their scope and began the shift toward being electrical utilities in a more general sense. That shift planted the seeds of a slowly growing separation of interests between lamp makers and utilities that grew more pronounced throughout the twentieth century, affecting policies and corporate strategies alike.

Yet lighting remained important as a major evening and early morning load and also as a visible advertisement for electricity. Central station managers knew that people who could afford few appliances would pay for light, and demand for electric lighting grew during this period.[54] Most operators provided free lamp renewals to their customers to keep the electricity flowing. As bulk purchasers they held leverage in the choice of lamps, though apparently some put short term profit over longer term gain by running their systems below rated voltage to prolong lamp life at the expense of energy efficiency.[55] Indeed, some central station operators began to resist lamp improvements they believed might result in reduced power sales.

For example, in the mid-1890s several manufacturers introduced carbon lamps containing two filaments, one of which emitted much less light than the other.[56] The user could select the high output filament when needed and switch to the low output filament as a night light or to save electricity. An advertisement for HyLo lamps shows an operator

53. Hirsh, *Technology and Transformation*; Richard F. Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System* (Cambridge, MA: The MIT Press, 1999).

54. A handwritten note by William J. Hammer records, “1880 – 25,000 lamps / 1910 – 100,000,000 used in U.S. alone.” It’s unclear if Hammer was counting just incandescents or both incandescent and arc lamps but the trend is obvious regardless. Found in a copy of James Swinburne, “New Incandescent Lamps,” *Journal of the Proceedings of the Institution of Electrical Engineers* 38, part 182, (1907, reprint NMAH EC-LRF).

55. Howell, “New Lamp,” 18-32.

56. Produced by Phelps Co., Economic Electric Light Co., and others, HyLo was the trade name used by Phelps. Economic’s company name is telling. The most common version used 16 cp and 1 cp filaments.

telling a company salesman that he “couldn’t think of” buying HyLo lamps for his customers since the lamp would result in lower power sales.[57] Whether depicting a real conversation or just marketing hype, the advertisement’s sentiment was accurate. Station operators could not prevent customers from purchasing and using such lamps or early dimming adapters to save electricity, but these devices required customers to spend their own money. Most people either could not afford or chose not to pay for HyLo lamps or dimmers, opting instead to continue receiving free (regular) replacement lamps.

The HyLo lamp presaged two tendencies that recurred throughout the twentieth century: consumers often chose short-term over longer-term savings, and electrical utilities resisted lamps that saved energy. Edison warned franchisees to remember that they sold light, mainly concerned that users might reject electric power entirely if the quality of lighting service suffered. Meters measured current, however, not light, and selling electricity came to predominate as people adapted the system for more than illumination. System operators grew wary of new devices that promised efficient energy use believing that such devices would cut electricity sales. That the HyLo lamp offered users a choice of light levels mattered not; using the lower output filament consumed less energy and represented a direct threat to their profits. They gave little credence to the idea that adopting efficient lamps might increase the number of lamps in service and thus total energy used, what later became known as the rebound effect.

If residential consumers were unwilling or unable to push for higher efficiency lighting devices, other lighting consumers demonstrated more persistence and capability.

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57. Phelps Company, *HyLo Magazine* (January 1907), NMAH EC-LRF.

The divergence of lighting consumers into distinct market segments that used differing lamp technologies began during this early period. Commercial and industrial customers paid close attention to costs; for them lighting constituted a critical resource in doing business. Though their needs differed somewhat—commercial users required lamps that gave better color quality, for example—both market segments needed higher output lamps than residential consumers and could afford advanced technology. Research into such technology, generically referred to as discharge lamps, had been underway since the 1850s, and now several entrepreneurs were ready to introduce products.[58]

In 1894 former Edison employee Daniel McFarlan Moore founded the Moore Light Company to produce a gas-filled tubular lighting system for commercial and institutional users (churches, for example). Depending on the gas used, his system gave a white or yellowish light at an efficacy of 5 or 10 lpW, either one better than the 3.4 lpW of contemporary carbon filament lamps. Custom made for each customer, the lamps' expense prevented widespread acceptance.[59] In 1902, Peter Cooper Hewitt designed a discharge tube that used mercury and pushed his invention for industrial use. Large and heavy, his lamps produced a lot of garish green light at an efficacy of about 12.5 lpW. Many industrial users, newspaper printing rooms for example, needed lots of light at low cost and did not care about color, so the lamps sold moderately well.[60] However, most industrial users tended to adopt incandescent lamps despite the lower lumen output because incandescents

58. Ernst M. Cohn, "First Portable and First Airborne Electric System," *Journal of the Washington Academy of Sciences* 58 (1968): 96-107, for an 1860s device built around a Geissler tube.

59. Bright, *Electric Lamp Industry*, 223.

60. Bright, *Electric Lamp Industry*, 225-227.

provided flexibility in illuminating individual work stations wherever those might be on the shop floor. Lighting makers in the new century found one of their biggest marketing challenges lay in convincing business people to raise light levels.

Introductory period: setting a path for lighting

The United States exited the nineteenth century a far different place from when it entered; more urban, industrial, and increasingly electrified, and with many challenges. The Panic of 1893 shook national confidence, fueled populist sentiments, and brought William McKinley to the White House.[61] Growing industrial power, the "closing of the frontier," and a short, successful war against Spain combined to convince some policy makers that the US should take a more active role in international affairs.[62] As scientists and engineers gained greater understanding of and ability to manipulate natural forces, a feeling grew that solutions to fundamental human problems, technical and social, might be within reach. A growing pragmatic approach to defining problems and identifying solutions extended to government.[63] Politicians like the brash and confident Theodore Roosevelt, emerged onto the national stage with an outward international focus intent on increasing American influence and an inward domestic focus intent on bettering lives by busting trusts and raising living standards. Not everyone welcomed these new ideas and the proposed changes.

61. Edwards, *New Spirits*, 235-240.

62. Edwards, *New Spirits*, 256-261.

63. Edwards, *New Spirits*, 151-169.

As Americans wrestled with political and economic changes, they adopted electric lamps to illuminate their lives. Indeed, lighting served as a prime example of the changes taking place. In less than a century, people moved from a decentralized world of oil lamps and candles to a networked world of gas and electric lamps that required them to connect to centralized systems. Wolfgang Schivelbusch noted "the loss of domestic autonomy" inherent in adopting a consumerist, industrial system such as gas lighting.[64] Taking gas or electric service offered advantages in convenience and economy for those prepared to cede some authority and adopt the routines needed to operate systems safety, a difficult step even today for Americans who cherish an ideal of self-sufficiency. These two networked systems generated debate about the tradeoffs, but nevertheless most people adopted gas or electric lights given the opportunity. Though the systems in question changed, the debate about tradeoffs, convenience, and personal autonomy continued through the twentieth century and into the twenty-first. Unexpectedly, electric lighting still plays a role in that debate, as will be discussed in chapter ten.

As more people chose electric over non-electric lights, more companies were established to meet the growing demand. For most of those companies lighting became the key sales feature, as reflected by the fact that the word "light" often appeared in the company name. Established as lighting companies, they shifted paths in the following years to become electrical utilities in a more generic sense. Gas companies benefitted by offering a mature technology, but rightly saw electric lighting as strong competition in safety and convenience—though not initially in energy efficiency since both systems

64. Wolfgang Schivelbusch, *Disenchanted Night: The Industrialization of Light in the Nineteenth Century*, trans. Angela Davies (Berkeley: University of California Press, 1988).

depended on coal for fuel. An economically healthy competition between the two systems ensued such that prices fell and the quality of products and services rose. No one, including policy makers, knew which system might survive as electrical investors and producers pressed that competition. The first research question that asked how changes in lamp efficacy affected lighting policy thus had no influence in this introductory period.

Consolidation in the 1890s culled producers, focused resources, and created two industrial giants with the capacity to serve national markets: General Electric and Westinghouse. As applications beyond lighting emerged, utilities faced the need for standards and turned to newly professionalized communities of experts for advice. Those electrical professionals did not reside in government. Electrical standards established in that period continue in use today, and economic decisions altered existing paths and founded new ones that shaped illumination and electrical markets in general. These standards tended to be privately developed, sometimes driven by local governments and sometimes by private actors such as insurance companies but not by federal authorities; at least not outside Washington, DC. Safety and efficiency in this era were mostly technical and economic matters, not yet policy issues. Lighting specific policies, the focus of the second research question, stayed within the geographic limits of the District as Congress exercised oversight in choosing lighting systems for DC and for government use.

The relative lack of lighting specific policies restricted private sector adaptation (the third research question) to broad areas that affected most technologies, patents for example. Private sector actors used patents during this introductory period to secure markets and eliminate competitors. The overall impact on lighting markets and technology declined after the 1890s, though. Patents remained commercially important, especially for GE's continued market dominance, but patent litigation never again played such a critical role in defining the path of developments. Subsequent patent decisions only modestly affected the course of increasingly mature markets and institutional systems. Early in the new century however, as the nation experienced some of the negative consequences that came from embracing an industrial economy, the federal government showed more interest in lighting policy. That included broadly based policies such as antitrust actions, and lighting specific policies such as blackouts and other use restrictions when the nation went to war.

Chapter Five: Metal lamps and the Great War, 1900-1920

A blaze of light creates the impression that things are all right after all. This is not the idea we desire.

—Osborne Monnett, 18 October 1918[1]

Energy use marked a major area of difference between the United States that entered the twentieth century and the new republic of the early nineteenth. Plentiful sources of energy on the North American continent gave people little reason to conserve or even think about limits before 1900.[2] As David Nye noted, "Access to energy [became] an inalienable American right,..."[3] In Europe, less plentiful supplies made efficient energy use a necessity, and gave later inventors incentive to improve electric lamps.[4] As US entrepreneurs built coal fired power plants to run their new electric lighting systems in the late 1800s, they attended to efficiency to contain fuel production and transportation costs, not out of concern for failing supplies. By 1900, coal constituted a critical national resource that provided energy for space heating, cooking, transportation, industry, and the military.

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1. Osborne Monnett, "Lighting and the War Program," *Transactions of the Illuminating Engineering Society* 13, no. 9 (30 December 1918): 537. Monnett (1876-1951) served as an Advisor in Conservation for the Fuel Administration in Illinois and was addressing the evening session at the IES' 12th Annual Convention.

2. Frederick Frankena, *Strategies of Expertise in Technical Controversies: A Study of Wood Energy Development* (Cranbury, NJ: Associated University Presses, Inc., 1992), 73.

3. Nye, *Consuming Power*, 250-251.

4. Ruth Schwartz Cowan, *A Social History of American Technology* (New York: Oxford University Press, 1997), 18-21, for European views of American wood wastefulness.

The growing demand for coal stressed production and transportation systems, leading to initial steps toward crafting energy policies at the federal level. Ideas about conservation and exactly what that term meant—minimal use or efficient use—took place as Progressive political influence waxed. A loose alliance of reformers united by a desire to rid government of cronyism and inefficiency, Progressives "created a code of professional public administration" to advance those goals.[5] That included a rationalist approach to policy that influenced planning and laid the groundwork for interventions in areas such as resource management. Establishment of a National Bureau of Standards (1901) brought professionals into government to promote economic efficiency in a way that would assist, not compete with, the private sector.[6] At the same time, another area of Progressive concern centered on the emergence of large corporations perceived as a threat to basic American values. Progressives pursued antitrust actions as one way to control large private sector actors.[7] Lighting industry consolidation drew their attention as General Electric's ability to control the market and influence the political process grew.

Outside of government, communities that shared interests and values organized to advance their fields. Formal institutional structures allowed those communities to focus economic and political resources, and establish social networks that defined standards of quality and procedures to which members were expected to adhere. Electrical interests founded organizations that included the American Institute of Electrical Engineers, the

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5. Campbell, *Growth*, 61.

6. McGerr, *A Fierce Discontent*.

7. Arthur S. Link and Richard L. McCormick, *Progressivism* (Wheeling, IL: Harlan Davidson, Inc.,1983), 27-41.

National Electrical Contractors Association, and the International Brotherhood of Electrical Workers.[8] Lighting professionals also organized during this period, with the Illuminating Engineering Society and the Commission Internationale de L'éclairage being especially important. These new groups began developing what one practitioner termed, "the science of seeing," advocating for higher light levels and better application of light.[9] Illuminating engineers brought an economic approach to concepts of lighting efficiency, arguing that better lighting would enhance industrial production.[10]

When the US entered World War I, the federal government took control of several important activities, such as railroads, in which the private sector would not put aside self-interest. The emergency temporarily made such interventions politically viable. Pressured to take action, policy makers focused on energy efficiency and Woodrow Wilson tasked the US Fuel Administration (USFA) with prioritizing coal use. Policies that used lighting to meet energy goals, in this case rationing electricity produced in coal fired plants, were enacted. But as seen in Osborne Monnett's comment above, light's symbolic ability to convey an "impression" also played a role, as policy makers encouraged people to conserve fuel, food, and other resources. Policy makers' need for cooperation gave private sector actors and newly organized lighting professionals an opportunity to use federal initiatives for their own purposes. GE took advantage of that opportunity to promote

8. Louis K. Comstock, "Joint and National Counseling in the Electrical Construction Industry," *Proceedings of the Academy of Political Science in the City of New York* 9, no. 4 (January 1922): 75-85.

9. Luckiesh and Moss, *The Science of Seeing* (New York: Van Nostrand), 1937. GE's Luckiesh began writing on this topic during the 1910s.

10. Historical Committee, "Illuminating Engineering Society," *General Electric Review* 57 (July 1954): 39-41.

diffusion of a new, efficient lamp despite resistance from various groups. This would not be the last time public and private sector interests converged to promote efficient lamps.

Technology: a burst of innovation

Incandescent lamp technology began to change in the late 1890s courtesy of Carl Auer von Welsbach. Already known for his gas mantle, Welsbach invented an electric lamp that used a filament made of the element osmium. Expensive, difficult to make, and fragile, osmium filaments nevertheless gave 5.5 lpW, better carbon's 3.4 lpW.[11] Sold only in Europe, the product was superseded in 1902 by lamps using filaments made of tantalum that gave 5 lpW.[12] Though less efficient than osmium, tantalum could be drawn into a malleable wire, making them easier to fabricate and ship.[13] US manufacturers saw no reason to license osmium lamps given their fragility and expense, but tantalum lamps were another matter. Industrial users looking to cut energy costs helped create demand for the product and at least three US makers, GE, Westinghouse, and Franklin Electric, licensed and sold tantalum lamps for about ten years. That included a vibration resistant design specially made for use in industrial plants.[14]

The European lamps showed the public that higher efficiency lamps existed and

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11. "The New Welsbach Incandescent Lamp Filament," *Electrical Engineer* 26, no. 538 (25 August 1898): 186. Welsbach Company, osmium filament lamp, ca. 1900, NMAH-EC, catalog number 1997.0388.53.

12. Werner von Bolton and Otto Feuerlein, "The Tantalum Lamp," *Smithsonian Annual Report for 1905*, Washington, DC: GPO, 1907, reprint).

13. Bright, *Electric Lamp Industry*, 169 for lamp ratings, 174-178 for osmium and tantalum lamps. General Electric, tantalum filament lamp, ca. 1908, NMAH-EC, record serial number 80595U05.

14. Westinghouse, tantalum mill lamp, ca. 1908, NMAH-EC catalog number 2014.0058.05.

raised questions about the "Electric Trust's" commitment to improved products, but US lamp makers reacted cautiously.[15] George Westinghouse licensed a radically different European lamp in 1897 that required neither a vacuum nor a filament. Invented by German chemist Walther Nernst, the lamp gave 5 lpW, but more importantly for Westinghouse avoided infringing others' patents.[16] Expiration of Edison's early patents raised the specter of competition from inexpensive carbon lamps and put GE in a bind. Introducing the new European designs meant paying license fees and would annoy power companies that might start buying cheap carbon lamps from other suppliers. Ignoring the new lamps risked further bad press and government scrutiny. So GE decided to introduce tantalum lamps for limited applications while working to improve the carbon lamp.[17]

Willis Whitney, first director of GE's research laboratory in Schenectady, New York, used a new electric furnace to produce an extremely pure carbon filament that exhibited metal-like properties. Introduced in 1904, the General Electric Metalized or GEM lamp seemed the perfect answer to GE's problems. GEMs shared most of the attributes of regular carbon lamps, so they required little new production equipment and few changes to process flow.[18] Visually identical to regular carbon lamps, GEMs gave customers a familiar looking product. Even better, GEMs gave 4 lpW, enough of an increase for GE to tout them as a "high efficiency" product but not so high as to raise the

15. Reich, "Lighting the Path," 314, for GE as the "Electric Trust" and its political utility in antitrust cases.

16. Bright, *Electric Lamp Industry*, 170-173. Nernst Lamp Co., incandescent lamps, ca. 1902, NMAH-EC catalog numbers 214330, 214331 and 214332.

17. Reich, "Lighting the Path," 305-34.

18. Bright, *Electric Lamp Industry*, 179-183. Howell and Schroeder, *History*, 84-88.

hackles of power companies. Westinghouse and others soon took licenses and offered their own GEM lamps for sale.[19]

Unfortunately for GE, European inventors refused to stop inventing. Two years later three independent teams introduced lamps containing tungsten filaments that each provided about 8 lpW—double the efficacy of the GEM.[20] The hotter a filament runs, the more efficiently it converts electricity to light. After carbon, tungsten has the second highest melting point of any element (3380º C) but can be heated much closer to that temperature before evaporating (about 2700º C), resulting in higher efficacy.[21] These first generation tungsten lamps were fragile but less so than osmium, worked well on ac unlike tantalum, and gave a higher efficacy than either.[22] Convinced that tungsten lamps were a significant threat and faced with licensing more European inventions, GE officials turned again to Schenectady. William Coolidge studied the problem and by 1910 developed a way of drawing tungsten into a malleable wire. His lamp required a complex internal structure but it gave 10 lpW, a milestone that not only assured GE's continued patent dominance but also knocked several competitors from the market. Improved gas burners, Nernst lamps, and early forms of discharge lighting like Moore's lamp could not match the combined

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19. Willis R. Whitney, Carbon Filament, and Method of Making the Same, US Patent 916,905, filed 2 February 1905, and issued 30 March 1909.

20. Bright, *Electric Lamp Industry*, 184-194.

21. John E. Kaufman, ed., *IES Lighting Handbook: the Standard Lighting Guide*, 6th ed. (New York: Illuminating Engineering Society of North America, 1981), 1:8-2.

22. Clayton H. Sharp, "New Types of Incandescent Lamps" (Advance copy of paper presented at meeting of the American Institute of Electrical Engineers, New York, 23 November 1906): 809-840. Just & Hanaman tungsten filament lamp, ca. 1908, NMAH-EC, catalog number 1997.0388.55, and Kuzel tungsten filament lamp, ca. 1908, NMAH-EC, catalog number 1997.0388.54.

simplicity and efficacy of Coolidge's second generation tungsten lamp.[23] This comparison can be seen in table 5.1 that shows the relative efficacies of commercially available lamps of that time. Though a few remain on the market today for specialized applications, manufacturers soon discontinued most of these products.

Table 5.1: Commercial lamp comparison, 1883-1913[24]

Lamp name and characteristic	Dates	Approximate efficacy (lpW)
Welsbach mantle (gas lamp)	1883 – present*	4-6 to 60-70 (cp/cu ft/hr)
Carbon filament (cellulose)	1884 – present*	3.4
Nernst burner (incandescent - Westinghouse)	1897 – 1912	5
Moore tube (discharge lamp - CO2 or N filled)	1898 – 1912	5-10
Osmium filament	1898 ~ 1905	5.5
Cooper Hewitt tube (discharge lamp - mercury)	1902 ~ 1930	12.5
Tantalum filament	1902 – 1913	5
General Electric Metalized filament (carbon - GEM)	1904 – 1919	4
1st generation tungsten filament (Europe)	1906 ~ 1912	7.85
2nd generation tungsten (Coolidge – Mazda B)	1910 – present*	10
3rd generation tungsten (Langmuir – Mazda C)	1913 – present	12+

* Niche product only since the 1930s.
Efficacy ratings vary due to product differences, such as the type of gas used (Welsbach, Moore).

GE's researchers did not stop there, however. Irving Langmuir undertook a series of experiments with tungsten wire and made two important discoveries. First, he found that a tight coil of tungsten wire radiated energy as if it were a solid rod, simplifying lamp construction. Second, Langmuir filled his lamp with inexpensive nitrogen, an inert gas that retarded filament evaporation. That allowed Langmuir to operate his coiled-filament lamps

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23. Bright, *Electric Lamp Industry*, 194-197.

24. Bright, *Electric Lamp Industry*, 166-200, 212-213, 221-229.

at higher temperatures, boosting efficacy to 20 lpW or more with higher wattages although the most common lamps averaged less. US manufacturers ceased selling tantalum and first generation tungsten lamps in favor of GE's two new designs referred to by the soon-to-be-common trade names Mazda B (Coolidge's) and Mazda C (Langmuir's).[25] GE placed the third generation tungsten lamp on the market in 1913 and it became ubiquitous; derivatives of Langmuir's lamp remained in mass production for over a century.

GE needed the good news. Since the 1892 merger that formed the company, Charles Coffin and his team had worked to solidify patent positions, reduce competition, and drive down costs through size and scope.[26] By 1910, three companies controlled the US lighting market: GE (42%), Westinghouse (13%) and a conglomerate of small lamp makers operating as the National Electric Lamp Company (38%).[27] Like many Gilded Age capitalists, Coffin saw competition as a wasteful diversion of resources that sapped value from shareholders and consumers alike. Rational control of markets would provide quality products at reasonable (though not the lowest) prices and protect shareholder value. That approach drew the ire of Progressive trust busters and the Justice Department filed suit in March 1911, charging violations of the Sherman Act.[28] The investigation revealed that GE secretly owned and operated National as a supposed independent competitor, "whereas no

25. Bright, *Electric Lamp Industry*, 317-323.

26. Reich, "Lighting the Path," 307-309.

27. Bright, *Electric Lamp Industry*, 151.

28. "Government Sues Electrical Trust," *New York Times*, 4 March 1911, 1, http://search.proquest.com. Bright, *Electric Lamp Industry*, 156-159; Reich, "Lighting the Path," 314-315.

such independence or competition exists or has existed."[29] The company was also charged with seeking to restrain trade by means of various price fixing arrangements and agreements to prevent suppliers and buyers from dealing with truly independent lamp makers. In October, GE signed a consent decree that forced it to publicly absorb—but not divest itself of—the National companies and commit to ending some anticompetitive practices.[30] Coffin resigned as company president but remained chairman of the board, and GE soon learned to work around the decree—in part by relying on the new tungsten patents. This was only the first round between GE and the Justice Department in a legal battle that continued for decades.

1900s: experts and professionals

As noted in the previous chapter, federal government involvement with lighting in the late nineteenth century mostly involved buying products and services for itself and for the District of Columbia. After settling the issue of putting wires underground in the downtown area, Congressional debates about lighting subsided and franchise holders began installing electrical systems throughout DC. Policy activity moved to mundane purchasing arrangements, another area of interest for Progressive reformers. After Alexander Hamilton's brief foray into centralization, government purchasing authority devolved to individual federal agencies. That situation led to inefficiencies and, as with the

29. United States v General Electric Company et al., In equity, no. 8120 (N.D. Ohio, 1911), 3, https://archive.org.

30. Robert P. Rogers, *The Impact and Relevance of the 1911 General Electric Lamp Case*, working paper no. 78 (Washington DC: Bureau of Economics, Federal Trade Commission, November 1982). "Electric Trust Must Dissolve," *New York Times*, 13 October 1911, 8, http://search.proquest.com. Rogers points out that no such dissolution took place, unlike other famous cases of that era like Standard Oil.

lighthouses, created opportunities for financial mischief. Government-wide reforms began in 1894 when the Cleveland Administration organized a Board of Awards in the Treasury Department. Although only advisory, the Board opened the system to further reforms and in 1909, Theodore Roosevelt's administration established a General Supply Commission in Treasury that centralized civilian purchasing activities.[31] Incandescent lamps and luminaires became office supplies along with pencils and paper.

Scientific research into lighting accelerated at this time and the new National Bureau of Standards (NBS) played an active role. Congress established NBS in 1901 to set and distribute uniform standards of measure, as well as design and fabricate precise measuring equipment.[32] Working with federal procurement agencies, NBS also provided quality control for electric lamps sold to the government, a necessary activity in an era when many standards remained unsettled. A set of lamps submitted in 1904, for example, tested so poorly that "the Bureau promptly threw out three-quarters of the bulbs."[33] In 1907, NBS issued a specification that, among other criteria, mandated "carbon-filament lamps consume no more than 3.76 watts per mean spherical candle" and exhibit a minimum useful life of about 400 hours.[34] NBS determined new standards as discoveries were made and provided results to anyone interested, including "corporations, firms, or

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31. Clem C. Linnenberg Jr., "Policies & Procedures in Federal Civilian Procurement," *Accounting Review* 18, no. 1 (January 1943): 19. 16-26. Richard D. White, Jr., "Executive Reorganization, Theodore Roosevelt and the Keep Commission," *Administrative Theory & Praxis* 24, no. 3 (March 2002): 507-518.

32. Lyman J. Briggs, "Early Work of the National Bureau of Standards," *Scientific Monthly* 73, no. 3 (September 1951): 166-175, http://www.jstor.org. "National" was not in the Bureau's name from 1903 to 1935. For convenience, I use NBS until the 1988 change to NIST.

33. Rexmond C. Cochrane, *Measures for Progress: A History of the National Bureau of Standards* (Washington, DC: US Department of Commerce, 1966), 90-91.

34. Cochrane, *Measures*, 112.

individuals..."[35] NBS's situation in the new Commerce and Labor Department emphasized its mandate to be helpful to the private sector.[36]

NBS electrical activities included defining absolute measures for phenomenon like resistance and capacitance, and calibrating devices to measure those standards. US labs public and private previously sent devices to European labs for that service.[37] GE's Elihu Thomson sat on the Bureau's Visiting Committee, a board of professional oversight that reported to the Commerce Secretary.[38] Thomson, co-founder of Thomson-Houston Company, became chief researcher at GE after the merger and specialized in electric meters. His presence on the Visiting Committee provided a direct and influential channel of communication between both organizations' senior managers.[39]

In electric lighting research the Bureau performed two main functions. First, they conducted research into the nature of light with special attention to "electrical discharges in gases, to determine...conditions necessary for producing a given spectrum...."[40] Laboratories needed data on the spectral output of various gases along with guidelines for standard lamps then produced by private firms. Also, lamp makers wanted information about new discharge lamps like Cooper Hewitt's and Moore's inventions. NBS's second major area of lighting research involved working with industry to craft photometric

35. Edward B. Rosa, "The Organization and Work of the Bureau of Standards," *Science* NS 19, no. 495 (24 January 1904): 937-949, http://www.jstor.org.

36. Dupree, *Science*, 271-277, 287-288.

37. Rosa, "Organization and Work," 949. Briggs, "Early Work," 166.

38. Rosa, "Organization and Work," 940.

39. Briggs, "Early Work," 169. GE's Willis Whitney appears in a 1926 photo of the Visiting Committee.

40. Rosa, "Organization and Work," 943.

standards of lamp output and efficiency.[41] At the time of the Bureau's founding the Hefner served as international standard for lighting, based on the light output of a specially made open-flame lamp, but variability of fuel and atmospheric conditions made that standard unreliable.[42] To improve reliability and convenience, the Bureau adopted as standard "the mean of the value of several 16-candle power [electric] lamps," and tested samples from many manufacturers. They found the lamps in tolerable agreement with their standard although they declined to regularly test commercial products, "apart from testing done for the government."[43]

The Bureau may have had little interest in serving as a commercial test facility but they paid close attention to lighting industry needs and developed a device to quickly and easily measure the energy efficiency of 16 cp incandescent lamps. While acknowledging that "the proper definition of...'efficiency' would be lumens per watt," the researchers who designed the meter used the term "to designate the watts per mean horizontal candle, *in accordance with the more common use of the term in industrial practice*."[44] By 1906, metal filament lamps started to draw attention to relative efficiencies as a selling point and US manufacturers needed a quick way to compare lamps. GE could have developed this meter at their Schenectady laboratory, established about the same time as NBS and staffed

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41. Various manufacturers, incandescent lamps, ca. 1914, NMAH-EC, accession number 1992.0342, includes sixteen pre-WWI incandescent lamps tested at NBS along with data sheets.

42. Adrien Palaz, *A Treatise on Industrial Photometry*, trans. George W. Patterson and Merib Patterson (New York: D. Van Nostrand Company, 1894), 136-143.

43. Rosa, "Organization and Work," 946-947.

44. Edward P. Hyde and Herbert B. Brooks, "An Efficiency Meter for Electric Incandescent Lamps," *Bulletin of the Bureau of Standards* 2, no. 1 (1906): 145-160. Emphasis mine.

by skilled researchers. Coffin and Thomson may have decided that rising antitrust sentiment in the country made NBS a politically expedient location for the research.

GE's disjointed efforts to introduce so-called high efficiency incandescent lamps generated confusion in the market. From 1904 through 1910 the company promoted GEM, tantalum, and first generation tungsten lamps for their efficiency, the introduction of even higher efficacy tungsten lamps would only compound the problem. In 1909, the company adopted the name Mazda for metal filament lamps partly to resolve the confusion. For the sake of their ongoing antitrust fight the company doggedly insisted the name was "the mark of a service, not a product," but two generations of Americans associated the name Mazda with electric lamps.[45] Despite the company's strong push for Mazda lamps, many consumers continued to purchase older, inexpensive carbon lamps or adopted the familiar looking GEM lamp.[46] Aside from the marketing problems, GE walked a fine line between regulators, utility operators, and lamp sellers over the definition of efficiency—and who would define that term.

The Bureau of Standards, involved with meters, ratings, and nomenclature, found itself in the middle of a battle between scientists and engineers on one side and business managers and central station operators on the other. Lighting researchers spent time and effort defining fundamental units then devising ways to measure those units. Various groups including NBS and IES agreed on two principle measures of light: the candela (cd)

45. Howell and Schroeder, *History*, 100-101. Mazda "is not the name of a thing but the mark of a research service." Such disclaimers appear in many GE ads and statements.

46. Bright, *Electric Lamp Industry*, 180-182 for GEM lamps.

for luminous intensity, and the lumen (lm) for luminous flux.[47] Although scientists adopted the lumen and lumens per watt as the measure of luminous efficacy, many workaday electricians and plant operators kept the older measure: candlepower. More importantly, they reversed the order and spoke in terms of watts per candlepower (w/cp). Their main concern lay in measuring the power output of generators and load demands on their systems. In an era before computers, placing the most important parameter first allowed operators to quickly read and comprehend data.

To confuse matters further, the two sides argued over how to measure a lamp's light output. The output of an arc or gas lamp could only be measured accurately in a horizontal plane, not spherically due to the way those lamps were made. Electrical companies commonly used mean horizontal candlepower for performance comparisons and in contracts with cities that bought streetlight services. However, new tungsten lamps with coiled filaments could be measured accurately with a new tool, the Ulbricht sphere, and scientists wanted to use mean spherical candlepower or simply lumens to denote lamp output.[48] Utility managers who operated three radically different lamp types—gas, arc, and incandescent—found this an impractical, ivory tower exercise.[49] Extrapolation of

47. John E. Kaufman and Jack F. Christensen, eds., "Dictionary of Lighting Terminology," section 1 in *IES Lighting Handbook: Reference Volume* (1984). There are many lighting standards, the details of which are not important here. Suffice that the candela is the intensity of light radiated over an angle of 1 steradian (cd=lm/sr). The lumen is the total amount of light from a source emitting 1 candela (lm=cd*sr). Alex C. Humphreys, "Report of the Committee on Nomenclature and Standards," *Transactions of the Illuminating Engineering Society* 4, no. 7 (October 1909): 520-550.

48. George Loring, "Illuminating Efficiency vs. Candle-Power Efficiency of Electric Lamps," *Illuminating Engineer* 1, no. 1 (March 1906): 10-13.

49. "The Integrating Sphere and Arc-Lamp Photometry," *Electrical World* 65, no. 6 (6 February 1915): 330. "Rating of Incandescent Lamps," *Railway Electrical Engineer* 7, no. 10 (March 1916): 283-284. Several letters commenting on the latter are in *Railway Electrical Engineer* 7, no 11 (April 1916): 312-313.

horizontal measurements would not compare favorably to direct spherical measurements, and might lead customers to think they were being cheated.[50]

Listing watts as the numerator, however understandable from an operator's standpoint, carried larger commercial significance. Utility managers fought using measures of light in public, claiming that "the ordinary person does not know a lumen from a Croton bug," no matter that people had been buying lamps rated in candlepower since Edison's invention.[51] They sold power, not light, and wanted users to equate lamp output with wattage despite the scientifically preferred usage, as well as to standardize merchandising efforts with appliances rated in watts.[52] Gas companies fighting to keep lighting markets and arc lamp maintenance personnel fighting to keep their jobs also had a stake in defining efficiency and how to measure it. GE worked to be accommodating for reasons beyond placating buyers of electrical equipment. Lamp makers could not precisely control the voltage rating of carbon lamps during manufacture, a problem solved by switching to tungsten filaments. A high level of quality control allowed GE and its licensees to ensure that tungsten lamps would produce consistent light levels; they could then discredit cheap imported and unlicensed lamps. The two sides came to ignore each other: researchers used lumens and lpW in their publications while power stations sold electricity and consumers bought lamps by the watt. The use of input power instead of light

50. "Rating Lamps in Lumens," *Electrical World* 68, no. 1 (January 1917): 3. Arc and gas lamps do not radiate light spherically. Extrapolations of horizontal ratings to spherical appeared to show reduced output due to averaging effects.

51. "Rating Lamps," *EW* 68:3.

52. "Recommended Terminology," *Electrical World* 67, no. 22 (27 May 1916): 1226. Engineering Department, National Electric Lamp Association, "Economical Operation of Incandescent Lamps," Bulletin 17 (15 May 1911), in NMAH EC-LRF.

output to rate lamps created problems for policy makers in the decades to come.

This also left open a debate about the meaning of efficiency in lighting that tied into national questions about the meaning of conservation, and those questions resurfaced throughout the twentieth century. Did conservation mean consuming less of a resource or getting more out of the resource consumed? Did a more efficient lamp use less electricity or give more light? Which side of the output / input equation should predominate, if either? Both approaches appeared in period advertising, reflecting the conflicted values of lamp makers and retailers.[53] This was not purely an academic exercise since choosing the wrong approach carried real consequences. When "many dealers" began selling tungsten lamps on the basis of "same light, less expenditure [of power]," executive Henry L. Doherty "explained that he adopted the policy of cutting prices on tungsten lamps so low that the dealers could not [profitably compete]."[54] The alternate value of reducing power consumption soon became official government policy however when a coal shortage began to impact people and industries around the nation.

As centralized electrical systems grew larger, operators diversified loads beyond lighting by promoting devices like elevators and fans that ran anytime. That required more fuel to run generators, adding to the nation's growing reliance on coal. Some areas continued to use wood as fuel and new hydroelectric plants entered service, but residents and businesses in most cities became dependent on coal for heat and commercial

53. "The Edison GEM Lamp," ink blotter 116, NMAH Archives Center, AC#789, GE Nela Park Collection, touts the GEM lamp's efficiency as more light for the same current. Yet, "If You Can Get Better Light," ink blotter 3904, states Mazda lamps save "more than half the current" of older lamps.

54. "Conference of Electrical Development Society," *Electrical World* 61, no. 10 (8 March 1913): 505. Doherty founded Cities Service Co., later Citgo, and at the time served as EDS president.

operations.[55] The increasing demand aggravated problems with coal production and transportation systems. Strife between unions and mine owners affected operations and in some instances became predictable.[56] Railroad owners and managers added to the problems both directly and indirectly in ways that ultimately brought federal intervention.

Coal moved in all-purpose gondola cars that could not be quickly unloaded, and trains that mixed coal-carrying cars with other rolling stock slowed switchyard operations and limited coal quantity delivered.[57] All rail users suffered from a shortage of cars due to intramural competition for rolling stock when railroads could not retrieve empty cars from "foreign" roads or recipients. Some roads used other lines' cars rather than purchase their own, making wealthier roads loath to buy cars or invest in new technology like coal hoppers. Some freight recipients used cars as storage buildings. Demurrage fees tended to be ignored leading to embargos on shipments to certain regions.[58] By 1916, inability to put aside self-interest, resistance to Interstate Commerce Commission orders, and fear of antitrust laws among other issues brought US railroads to a crisis.[59] The combination of

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55. Platt, *Electric City*, 102. Nye, *Consuming Power*.

56. "Storing Coal for Strikes," *Electrical World* 63, no. 5 (31 January 1914): 237. *Electrical World* noted that Mid-West railroads and central stations were stockpiling coal in anticipation of "the expected biennial April strike in the bituminous coal regions."

57. Richard L. Gordon, *Coal in the U.S. Energy Market: History and Prospects* (Lexington, MA: Lexington Books, 1978), 94-97. Specialized coal hopper cars and automatic handling equipment were just being invented at this time. General use of dedicated unit-trains for coal did not occur until after 1957.

58. "Coal Famine Feared in the East," *Electrical World* 66, no. 26 (25 December 1915): 1408. Also, "Coal Shortage Being Relieved," *Electrical World* 68, no. 20 (11 November 1916): 940. Some state regulators approved embargoes on shipments over state lines when rolling stock left railroads' physical control.

59. "Coal Cost and Shortage—Meeting the Problem," *Electrical World* 69, no. 10 (March 1917): 478-479; "Shortage of 50,000,000 Tons in Nation's Coal Supply," *Electrical World* 70, no. 20 (November 17, 1917): 971. Skowronek, *Building*, 274-275.

transportation dysfunction, labor unrest, and growing demand boosted coal prices and disrupted deliveries, creating a "coal famine" in that year.[60] The Wilson Administration grew acutely concerned about coal supplies, fearing shuttered industrial plants and freezing homes as they considered involvement in World War I.

1910s: lightless nights

The First World War began in Europe in mid-1914 and the US electrical industry took immediate note. One trade group reported that, "American lamp manufacturers find themselves practically independent of European raw materials."[61] An observer noted that while tungsten supplies might "run short in some [countries, driving] the users back to carbon, ...manufacture of incandescent lamps will perhaps suffer least owing to the small proportion of male labor involved and the steady demand for [lamp] replacements."[62] War preparations that many business people and Progressives felt prudent proved hard to enact. Many Americans wanted to stay out of Europe's troubles and reelected Woodrow Wilson in 1916 partly because, "he kept us out of war."[63] Though officially committed to neutrality, Wilson instituted a program of national preparedness that engineers in industry

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60. "The Coal Famine," *Electrical Review and Western Electrician* 69, no. 20 (11 November 1916): 833.

61. "Convention of the Edison Illuminating Company," *Electrical World* 64, no. 12 (19 September 1914): 555.

62. Louis Bell, "The War's Effect on the Electrical Industry," *Electrical World* 64, no. 9 (29 August 1914): 411. Lamp fabrication was a gendered occupation employing many women for much of its history.

63. John Milton Cooper, Jr., *Pivotal Decades: The United States, 1900-1920* (New York: W.W. Norton and Co., 1990), 247-248.

believed they could assist.[64] Thomas Edison suggested harnessing the latest technology and in 1915 a new Naval Consulting Board began assessing US technical resources.[65] Shifting to a wartime economy would create problems made worse by fuel shortages, so Wilson set up the Council for National Defense in 1916.

US industry received orders for war equipment from home and abroad. The surge in production worsened coal shortages in 1915 and 1916 as consumption rose and more railroad cars were needed to move raw materials and finished goods. Stories appeared in the press of power stations reduced to days or even hours of coal reserves.[66] US entry into the war in April 1917 brought railroad chaos and a fuel crisis, resulting in federal intervention that prioritized production and rationed raw materials until war's end and for a time after. The War Industries Board, established in July, set prices, rationalized raw material supply and production, and dealt with labor unions.[67] The Railway War Board (later the US Railroad Administration) was tasked with unsnarling transportation. To deal with energy issues in general and coal in particular, Wilson used Congressional authority under the Food and Fuel Control Act to establish the United States Fuel Administration (USFA) and named Harry A. Garfield, son of President Garfield, as Administrator.[68]

Garfield and his team quickly set up state level subsidiary organizations and named

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64. Robert D. Cuff, *The War Industries Board: Business-Government Relations during World War I* (Baltimore: Johns Hopkins University Press, 1973), 18-20.

65. Dupree, *Science*, 306-308.

66. "Coal Famine Feared in the East," 1408. "Coal Supply Threatened by Railroad Strike," *Electrical World* 68, no. 8 (19 August 1916): 353. "The Ranking Problem in Operation" and "Coal Cost and Shortage," *Electrical World* 69, no. 10 (10 March 1917): 449, 478-479.

67. Cuff, *The War Industries Board*.

68. USFA, *General Orders*, 26-27.

administrators for each to coordinate and customize federal policies. They enacted price restrictions for coal not already under contract and requested voluntary cooperation in providing coal at the restricted price—and reminded suppliers that they could force cooperation if needed.[69] USFA also worked to improve efficiency in coal use by issuing pamphlets to educate plant operators on test methods, component design, and boiler firing practice.[70] They began to prioritize who would receive coal and uses that might be curtailed, including some forms of electric lighting. Railway War Board members urged "[prohibiting] the use of coal for the production of electrical energy used in advertising." They argued that a 1 percent savings in coal would provide enough fuel for 1.5 million families as well as "impress upon the people the lesson that economy is necessary in the use of fuel generally."[71] Curbing outdoor lighting would not be easy. One editorial ridiculed coastal blackouts, and an article extolled security lighting for industrial plants.[72]

Garfield's team took the suggestion seriously however and began drafting regulations despite industry assertions that not much coal was used to run electric signs.[73]

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69. USFA, *General Orders*, 36.

70. For example: United States Fuel Administration in collaboration with the Bureau of Mines, *Saving Coal in Steam Power Plants*, Engineering bulletin no. 2 (Washington, DC: GPO, 1919, reprint). United States Fuel Administration in collaboration with the Bureau of Mines, *Saving Steam in Industrial Heating Systems*, Engineering bulletin no. 6 (Washington, DC: GPO, 1919, reprint).

71. Letter, C. M. Shaeffer, et al., to H. A. Garfield, 19 October 1917, reprinted in Wayne P. Ellis, *Report of the Distribution Division: 1918-1919—Part II The Zone System* (Washington, DC: GPO, 1919), 8.

72. "Lighting In War Time," *Electrical World* 69, no. 17 (28 April 1917): 786; "Electrical Industry in War Time," *Electrical World* 69, no. 15 (14 April 1917): 717.

73. New York City reportedly used 2.75 tons of coal and Chicago used 7 tons to light all of their signs each night. "Dr. Garfield expressed himself as frankly incredulous of these statements." "Regulation of Sign Lighting Is Nearer," "Sign Owners Urge a Compromise Plan," and "Action on Sign Lighting by National Committee," *Electrical World* 70, no. 19 (10 November 1917): 920-921.

With demand surging and an expected shortage of 50 million tons, USFA determined to "prevent the waste of fuel and the unnecessary use of coal [so as not] to embarrass the war industry...."[74] After reiterating that electric signs used little coal, the *Electrical World* editors conceded, "The strongest argument...is the moral or psychological one; *people imagine that the waste is a thousand times more than it is*. If we are called on to cut to the bone, let us do it willingly and show the public that we are ready to do our part."[75] Willing or not, a rather limited order took effect on 13 November 1917 banning coal use for illuminated advertising signs, searchlights and ornamental lighting of buildings before 7:45 pm and after 11 pm. The order exempted streetlights and porch, exit, and safety lighting on hotels, homes, and factories open all night.[76] Unfortunately for the USFA many people simply refused to comply or actively sought to circumvent the order.

Within two weeks of the ban Commonwealth Edison "at its own expense" erected large electric signs on Chicago's City Hall and a county building that read: "Food Will Win the War."[77] Other utilities began sponsoring similar patriotic signs urging the public to buy Liberty Bonds and support the Red Cross. Garfield issued a pointed rebuke that threatened to remove exemptions, and told the industry that follow-on orders for "'lightless nights'...similar to 'wheatless' and 'meatless' days" were "under definite consideration."[78]

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74. "Shortage of 50,000,000 Tons," 971.

75. "Unnecessary Waste of Energy," *Electrical World* 70, no. 16 (20 October 1917): 751. Emphasis mine.

76. USFA, *General Orders*, 532-534.

77. "Electric Signs Help Conservation of Food," *Electrical World* 70, no. 21 (24 November 1917): 1022. Government buildings were exempt from the USFA order.

78. "Electric Sign Ruling by Fuel Administration," *Electrical World* 70, no. 23 (8 December 1917): 1114. "'Lightless Nights' Planned by Fuel Administration," *Electrical World* 70, no. 24 (15 December 1917):

His warning had little effect. So on 14 December Garfield signed the order for lightless nights on Sunday and Thursday evenings and asked everyone to observe the restrictions as a patriotic gesture. "In addition to the saving of a large quantity of coal, it is believed by [USFA] that 'lightless nights' will provide startling evidence that the United States is in the greatest of world wars."[79] In a direct statement to the electrical industry USFA unequivocally announced, "It is a recognized fact that there is an enormous waste of coal due to the extravagant and luxurious use of electric light."[80]

While not a total blackout, Garfield's order reflected the seriousness of the fuel situation. On 26 December the government took control of the railroads. Aside from the coal problem, gridlock on the rails kept military personnel and war materials from reaching the Atlantic coast for transport to France. To help, Garfield announced a five day business shutdown in January 1918 so the government could focus on getting coal to ships "held in harbor by lack of fuel," and to begin straightening out "the domestic railroad tangle."[81] Some state-level fuel administrators imposed even harsher lighting restrictions to reduce consumption and prioritize use of energy supplies. New York's fuel administrator, for example, placed an absolute prohibition on exterior lighting for every night except

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1159.

79. USFA, *General Orders*, 532-535. "Sundays and Thursdays Set Aside," 43. For quote, "'Lightless Nights' Order of Fuel Administration," *Electrical World* 70, no. 25 (22 December 1917): 1209.

80. United States Fuel Administration, "To Save Fuel Use the Central Station," *Electrical World* 71, no. 1 (5 January 1918): 5.

81. USFA, *General Orders*, 433-435. "Saving Fuel Supplies for the War," *Electrical World* 71, no. 4 (26 January 1918): 185.

Saturday.[82] These lighting prohibitions faced intense industry criticism.[83]

Throughout the war, utility representatives decried the idea that light was non-essential and claimed the small savings of coal were not worth the effort, even though many accepted the symbolism that lightless nights conveyed.[84] Some argued that lightless nights wasted energy by impairing production and safety, and sought to shift the burden by arguing for increased coal production and use of hydropower, and closure of non-essential businesses.[85] New Orleans and other cities proceeded with installation of "white ways" street lighting, despite the inclusion of these energy intensive designs in the ban.[86] In mid-1918 hearings were held in Massachusetts on why beach resorts should be exempt from the orders.[87] The imposition of daylight savings time on 31 March seemed to reduce the need for lightless nights and they were suspended until 1 September.[88]

Straightening out the railroads and getting mines to full production took longer than expected however, and appliance sales helped some utilities evade the goal ofsaving coal.

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82. "Rigid 'Lightless' Order Made for New York State," *Electrical World* 71, no. 1 (5 January 1918): 58.

83. "Carrying Lighting Curtailment to Absurdity," *Electrical Review* (New York) 73, no. 11 (14 September 1918): 410. "Lightless nights to be resumed," *New York Times* (20 July 1918): 7. Platt, *Electric City*, 201-218.

84. "The Electric Light a Necessity," *Electrical World* 71, no. 2 (12 January 1918): 32. "The Curtailment of Lighting," *Electrical World* 72, no. 3 (20 July 1918): 99. "Pound-Foolish Lighting Curtailment," *Electrical World* 72, no. 12 (21 September 1918): 530.

85. "Lightless Nights in Hydroelectric Territory," *Electrical World* 71, no. 3 (19 January 1918): 156.

86. "White Way Lighting Begun in New Orleans," *Electrical World* 71, no. 6 (9 February 1918): 297.

87. "Conservation Restrictions on Summer Resort Lighting," *Electrical World* 72, no. 13 (28 September 1918): 603.

88. "Daylight Saving Hour Will be Put in Force," *Electrical World* 71, no. 12 (23 March 1918): 636, "Lightless Order Suspended by Fuel Administration," *Electrical World* 71, no. 17 (27 April 918): 888. "The Effect of Daylight Saving on Load," *Electrical World* 71, no. 19 (11 May 1918): 972 claimed, "No large coal saving."

In July 1918, USFA announced that new lightless nights might be coming.

> It now appears that in every city and village of the country from which statistical and other reports have been gathered electricity is being wasted in large quantities in the production of light for advertising, street and store illumination and other similar purposes. The country needs now—and for the whole period of the war will need—more coal than it can possibly produce and transport.[89]

Later that month USFA officially re-imposed lightless nights and the sign ban saying,

> The Bureau of Standards has advised the Fuel Administration that it is estimated that about 500,000 tons of coal per year is used for advertising purposes, including display and show-window lighting, in the United States. Similar estimates fix the amount of coal used in advertising lighting in New York City at 16,000 tons per year.[90]

The Bureau's numbers did not impress the editors of *Electrical World* who complained about "ridiculously small" savings of coal from the lightless nights.[91]

Below the announcement of new lightless nights came a deceptively simple note: "It is understood that [USFA] has under consideration some measures providing for *the possible curtailment of production and distribution of the less efficient types of incandescent lamps*."[92] This presaged a lighting industry effort to completely remove carbon lamps from the market in favor of tungsten lamps. Market diffusion of tungsten lamps proceeded throughout the prewar era but faced significant hurdles. Many people liked low cost carbon lamps and complained that expensive tungsten lamps were too bright

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89. "Appliances to Offset Daylight-Saving Loss," *Electrical World* 71, no. 22 (1 June 1918): 1144, about one company's work to counteract lost power sales, defeating the purpose of the policy. USFA, *General Orders*, 532-538. "Further Restrictions to be Made in Lighting," *Electrical World* 72, no. 1 (6 July 1918): 26.

90. "Lightless Nights Ordered Again," *Electrical World* 72, no. 4 (27 July 1918): 176. The nearly 44 tons a day was significantly more than the 2.75 tons cited by industry in "Regulation of Sign Lighting."

91. "Lightless Nights and What They Entail," *Electrical World* 72, no. 5 (3 August 1918): 193.

92. "Lamps Under Consideration," *Electrical World* 72, no. 4 (27 July 1918): 176. Emphasis mine.

and glaring. Confused by competing claims of high efficiency and unwilling to install shades to control the glare, many refused to pay for tungsten lamps.[93] Some utilities stopped providing free lamp renewals around this time, and in any case station managers did not wish to give away high priced lamps that would lower demand for electricity.[94] Affected consumers began purchasing cheap carbon lamps from retailers.

Demand for regular carbon lamps started declining in 1904 after the introduction of GEM carbon lamps and European metal filament lamps. When GE unveiled their two new tungsten lamps, the GEM lamps appeared headed for obsolescence too, until sales unexpectedly surged in 1915, 1916, and 1917.[95] *Electrical World* attributed the root cause of the resurgence to the lack of free tungsten lamp renewals and added,

> Pressure is being brought now on the users of light to cut down their consumption, and it strikes us that the wise method of doing this is to use lamps consuming less energy and more skillfully installed, instead of cutting out altogether illumination which is really valuable and ought not to be discontinued.[96]

The surge in demand for carbon lamps, especially GEMs, presented problems for lamp makers. GEM profits fell due to rising fuel and material costs, and its claim to high

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93. Sixteen candlepower carbon lamps usually had clear glass envelopes; the filament could be directly viewed without discomfort. Preston S. Millar, "Progress in Illuminants and Illuminating Engineering," *Electrical World* 67, no. 1 (1 January 1916): 28.

94. Francis W. Willcox, "Higher-Efficiency Lamps: Their Value and Effect on Central-Station Service," in *National Electric Light Association, 29th Convention*, vol. 1, *Papers, Reports and Discussions* (New York: The James Kempster Printing Co., 1906), 597-635.

95. John Lieb, "urged that central station members speed the departure of the gem and carbon lamp, pointing out that it will reduce the cost of lamp manufacture very materially...and that the industry will benefit." "Report of the Lamp Committee," *Electrical World* 67, no. 22 (27 May 1916): 1231.

96. "Business Conditions with the Lamp Manufacturers," "G.S. Stickney Addresses Chicago Section, I.E.S.," and "Development in Incandescent Lighting," *Electrical World* 70, no. 16 (20 October 1917): 777, 830, 849.

efficiency was no longer credible. Unlike tungsten lamps, no carbon lamp could be made to precise voltage specifications; converting would solve the problem of "central stations maintaining domestic service voltages at...odd pressures."[97] Manufacturers batched carbon lamps for sale to utilities that supplied a given voltage, but as central stations sold more appliances they standardized voltages. That reduced the number of customers for outlier voltage lamps, resulting in unsalable inventory.[98] With only a few years of patent protection remaining and costs rising, making GEMs in batches was unsustainable. GE wanted to phase out the product, but did not want to lead the way. They lacked the short run production capacity to simply close GEM lines in favor of tungsten, and jealously guarded even small market shares.[99] Despite claims that material shortages made it "impossible" to meet demand, GE pushed a new licensing agreement that included central stations in an "agency plan [that made] the importation of tungsten lamps...illegal."[100] They also announced a new pricing schedule that included four ratings of GEMs, all cheaper than tungsten lamps.[101]

The rationing of strategic materials such as copper and the push to save coal gave GE the chance to move the entire industry away from carbon lamps, especially GEMs. Re-imposition of lightless nights and a promise of even tighter restrictions seems to have

97. "Movement for Lamp Voltage Standardization," *Electrical World* 68, no. 4 (22 July 1916): 200.

98. "Price of Incandescent Lamps Not to Increase," *Electrical World* 69, no. 19 (12 May 1917): 943, "fewer stations are using these lamps, although the range of voltages in production remains the same."

99. "Replacing Carbon and 'GEM' with Tungsten Lamps," *Electrical World* 72, no. 5 (3 August 1918): 229. "It is estimated that it would require the entire output of all American lamp factories for two years to replace all of the carbon and "gem" lamps now operating."

100. "Electrical Trade Shows Strength in First War Year," *Electrical World* 71, no. 1 (5 January 1918): 67.

101. "New Prices for Large Incandescent Lamps," *Electrical World* 71, no. no. 1 (5 January 1918): 68.

been the final straw for the company and the lighting industry overall.

> Data on the subject worked out by lamp manufacturers indicate that 17% of all fuel burned to produce incandescent lighting is consumed [by] carbon and "gem" lamps. Obviously to secure the same amount of light by the use of tungsten lamps instead of these carbon and "gem" lamps would require the burning of considerable less coal.... It is entirely within reason...to go about replacement of the less efficient lamps gradually.[102]

This time, industry and government interests aligned. Garfield's team cared about saving energy and if getting inefficient carbon lamps off the market would help, so be it.

Company representatives met with USFA officials in Washington on 15 July. Four days later John Lieb, electrical engineer, former Edison employee, and president of the National Electric Light Association, called an emergency meeting of lighting manufacturers in New York. Over the following six days a subcommittee of five met and hammered out details of a plan to which the assembled representatives gave "unanimous" approval. Back in Washington on 28 August, Lieb and his associates submitted the plan to Charles Stuart, head of USFA's power and light section. Their eleven recommendations included: banning GEM lamps, phasing out most regular carbon lamps, ending free carbon lamp renewals by utilities, changing price structures to encourage higher wattage lamp sales, eliminating certain less efficient tungsten lamps, and joint advertising by government and industry about conservation and the reasons for these actions.[103]

Several provisos are telling. The ban on GEM lamps, "an intermediate type between carbon and tungsten," shows this policy was less about saving energy and more

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102. "Replacing Carbon," 228-29.

103. "Abolishing Inefficient Types," 685-688. "Lamp Policy of the Fuel Administration," *Electrical World* 72, no. 10 (7 September 1918): 457-460.

about aiding technology diffusion. Rather than immediately ban less efficient carbon lamps and allow "the intermediate type" for a time, the reverse would occur.[104] The committee stressed that the "temporary departure from" their policy of encouraging higher wattage lamps "must be recognized" as only for the war emergency. USFA was to "urge" state public service commissions to end free lamp renewals and pass the higher costs of tungsten lamps to rate payers as it was "impossible [for utilities] to bear this increased burden of cost..." Despite prior statements that no smaller firms made carbon lamps:

> agreement may be had with the larger manufacturers whose principal business is the production of tungsten lamps that they may abandon their output of carbon lamps, and transfer of the production of carbon lamps may possibly be arranged under a mutual agreement made through the administrative authorities at Washington between the larger manufacturing companies and the smaller businesses now producing carbon lamps.

Ostensibly that would keep companies that made carbon lamps from going immediately out of business. In practice it would allow GE and Westinghouse to offload unprofitable carbon lines that would soon be extinct anyway. GE would presumably then license the "smaller businesses" if they wanted to make Mazda lamps.[105]

Replacing carbon lamps would make lighting in the US more efficient, but the policies would also allow GE to close (or sell) older production lines, and give the company a patriotic excuse for discontinuing an inexpensive, popular product. In October, USFA approved the program "agreed to voluntarily by all the manufacturers of the...lamps."[106] Unfortunately for Lieb and his colleagues peace intervened; an Armistice

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104. "Lamp Policy," 460.

105. "Abolishing Inefficient Types," 685.

106. Augustus J. Cobb, "Final Report of the Bureau of Conservation," in United States Fuel Administration,

ending hostilities was signed on 11 November 1918. On 30 November, *Electrical World* announced both suspension of lightless nights and USFA's approval of the carbon lamp ban.[107] Despite official approval, the end of the war spelled the end of the phase out, and Lieb soon informed lamp makers that the plan had been abandoned.[108] Or had it?

Early period, first phase: mixed results

"Gloom no longer pervades our streets. Our signs and windows once more blaze forth with welcome light, and the whole country rejoices in the removal of the ban that kept them so long darkened. What an impressive tribute to electricity our 'white ways' are!"[109] Before WWI the lighting industry pushed for more and better quality illumination while trying to convince utilities that higher lamp efficacy would not hurt power sales. They continued that theme after the war and added the experience of "gloomy" lightless nights to their sales pitches. Unfortunately the prewar coal shortages also continued. Miners struck in November 1919 and many immigrant miners returned home.[110] The USFA, disbanded in June 1919, was revived during the strike but closed in December in favor of a Bituminous Coal Commission. Over time the fuel situation stabilized. The railroads

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Report of the Administrative Division 1917-1919—Part II: Reports of Bureaus with Headquarters at Washington, DC (Washington, DC.: GPO, 1920), 249.

107. "The 'Lightless Night' Order is Set Aside," and "Approves the Lamp Conservation Plan," *Electrical World* 72, no. 22 (30 November 1918): 1040.

108. "Lamp Curtailment Abandoned," *Electrical Review* 74, no. 1 (4 January 1919): 3.

109. *Electrical World* 72, no. 22 (30 November 1918): 1018.

110. "Coal Mining Situation," *Electrical Review* 74, no. 22 (31 May 1919): 900. "The Coal Miners' Strike," *Electrical Review* 75, no. 18 (1 November 1919): 741. "Some Factors Affecting the Coal Problem," *Electrical Review* 75, no. 21 (22 November 1919): 870.

reverted to private ownership after passage of the Esch–Cummins Act in 1920 with stronger oversight by the ICC that in time resolved that part of the fuel problem.[111]

Policy maker's goals for lightless nights (as per the second research question) were twofold: ration limited coal supplies, and symbolize the war emergency so as to promote frugality among the citizenry. The success of lightless nights depended on one's view. To industry there was much pain, little gain, and significant non-compliance. The trade press complained all through the war. Frequent reports of exempt signs and new street lighting installations support the view that USFA did not win broad support. Only twenty-three of fifty-one state fuel administration reports mentioned lighting restrictions, and while most reported general compliance with lightless night orders they said little more. Few mentioned major energy savings. H. C. Couch, Administrator for Arkansas, reported "large savings" of fuel attributable in part to lightless nights but the experience in Florida seems more typical. Administrator Arthur T. Williams reported that the "advantages derived [from lightless nights] were principally the moral effect..."[112] Those that did not mention lightless nights presumably either did not enact the restrictions (like Maine), encountered "considerable objection" to the program (Wyoming), or felt the savings "scarcely appreciable" (West Virginia).[113] In the end, the USFA's Bureau of Conservation

111. Paul Stephen Dempsey, "The Rise and Fall of the Interstate Commerce Commission: The Tortuous Path from Regulation to Deregulation of America's Infrastructure," *Marquette Law Review* 95, no. 4 (Summer 2012): 1165-1166.

112. United States Fuel Administration, *Report of the Administrative Division 1917-1919—Part I: Reports of the Bureau of State Organizations and of the Federal Fuel Administrators for the Various States and Districts*, ed. George E. Howes (Washington, DC.: GPO, 1920). Couch's quote is on page 23, Williams' on 67. The 51 "state" reports included DC, the Pittsburgh District, and Cuba.

113. USFA, *Report of the Administrative Div.*, Maine, 139; Wyoming, 425; West Virginia, 399.

reported fuel savings from lightless nights amounted to about 250,000 tons of coal, less than 1 percent of total savings obtained by the Administration. Without doubt, the symbolic effect of lightless nights in reminding people of the ongoing war emergency outweighed fuel savings in importance.

The policy of encouraging cooperative research worked to a point but could not alter the cultural fragmentation of increasingly specialized professions. Lighting became professional as trained scientists and engineers displaced lone inventors, and recognized standards aided the flow of information across international borders. During the war, lighting experts in academia, the private sector, and government cooperated to draft codes for better illumination, especially for industry.[114] The Bureau of Standards tested lamps for quality, advised on lighting designs, and conducted research into lighting physics and optics.[115] After the Armistice they continued working with the lighting industry, but the growing sophistication of labs such as GE's in Schenectady made industry less reliant on NBS.[116] Standards also translated better between likeminded groups than between groups with differing goals, as seen in the tension between utility and lighting professionals. As utilities became less dependent on lighting as anything other than an energy load the formerly unified interest networks began to follow differing paths. IES president Samuel

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114. "Training Inspectors in Illumination," and "Development of Codes for Industrial Lighting," *Electrical World* 72, no. 1 (6 July 1919): 3, 32. Illuminating engineer Clarence E. Clewell, among others, published several articles on industrial lighting design during the war.

115. Department of Commerce, *War Work of the Bureau of Standards*, Miscellaneous Publications of the Bureau of Standards 46 (Washington, DC.: GPO, 1 April 1921), 117-139, 263-265.

116. "Lighting Legislation Discussed in New York," *Electrical World* 73, no. 16 (19 April 1919): 806. Edward B. Rosa, "Is the National Electric Safety Code Suitable for California," *Journal of Electricity* 43, no. 2 (15 July 1919): 57-59.

Doane remarked in 1919 that, "A [utility] man should be as familiar with the scale on a foot-candle meter as he is with the one on a thermometer."[117] Power company executives disagreed, relegating illuminating engineers to a supporting role with other applications engineers then emerging on the scene, such as in refrigeration and heating.

Never formally adopted, the GEM lamp ban as government policy cannot be termed success or failure, but regardless served its purpose for GE. In terms of the first research question, the availability of tungsten lamps that featured higher efficacy than carbon lamps gave policy makers a reasonable expectation that such a ban would be effective. That the continued fuel crisis sufficed to kill the GEM lamp even after abandonment of the wartime plan shows clearly the private sector's intended use of this federal policy (as per the third research question). "The Fuel Administration's recommendations have caused central stations to stop supplying Gem lamps. At the present time the Gem lamp is practically dead."[118] The NELA Lamp Committee reported that GEM lamp manufacture had ceased and regular carbon lamps were "confined to places where service is severe, where their use is temporary or where protection from theft cannot be afforded."[119] In 1925, imported carbon lamps constituted about 10 percent of the market but by then tungsten lamp prices had declined, and internal frosted envelopes addressed the problem of glare.[120] Improved tungsten filaments and rough service lamps

117. "Lighting Business Sustains Utilities in Dull Times," *Electrical World* 74, no. 3 (19 July 1919): 150.

118. "Steps Taken to Increase Turnover of Lamp Stocks," *Electrical World* 73, no. 6 (8 February 1919): 290.

119. "Fourth General and Executive Session," *Electrical World* 73, no. 21 (24 May 1919): 1080.

120. Bright, *Electric Lamp Industry*, 245-247 for 1925 sales and import figures. Howell and Schroeder, *History*, 176-179.

for vibration areas allowed users to dispense with carbon lamps.[121]

After the war, most direct federal involvement with lighting receded into the labs of the NBS. For energy policy, some participants later questioned the existence of a coal famine claiming, "certain features of the emergency were considerably overdrawn."[122] That view seems questionable given the unprecedented federal attention to energy. The increasing reliance on coal during the war emergency focused federal attention for the first time on energy efficiency in general and on lighting in particular. Federal intervention waned quickly after the war consistent with contemporary views about the proper role of government in everyday life. Though lighting policies of this era showed mixed results at best, several precedents were set, and many of the same policies would reappear twenty years later as another war loomed.

121. "Some Developments in the Electrical Industry, 1919," *General Electric Review* 53, no. 1 (January 1920): 49-50.

122. George G. Watkins, "The Coal Panic of 1917-1918," *Proceedings of the Massachusetts Historical Society*, 3rd ser., 65 (May 1936): 582-592, http://www.jstor.org.

Chapter Six: Discharge Lamps and Great White Ways, 1920-1945

> *While [fluorescents are] more efficient than tungsten lamps, the simplicity and low cost of the latter are such that there are no immediate prospects of their being replaced for general lighting.*
>
> —Saul Dushman, November 1936[1]

In many respects the prewar political and economic contexts within which policy makers worked changed little immediately after World War I, and electric lighting policy soon faded. Even with lingering coal shortages, the Republican administrations of the 1920s lowered the priority of energy efficiency and put less stress on antitrust action as the nation returned to "normalcy."[2] Though General Electric controlled over 95 percent of the US lamp market, a 1924 antitrust suit was "quickly dismissed" by federal courts.[3] Import tariffs on electric lamps helped to exclude low cost international competitors.[4] Mass production and standardization reduced lamp costs for GE and its licensees, and technical advances encouraged illuminating engineers to push higher light levels in the name of economic efficiency. Cities and towns reveled in Great White Ways, highly illuminated main streets that exemplified both the more-light-is-better-light philosophy of the Science

1. Saul Dushman, "Line Spectra and Light," *General Electric Review* 39, no. 11 (November 1936): 564.

2. Platt, *Electric City*, 211. William E. Leuchtenburg, *The Perils of Prosperity: 1914-1932*, 2nd ed. (Chicago, IL.: University of Chicago Press, 1993), 84-97. Karl, *Uneasy State*, 50-79.

3. United States v. General Electric Company, 15 F.2d 715 (N.D. Ohio 1925), https://law.justia.com. Reich, "Lighting the Path," 321; Bright, *Electric Lamp Industry*, 254-255.

4. Bright, *Electric Lamp Industry*, 249.

of Seeing and the exuberance of 1920s America.[5]

Then the economy fell into the Great Depression at the end of the decade. Early private sector recovery efforts meshed with Herbert Hoover's ideas about public-private volunteerism, where the government facilitated but did not dictate beneficial policies like agricultural cooperatives. However, the slow pace of recovery and many citizens' desire for a more active federal response brought Franklin Roosevelt and his New Deal policies to the fore. Based in Progressive philosophy and incorporating economic theories of John Maynard Keynes, New Deal advocates believed that commercial and political stability, as well as social equity, required government intervention in economic affairs.[6] One important program that combined social and economic goals promoted rural electrification, and that program used the convenience of electric lighting to persuade people to form electrical cooperatives. The effort coincided with an industry marketing campaign that pushed lighting upgrades in all market sectors. The Better Light, Better Sight campaign coordinated industry efforts to revive lighting sales without raising antitrust alarms. The campaign outlived both the New Deal and the Depression, and reinforced a developing path dependence that complicated later policy efforts.

During the global economic depression Europe continued to experience high energy costs. As before, that spurred researchers there to improve lighting efficiency. Their work resulted in new lamps that generated light by passing an electric current through gases instead of a solid; discharge lamps that eventually replaced incandescent lamps in

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5. Nye, *Electrifying America*, 54-57. A Great White Way, or simply a White Way, was a lighting design for main streets that featured high light levels provided by streetlights, shop windows, and electric signs.

6. Colin Gordon, *New Deals: Business, Labor, and Politics in America, 1920-1935* (New York: Cambridge University Press, 1994). Skowronek, *Building*, 168.

major market sectors. Protected from competition, the major international companies shared technical knowledge and GE paid close attention, anxious to avoid repeating the experience of paying for European inventions. Promising results on one device in particular, fluorescent lamps, caught the company's attention in 1934. Two years later, as Dushman wrote the above quote, GE was demonstrating a prototype to the US Navy.

Capable of producing white light, fluorescent lamps exhibited twice the efficacy of tungsten incandescent lamps and created turmoil in the US lighting industry. Although complicated and expensive, GE saw their new product line as a set of patents they could use to continue market domination. Westinghouse, their most favored licensee, supported that goal. Sylvania and other companies designed their own fluorescent lamps with the goal of beating GE at the patent game.[7] The abrupt introduction of fluorescent lamps at the 1939 World's Fair reignited utilities' fears of high lamp efficacies and their executives pressured GE and Westinghouse to sell colored lamps only.[8] They failed in that effort partly due to government policy makers who supported industrial expansion in order to speed economic recovery and prepare for a possible war. Subsequent US entry into the Second World War brought back lighting restrictions that proved marginally effective, and market interventions that accelerated fluorescent lamp adoption. As they had 20 years before, GE executives used the war emergency to push their efficient, expensive lamp onto the market over the objections of other network actors. As with WWI, lighting-specific policies did not last long after WWII but a radical change in lighting was by then well

7. Bijker, *Of Bicycles*, 232-233.

8. Bijker, "Majesty of Daylight," 199-267.

underway. Different market sectors adopted different lamps as best fit their needs, resulting in industry specialization that affected later policy and technology developments.

Technology: the commercialization of discharge lamps

Discharge lamps operate by passing an electric current between two electrodes though a mixture of gases, usually confined within a glass or quartz tube. Energized by the current, the gases radiate light. In the early 1900s, Cooper Hewitt and Moore lamps sold modestly well, as described in chapter four, but those discharge lamps could not compete with the color output and efficacy provided by tungsten filament incandescent lamps. By the 1920s, sales of discharge lamps were minor: a line of Cooper Hewitt lamps offered by GE for industry, spectral lamps for laboratories, and neon signs for business.[9]

In the early 1930s, two new discharge lamps emerged from Europe that pushed efficacy to new levels and found sustained commercial success. One became known generically as the mercury vapor lamp. Initially produced in England, mercury vapor lamps gave 40 lpW and produced a greenish-white light in a tube much smaller than a Cooper Hewitt lamp.[10] Starting in 1934, several US companies licensed the technology for lighting large areas. Modified and improved during the ensuing decades, mercury vapor lamps were produced for the rest of the twentieth century until phased out by minimum efficiency standards, as described in chapter nine.[11]

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9. Bright, *Electric Lamp Industry*, 221-228, for Cooper Hewitt's and Moore's lamps; 369-374 for neon tubes.

10. Leroy J. Buttolph, "A Review of Gaseous Conduction Lamps," *Transactions of the Illuminating Engineering Society* 28, no. 2 (February 1933): 153.

11. Bright, *Electric Lamp Industry*, 374-376.

The other new European discharge lamp used gaseous sodium, a troublesome element that seemed ill-suited for lighting.

> It is well known that sodium and metals of the same periodic group chemically attack ordinary glass,...the principal reason why a sodium-vapor lamp,..., has not heretofore been commercially exploited, *although a lamp of this type has an operating efficiency much greater than that of any lamp now in commercial use*.[12]

Although American Arthur Compton invented sodium resistant glass in 1926, US lamp makers saw no reason to market a sodium lamp. A European team from Osram, Philips, and GEC, seeking the "greater operating efficiency," devised a way to mass produce the glass, and Philips introduced a low pressure sodium lamp (LPS) in 1931.[13] The stark yellow color rendered most objects grey and limited applications but improved lamps eventually gave 200 lpW. Widely adopted in Europe, LPS was the most efficient light source commercially available until the twenty-first century.[14] While GE sold mercury lamps and LPS, they were content to emphasize incandescent product lines.[15]

The most successful discharge lighting invention to date came in the late 1930s: white light fluorescent lamps. Again, significant research first occurred in Europe and a

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12. Arthur H. Compton, Glass and article made therefrom, US Patent 1,570,876, issued 26 January 1926, emphasis mine.

13. G. B. van der Werfhorst, "The Development of Gaseous Discharge Lamps in Europe," *Transactions of the Electrochemical Society* 65, no. 1 (1934): 157-175. W. de Groot, "Scientific research of Philips industries from 1891 to 1951," *Philips Technical Review* 13, no.1 (July-August 1951): 3-47. GEC, General Electric Company of Britain was unrelated to US General Electric.

14. Bright, *Electric Lamp Industry*, 374-381. De Groot, "Scientific Research," 12-13. J. B. De Boer, "The Application of Sodium Lamps to Public Lighting," *Illuminating Engineering* 56, no. 4 (April 1961): 293.

15. General Electric Company, "Standard Price Schedule: Large Mazda Lamps and Type D Lamps," form 2195 (1 December 1939) in NMAH EC-LRF. This price sheet has over 5 pages of incandescent lamps and one-half page of fluorescent and mercury vapor lamps. Sodium is not listed.

1926 German patent disclosed a feasible design that Osram chose not to pursue.[16] In 1934, British researchers showed Arthur Compton a high voltage, neon-style tube that gave 35 lpW. Compton alerted GE and Westinghouse to the development and urged them to move quickly while patents remained in flux. Mindful that early tungsten lamp patents would soon expire, the "surprised" US companies shed their inertia.[17] They jointly developed a line of lower-voltage lamps in which ultraviolet light emitted by energized mercury was converted into visible light by a powder coating called a phosphor.[18]

Incandescent lamps deserve their reputation for technical simplicity but several issues make discharge lamps more complex. An incandescent filament has an electrical resistance that varies in a positive way with the flow of current; the resistance starts low and as more current (ac or dc) heats the filament, the resistance rises. Engineers design filaments to be compatible with an electrical system's voltage and amperage so that the resistance stabilizes at operating temperature. But the current in a discharge lamp flows across a gap between two electrodes rather than through a solid filament. The resistance is high at start, drops as the fill gas is ionized, and will not stabilize. This inverse resistance characteristic creates two problems: overcoming high resistance to start the lamp, and then controlling the current flow to keep the lamp from self-destructing. Starters and ballasts compensate for these problems but themselves affect the current flow via inductance and

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16. Bright, *Electric Lamp Industry*, 386.

17. Richard N. Thayer, "The Fluorescent Lamp: Early US Development," (unpublished manuscript, November 1989), photocopy, for an account of the "surprise." For patent motivation see Bright, "Some Broad Economic Implications," 440-441.

18. Richard N. Thayer and Bentley T. Barnes, "The Basis for High Efficiency in Fluorescent Lamps," *Journal of the Optical Society of America* 29, no. 3 (March 1939): 131-134, for technical coverage of varying phosphor formulations and efficiencies.

capacitance effects; and ac system frequency also plays a role.[19] Fluorescent engineers have the additional task of designing phosphor coatings that can simultaneously endure the harsh environment inside the tube, be made and applied economically, and be relatively safe when people inevitably break a lamp.[20] All components interact so that changing one affects the others, an important point for policy makers because separate components in these miniature systems later became subject to regulations aimed at improving efficacy.

The extent of the efficacy increase and the reason for utility fears can be seen in table 6.1, comparing the lamps. These levels of efficiency far exceeded those obtained with the modest improvements made since 1913 to Langmuir's incandescent design. Soon after Compton's 1934 alert, GE and Westinghouse made a test lamp and in 1936 showed a fluorescent prototype to the Navy.[21] The Americans understood they were in a race. In 1935, a GE engineer noted "quite a bit of gaseous-conductor lighting" in England, and the "widespread use of gaseous-conductor...light sources" in Paris.[22] The teams rushed to show fluorescents in 1939 at both the World's Fair and the Golden Gate Exposition, though each lamp component still had problems.[23] One engineer granted that the rollouts were

19. General Electric, *Fluorescent Ballast Tells Her Story*, publication GEA-5731B (Schenectady, NY: General Electric, 1956), gives a gendered overview of how fluorescent lamps and ballasts function.

20. Phosphor engineering is a genre of its own. Many pertinent papers appear in the *Journal of the Electrochemical Society*.

21. General Electric, experimental T7 fluorescent lamp, 1934, NMAH-EC, catalog number 1997.0388.41. General Electric, demonstration fluorescent lamp, 1936, NMAH-EC, catalog number 318197.

22. Alvin L. Powell, "European Lighting Advances," *Transactions of the Illuminating Engineering Society* 30, no. 12 (December 1935): 792, 801.

23. "Fluorescent Tubular Lamps Soon to be Available," *Electrical Engineering* 57, no. 5 (May 1938): 226. George E. Inman and Richard N. Thayer, "Low-Voltage Fluorescent Lamps," *Electrical Engineering* 57, no. 6 (June 1938): 245-248.

Table 6.1: Lamp efficacy comparison (lpW), 1920-1945[24]

Date	Incandescent	Mercury vapor	Low pressure sodium	Fluorescent
1920	9.3	26		
1925	10.5	26		
1930	12	26		
1935	12.5	32	50	
1940	13.9	33	72	50
1945	13.9	35	72	58

During the 1930s three major advances in discharge lighting raised efficacy far beyond that obtainable with tungsten filament incandescent lamps. LPS made few inroads in the US. But mercury vapor lamps that improved on Cooper Hewitt's earlier design (1933), and fluorescents (1939) were widely adopted. The extent of the increase raised utility fears about reduced power sales.

"perhaps premature," but fear of preemption by European producers made public demonstrations essential.[25] The companies then faced the task of selling an expensive, complex product that utilities wanted suppressed, a situation GE had faced two decades before with the GEM lamp although few seemed to remember.

1920s-1930s: boom and bust

Americans celebrated the 1918 Armistice with parades, patriotic revelries and lots of light. Though the ongoing coal shortage threatened to spoil the party, people welcomed the end of irritating lightless nights. That particular intrusion into everyday life was quickly

24. Source: product catalogs, NMAH EC-LRF.

25. George E. Inman, "Characteristics of Fluorescent Lamps," *Transactions of the Illuminating Engineering Society* 34, no. 1 (January 1939), 84; Bijker, *Of Bicycles*, 226.

abandoned and the federal government withdrew from lighting-specific policies. Some engineers argued for legally binding illumination codes, if only to ensure safety rather than "enforce the most efficient or effective lighting," but they looked to state and local governments for action.[26] With few exceptions, federal policy that affected lighting returned to the broad arenas of antitrust legislation, patents, and tariffs.[27] The concept of lamp efficacy appeared tangentially in those proceedings; only at the Bureau of Standards did federal policy directly concern efficacy and technological meanings of efficiency.

Already attuned to industry's needs, NBS's service mandate was reinforced when President Warren Harding nominated Herbert Hoover as Commerce Secretary.

> When Mr. Hoover went to Washington [he called] together leading business men [and said] 'Here is the Department of Commerce...what can it do for you?'...The Department is not in the regulation business [but is] a place where American business can express itself through the government, and where the Department...can perform useful services for business.[28]

Hoover, an engineer by training, believed in voluntary partnerships between government and industry, and took a special interest in the Bureau's activities. For lighting, those activities extended work already underway, such as calibration of the privately developed Munsell color standards still used today. The Bureau had also been actively involved, through cooperation with the IES Committee on Lighting Legislation, in defining codes of best practice that state and local regulators might enact.[29]

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26. H. E. Mahan, "Lighting Legislation," *General Electric Review* 22, no. 2 (February 1919): 110-113.

27. Bright, *Electric Lamp Industry*, 235-290.

28. Frederick M. Feiker, "The U. S. Department of Commerce and the Electrical Industry," *Electrical Merchandiser* 27, no. 1 (January 1922): 58. Hoover's press assistant Feiker (1881-1967), had worked at GE and was former editor of *Electrical World* and *Electrical Merchandising*.

29. Dupree, *Science*, 338. Samuel W. Stratton, *Annual Report of the Director of the Bureau of Standards to*

The Bureau's involvement with electric lamps began to decline however as professional groups such as the Illuminating Engineering Society (IES) and industrial research operations like that at GE's Nela Park grew more sophisticated.[30] University lighting programs spread professional standards while GE's market control gave them the ability to set de facto technology standards. In 1923, the Bureau issued its final edition of "Standard Specifications for Large Incandescent Electric Lamps" and focused on scientific lighting research.[31] During the 1920s, lighting efficiency came to mean system efficiency—getting the most out of a lighting installation—rather than lamp efficacy, whether lumens per watt or watts per candle. This was a commercial rather than scientific definition wherein lamp efficacy constituted only one part of lighting cost calculations, and not the most important part at that. Private sector illuminating engineers wrote about how much light could be gained by washing luminaires and putting a fresh coat of white paint on factory walls.[32] A holistic concept of lumen maintenance for lighting systems came to the fore as did the idea of using higher wattage lamps. More light equaled better light, and one could get more light from 300 W incandescent lamps than from 100 W. With many dim carbon lamps still in service, falling tungsten lamp and electricity prices made people

the Secretary of Commerce for the Fiscal Year Ended June 30, 1919 (Washington, DC: GPO, 1919): 134-135. Louis B. Marks, "Report of the Committee on Lighting Legislation," *Transactions of the Illuminating Engineering Society* 13, no. 9 (30 December 1918): 524-527.

30. Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876–1926* (Cambridge, MA: Cambridge University Press, 1985).

31. Cochrane, *Measures*, 112n8. A group within the Bureau of the Budget took over responsibility for publishing the "Standard Specifications."

32. Ward Harrison and J. R. Colville, "How to Reduce Your Light Wastage," *Electrical Review* 80, no. 1 (January 1922): 13-16. This is only one of many similar articles from this period.

receptive to installing higher power lamps.[33]

On the international level, the postwar reentry of German lamp producers into global markets threatening everyone's profits, so executives at the major manufactures formed the Phoebus cartel in 1924 to end "destructive competition."[34] Member companies divided the global market into exclusive regions and set production quotas.[35] GE played a major role in the cartel's organization, though the company interacted with Phoebus through a subsidiary, International General Electric. GE executives managed their association with the cartel very carefully given US ongoing antitrust litigation.[36] That same year, the Department of Justice charged the company with evading the 1912 consent decree through use of an agency system to fix retail prices. GE acknowledged the agency system but argued their patents allowed them broad latitude to sell directly to consumers through agents who never actually owned the product. The District Court agreed and dismissed the case, a decision affirmed on appeal by the Supreme Court in 1926. That decision kept most domestic rivals in check.[37]

Feeling protected from competition, GE began manipulating tungsten filament lamps to increase efficacy at the expense of life ratings in order to sell more lamps. As

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33. Robert A. Margo, "Price of light, current and real: 1800–1992," Table Cc61-62 in *Historical Statistics of the United States, Earliest Times to the Present*, Millennial Edition, eds. Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, (New York: Cambridge University Press, 2006), http://dx.doi.org.

34. Stocking and Watkins, *Cartels*, 324.

35. Reich, "Lighting the Path," 325.

36. Stocking and Watkins, *Cartels*, 325-344. Bright, *Electric Lamp Industry*, 480.

37. United States v. General Electric Co . 272 US 476 (1926). Bright, *Electric Lamp Industry*, 253-255; Reich, "Lighting the Path," 320-321.

noted in chapter five, increasing the current through an incandescent lamp makes the filament run hotter, emit more light, and fail faster. Lamp makers claimed that higher efficacy combined with reduced lamp prices made the shorter life worthwhile. The gamut failed when marketers could not convince consumers to look beyond life ratings, at which point GE found flaws in their competitive protection. Users in the 1930s who showed a preference for long lived lamps bought cheap tungsten lamps imported from Japan.[38] Made by producers outside the cartel, these imported lamps met demand and created a problem for GE, as two engineers pointed out:

> Most of these [competing] lamps are at somewhat lower efficiency than ours and inherently have a longer life. It is very difficult to convince the typical consumer that efficiency of the lamp is the important thing. He is prone to judge quality by life alone. We realize that the constant reduction in lamp life that we have been in the process of carrying on has kept the volume of business up, but cannot refrain from giving a word of warning...in view of the competitive situation.[39]

Ultimately, GE created a special low cost product for sale in regions where Japanese imports or lamps from the few unlicensed domestic producers were making inroads.[40] Along with higher tariffs on imported lamps, the low cost lamp kept the market in GE's control; a fortunate situation for the company when Wall Street crashed in October 1929 and the lighting industry faced economic chaos along with the rest of the country.

What started as a stock market crash resonated throughout the country, "[shaking] the American way of life to its foundations."[41] The Great Depression "tossed the high hats

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38. Bright, *Electric Lamp Industry*, 262-263.

39. Exhibit 1862-G from US vs. GE, as cited in Stocking and Watkins, *Cartels*, 356n132.

40. Bright, *Electric Lamp Industry*, 263-264.

41. David M. Kennedy, *Freedom from Fear: The American People in Depression and War, 1929-1945* (New

into the ash-can and knocked the stuffing out of the stuffed shirts," one electrical industry observer wrote.[42] Sales of electrical appliances of all types dropped, reminding the industry that their products were not indispensable.[43] Residential, commercial, and industrial lighting consumers cut back or maintained the numbers of lamps they used; many deferred lighting expansion and updates to save money, as seen by the declining number of lamps sold during the three years following the Depression's onset, as seen in figure 6.1. People in the electrical business understood declining sales of appliances during hard times but viewed these declining lamp figures with increasing alarm as they lived through the event.[44] Although it turned out that electricity sales remained steady in most areas, people in the midst of the crisis reasonably presumed that the worst was yet to come. The electrical utilities also began to worry, since lighting still represented nearly 40 percent of their load at that time.[45]

York: Oxford University Press, 2005), 10.

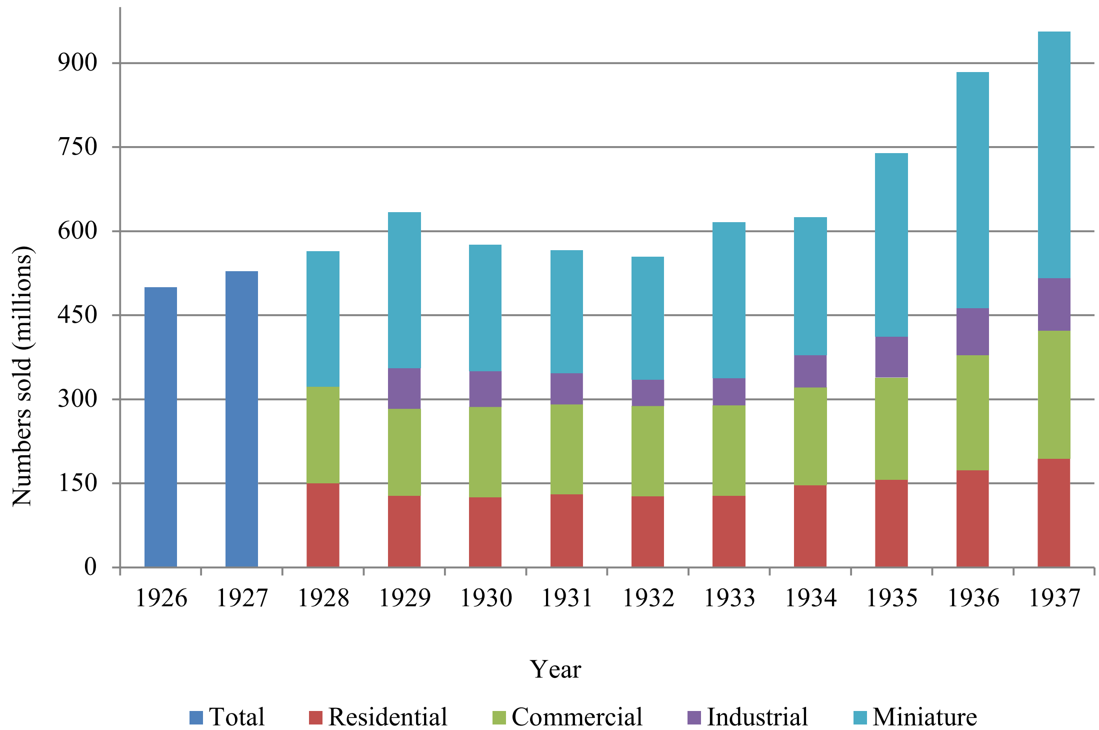
42. Frank B. Rae, Jr., "Industry Lighting Campaign ... an Invitation to Take the Feet Off the Desk," *Electrical Merchandising* (September 1933): 44.

43. "10 Years Sales & Retail Value of Electrical Merchandise," *Electrical Merchandising* 39, no. 1 (1 January 1938): 10-11. Jeremy Atack and Fred Bateman, "Physical output of selected manufactured products: 1860-1997," Table Dd366-436 in *Historical Statistics of the United States, Earliest Times to the Present:* Millennial Edition, eds. Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright., (New York: Cambridge University Press, 2006), http://dx.doi.org. Also, "10 Years Sales."

44. Merrill E. Skinner, "Lighting Fields to Explore with Profit," *Edison Electric Institute* 1, no. 4 (July 1933): 103-106, 132.

45. Lee A. Craig, "Consumption expenditures, by type: 1929-1999," Table Cd153-263 in *Historical Statistics of the United States, Earliest Times to the Present*: Millennial Edition, eds. Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, (New York: Cambridge University Press, 2006), http://dx.doi.org. Tables Cd186 thru Cd191 compares "Household Operations" expenditures including electricity (which remained stable between .6 and .7 billion dollars)and coal (which fell from 1.6 to 1.1 billion dollars from 1929 to 1932 before beginning to recover).

Figure 6.1: Incandescent lamp sales before and during the Great Depression[46]



Several points emerge from this chart. 1) The declining sales evident from 1929 through 1932 provoked alarm in the light and power industries, spurring creation of the Better Light, Better Sight sales campaign that began in 1933. 2) Other appliance sales figures are available for these years but only radio tubes and batteries exceeded 10 million units sold. Most sold considerably fewer, demonstrating the importance of lamp sales. 3) Market differentiation became important enough to track starting in the late 1920s. 4) This trade journal did not track sales of discharge lamps in the 1930s, reflecting their niche status in the United States.

In early 1932, the National Electric Lamp Association (NELA) began working on a nationwide sales program to stimulate lamp, luminaire, and electricity sales.[47] Later

46. "Sales of Electrical Merchandise for 1926-1927," *Electrical Merchandising* 29, no. 1 (January 1928): 70; "10 Years Sales & Retail Value of Electrical Merchandise," *Electrical Merchandising* 39, no. 1 (1 January 1938): 10-11. Separate figures unavailable in 1927, 1928. Commercial and Industrial sales were combined in 1928. Miniatures include switchboard and automotive lamps, separate product lines.

47. R. J. Malcomson, "Home Lighting: A New Program of Development," *Electrical Merchandising* (January 1932): 34-35.

dubbed Better Light Better Sight (BLBS), the industry rolled the program out in fall 1933 after NELA became the Edison Electric Institute (EEI), and after the election of Franklin Roosevelt.[48] An advertising barrage extolled the virtues of high light levels as a way of reversing "depression curtailments," and the relative affordability of upgrading to higher wattage lamps. Many ads bore the National Recovery Administration (NRA) logo, a blue eagle with the phrase "we do our part," that conveyed a patriotic tone and showed at least nominal tolerance for the controversial New Deal program. Sales people with light meters and demonstration kits showed business and residential consumers how more light could make daily tasks easier. Within a few months positive results led to the BLBS Bureau being established in EEI, devoted to increasing light levels in the name of safety and higher productivity, while boosting product sales in the process.[49]

More important than the short term commercial effect, the BLBS campaign and Bureau institutionalized the more-light-is-better-light philosophy of illuminating engineers like Matthew Luckiesh who called for higher light levels. Sincerely believing that more light boosted productivity, increased safety, and eased eye strain, they grew concerned about a Depression-driven regression into darkness.[50] Their holistic concept of efficiency meshed well with utilities' worries about falling power sales. As GE engineer Ward Harrison commented, "Incandescent lamps now consume more than one-fourth of all the

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48. Hirsh, *Technology and Transformation*, 213n28, for the NELA–EEI history.

49. "Better Light Better Sight," *Electrical Merchandising* 50, no. 3 (September 1933): 9-21, for selection of ads. Rae, Jr., "Industry Lighting Campaign:" 44 for quote.

50. Matthew Luckiesh, "A Decade of Watts in my Home," *Magazine of Light* 9, no. 6 (General Electric, 1939, reprint). Luckiesh cited his own home as a model of good lighting with many incandescent lamps of 150 or 300 watts and a bathroom illuminated by 10 fluorescent luminaires. Frank Rae noted that Luckiesh "and his associates" regarded 1930 lighting levels as too low.

current produced by all the power companies in the [US]," a figure that "will have to be increased at least 50 to 100%" to meet the emerging definition of good lighting.[51] The power companies certainly needed the help.

By the late 1920s electrical lighting and power interests had diverged. The former played little role in federal policy debates about public vs. private ownership of power systems, the economic power of holding companies, and the problem of electrifying rural America. Hoover's vision of private sector actors patriotically cooperating to address those issues because it coincided with their own interests, failed. Public frustration with private utilities found a voice in Franklin Roosevelt, who during his 1932 campaign castigated as self-serving "the Ishmael and Insull," (referring to Commonwealth Edison's founder Samuel Insull).[52] When Roosevelt won election and the New Dealers took office, they made electric power, especially rural electrification, part of their agenda; symbolized by the NRA's blue eagle clutching lightning bolts in one talon. Though some New Dealers balked, Roosevelt and others understood that they needed private sector participation to succeed.[53] They explored collaborative programs with the idea of creating markets and using the profit motive instead of patriotism to gain industry cooperation.

The goals of the Rural Electrification Administration (REA), Tennessee Valley Authority (TVA) and Electric Home and Farm Authority (EHFA) were straightforward: address social needs in economically stagnant areas, encourage people to stay on their

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51. "More Light," *General Electric Review* 38, no. 3 (March 1935): 153.

52. Associated Press, "Text of Governor Roosevelt's Speech at Commonwealth Club, San Francisco," *New York Times* (24 September 1932): 6, http://search.proquest.com.

53. Philip J. Funigiello, *Toward A National Power Policy: The New Deal and the Electric Utility Industry, 1933-1941* (Pittsburgh: University of Pittsburgh Press, 1973).

farms, and provide jobs.[54] The REA in particular used electric lighting to promote its mission. In 1932, only about 10 percent of rural America had access to electricity, and about half of those fortunate few provided their own power with stand-alone generating plants.[55] Privately owned power companies believed that stringing lines to rural homes was uneconomical due to low population density (a real problem) and few electrical applications (a flawed perception). REA gave low interest loans and technical advice to self-organized cooperatives that then built electrical systems and paid back the loans over decades. The key hurdle for REA lay in persuading people who placed a high value on personal independence and were skeptical of government to voluntarily organize.

REA agents understood the advance electric lighting represented, practically and symbolically, to farm people and used that to encourage program participation.[56] Rural Americans knew how inferior oil lamps were compared to electric lamps, and they also felt left behind by a country enamored with the bright lights of the big cities.[57] Other applications were valued but the magnitude of shifting from open flame to electric lamps, enhanced by the symbolic nature of moving from darkness into light, made lighting the

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54. Tobey, *Technology as Freedom*, covers the social aspects of rural electrification. D. Clayton Brown, *Electricity for Rural America: the Fight for the REA* (Westport, CT.: Greenwood Press, 1980). Gregory B. Field, "'Electricity for All': The Electric Home and Farm Authority and the Politics of Mass Consumption," *Business History Review* 64 (Spring 1990): 32-60.

55. Carol Anne Lee, *Wired help for the farm: individual electric generating sets for farms, 1880-1930* (Ph. D. dissertation, Pennsylvania State University, 1989; photocopy, Ann Arbor, MI: UMI Dissertation Information Service, 1998), 1.

56. "Lighting School Agenda: Regional Electrification Lighting School," Rural Electrification Administration, 19-22 March 1951, NMAH Archives Center, AC#862, Louisan E. Mamer Rural Electrification Administration Papers, box 13, folder 4. (Hereafter cited as Mamer Papers.) The collection includes trade literature from lamp and luminaire makers, and the BLBS Bureau.

57. Romeo, *Darkness to Daylight*, 59, shows a tombstone marking the burial of a coal-oil lamp by members of Adams Electric Cooperative in 1941.

application people wanted first. Many people remembered the day when the power came on and typically associated it with light. Bertha Ames recalled: "That light in the kitchen came on and that was the prettiest sight I ever saw."[58] Representative John Rankin of Mississippi told the House that all his constituents' letters mentioned electric lights.[59] The REA used lighting to recruit co-op members and then urge active participation as a community responsibility.[60] The nature of efficiency for REA programs typically meant increased productivity, since electric lights enabled more work to be done after dark and ended the daily chore of cleaning oil lamps.[61] As the 1930s progressed, more cooperatives organized and sales of new lamps and lighting devices grew apace.

The introduction of fluorescent lamps slid quietly into the REA program as GE, Westinghouse, Sylvania, and fixture manufacturers all promoted fluorescents to REA agents.[62] Not everyone was pleased with the prospect of a lamp having three or more times the energy efficiency of incandescents however. Electric power companies, fighting the whole idea of public power including the co-ops, feared a significant drop in power sales should fluorescents be widely adopted among their own customers and so waged a quiet war to suppress the technology. Suppliers of broad product lines like GE and Westinghouse walked a fine line between wanting to push a potentially profitable product

58. Romeo, *Darkness to Daylight*, 6, 55.

59. Field, "Electricity For All," 58n53.

60. Lee Lloyd and Louisan Mamer, "Does it End with Lights?" draft memorandum, Mamer Papers, box 20, folder 1.

61. Romeo, *Darkness to Daylight*, 54-55.

62. Sylvania Electric Products, Inc., *Lighting Design Data*, Mamer Papers, box 14, folder 3.

and sensitivity to purchasers of expensive generation and transmission equipment with whom they shared a long history.[63] Earlier products that made whitish light using mercury and tungsten lamps in combination raised no objections because they generated "equal lumens...obtained by using tungsten lamps aggregating approximately twice the wattage of the mercury lamps."[64] To be fair, utility engineers objected that widespread adoption of fluorescents could damage their equipment due to the lamps' low power factor. The problem of power factor will be discussed in chapter eight; suffice for now to say that illuminating engineers quickly found several ways to address that concern.

The introduction of fluorescent lamps threatened the carefully crafted idea that lighting should be sold by watts rather than lumens and exacerbated the growing split between the lighting industry and power utilities.[65] Although GE and Westinghouse issued instructions to push fluorescents as a source of more light rather than "a light source which will reduce lighting costs," significantly higher light levels could not be achieved with incandescent lamps.[66] Using incandescents to raise light levels to standards encouraged by illuminating engineers would create unacceptable heat loads within the lighted spaces; fluorescents could boost light levels in a practical manner.[67] Utility managers understood

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63. Bijker, "Majesty of Daylight," 228-229.

64. Matthew Luckiesh, A. Hadley Taylor, and George P. Kerr, "Artificial White Light," *General Electric Review* 41, no. 2 (February 1938): 90. Daniel R. Grandy, "Combining Mercury Vapor and Incandescent Lamps to Produce Commercial White Light," *Illuminating Engineering* 28 (November 1933): 762.

65. Stocking and Watkins, *Cartels*, 358n138.

66. *Patents. Hearings on S. 2303 and S. 2491, pt.9, Before the Committee on Patents*, 77th Cong, (18 August 1942), 4818, https://babel.hathitrust.org. Cited in Bright, *Electric Lamp Industry*, 402n3.

67. Walter Sturrock, "Effects of Artificial Lighting on Air Conditioning," paper presented to American Society of Heating and Ventilating Engineers (January 1938, reprint), NMAH EC-LRF, "for discussion only." Matthew Luckiesh, "Cooler Footcandles," in *Fluorescent Lighting* (collected reprints from*Magazine* the problem of heat loads but proposed solutions that would meet their needs. Shielding fluorescents and using indirect lighting designs would prevent glare but require more luminaires to achieve desired lighting levels, raising energy consumption; a solution Sylvania rejected for business reasons.[68] Utilities also proposed luminaires that combined incandescent and fluorescent lamps. The cooler fluorescents provided most of the light while incandescents improved the light's color and maintained electricity consumption.[69] Fluorescent lamps provided acceptable color output however, making combination luminaires hard to justify to commercial and industrial consumers.

Ultimately factors internal and external to the lamp industry resulted in the widespread adoption of fluorescent lamps despite utility protests. The major internal factors were purely competitive. Some lamp makers, especially Sylvania, wanted to use their own fluorescent lamp research and patents to escape GE's restrictive incandescent licensing agreements. GE and Westinghouse realized that they needed strong new patents to maintain the status quo as tungsten patents expired. Fluorescents could forestall competition and pass antitrust review, given the 1926 Supreme Court ruling that upheld their ability to use patents as they saw fit. To keep control of core lighting markets, they were prepared to sacrifice utilities' good will, as the utilities came to realize. "It is regrettable that the lamp companies did not [in 1938] take the utility lighting interests into

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of Light, nd., ca 1940): 6. Walter Sturrock, "Recommended Levels on Illumination," *Magazine of Light* 10, no. 6 (25 August 1941): 45-54.

68. Bijker, *Of Bicycles*, 248-249; 257 for tension between Sylvania and utility representatives.

69. "Wisconsin Electric Power Company, Milwaukee, Exemplifies Lighting Progress in its Auditorium," *Magazine of Light* 11, no. 4 (10 June 1942): 24-28. This utility design also used incandescent lamps incove fixtures rather than linear fluorescent lamps.

their confidence with their promotional plans for this new product."[70]

The major external factor influencing fluorescent adoption was the growing threat that a new European war would eventually involve the US. GE's demonstration of a prototype fluorescent lamp to the Navy in 1936 is significant. Military and civilian planners understood that energy issues had played a role in WWI and would likely do so again, putting energy efficiency back on federal agendas. Preparations for war boosted fluorescent sales as industry began expanding to fill orders for military equipment, as seen in the growth in industrial electricity use in the late 1930s seen in figure 6.2. When America entered the war, new federal regulations restricted illumination and promoted energy efficiency in ways that favored fluorescents.

1941-1945: dim-outs and rationing

The attack on Pearl Harbor on 7 December 1941 stunned most Americans. While Franklin Roosevelt and the "all-outers" fully expected eventual entry into Europe's war, the sudden Japanese attack caught them off guard as well.[71] Forced by political circumstance to move slowly, Roosevelt had taken steps to prepare for mobilization of the nation's industrial resources. Those steps proved inadequate.[72] Several prewar agencies

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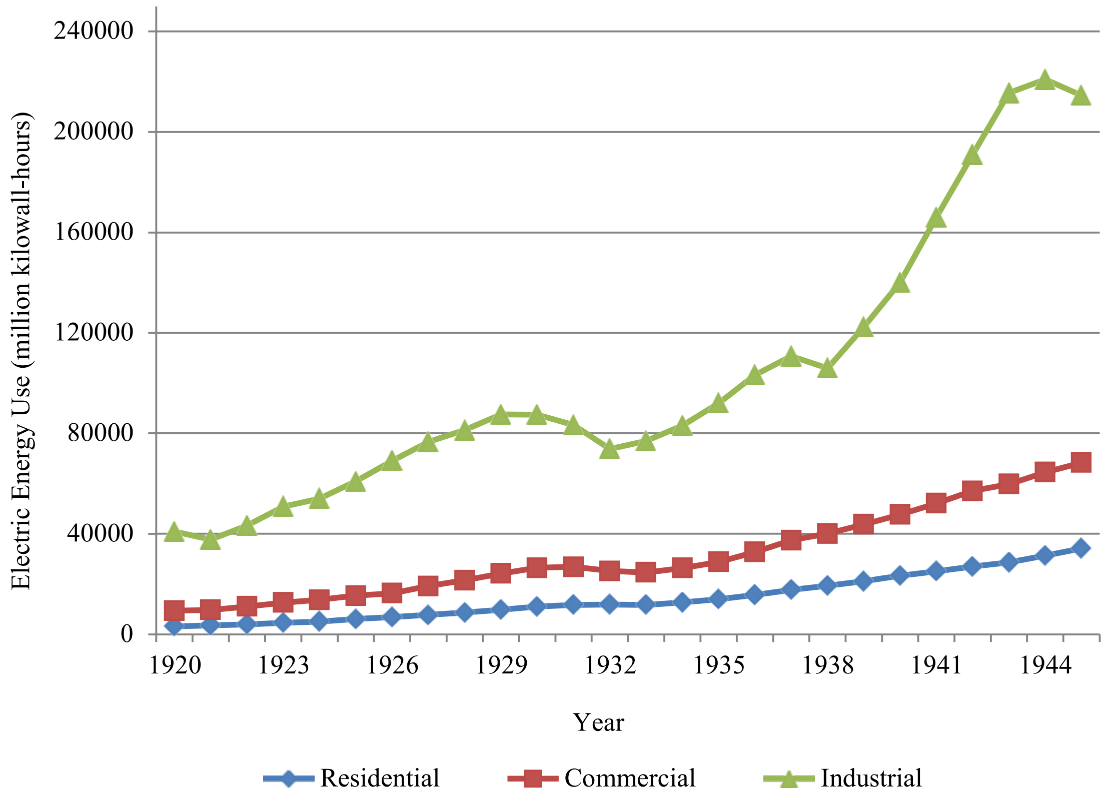
70. *Patents*, (August 1942), 4803, for John E. Mueller, Howard M. Sharp and Merrill E. Skinner, "Plain Talk About Fluorescent Lighting," confidential paper presented at the Annual Meeting of the Association of Edison Illuminating Companies, 15-19 January 1940, https://babel.hathitrust.org.

71. Paul A. C. Koistinen, "Mobilizing the World War II Economy: Labor and the Industrial-Military Alliance," *Pacific Historical Review* 42, no. 4 (November 1973): 443-478, http://www.jstor.org, for the term "all-outers."

72. Jim F. Heath, "American War Mobilization and the Use of Small Manufacturers, 1939-1943," *Business History Review* 46, no. 3 (Autumn 1972): 295-319, http://www.jstor.org.

Figure 6.2: Electric energy use in the United States, by sector, 1920-1945[73]



The impact on electric use of the onset of and recovery from the Depression is apparent in this chart. Growth in residential use after 1935 reflects rural electrification. Industrial growth after 1938 includes military production that fed demand for fluorescent lamps. Neither commercial nor residential use showed a decline during the war years.

such as the Office of Production Management were too weak to accomplish their goals, and New Dealers alienated business leaders by excluding them where possible.[74] Business and labor leaders saw little reason to cooperate anyway since many Americans opposed

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73. Source: Gavin Wright, "Electrical energy–sales and use: 1902–2000," Table Db229-231 in *Historical Statistics of the United States, Earliest Times to the Present, Millennial Edition*, eds. Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, (New York: Cambridge University Press, 2006), http://dx.doi.org. Wright noted: "Data beginning 1937 are not directly comparable with the data for earlier years," due to an industry accounting change.

74. Kennedy, *Freedom*, 476-479.

involvement in another European war, and few took the Japanese seriously. Unlike WWI in which the US gradually became involved, entry into WWII came in one chaotic day. Everyone looked back to WWI for guidance but 1941 differed from 1917, in large part because the Great Depression had altered political and economic networks and few policies in any area carried over.[75] Federal policies affecting lighting demonstrated the similarities and differences between the two war eras.

As in WWI, the Bureau of Standards undertook lighting research on behalf of industry and the military, and even before Pearl Harbor "fully 90% of the Bureau staff was engaged in war research."[76] Part of that entailed scaled-up routine tasks such as testing lamp samples to ensure quality and adherence to specifications.[77] New work involved research to meet specific military needs, such as vehicle headlamps for use in blackouts and better materials for naval searchlights. Research on lighting applications included finding uses for phosphorescent coatings and ways to minimize light leakage from windows during blackouts.[78] They also assisted Army and Navy studies of sky glow and aided the War Department in drafting blackout standards.[79]

Before the war, civil defense planning and blackout drills met with popular indifference and official hesitation. In May 1941, Roosevelt named New York mayor

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75. Kennedy, *Freedom*, 619-631.

76. Cochrane, *Measures*, 372.

77. Lyman J. Briggs, *NBS War Research: The National Bureau of Standards in World War II* (Washington, DC: GPO, September 1949), 113.

78. Briggs, "Optics, Color and Light," in *NBS War Research*, 99-114.

79. Cochrane, *Measures*, 372-373.

Fiorello LaGuardia to lead the new Office of Civilian Defense.[80] In August, OCD issued a detailed blackout guide with the mixed message that, "[in] no sense should issuance of this pamphlet be construed as a signal to start work immediately on any of the blackout procedures described."[81] Replaced after Pearl Harbor, LaGuardia complained that he "could get no one to take [OCD] seriously," and indeed, more thought was given to avoiding blackouts than planning them. The idea of a "dim-out, the lowering of lights to the glow of moonlight," was proposed instead of blackouts to protect from air raids and minimize the negative consequences of the lightless nights no one remembered fondly.[82]

The possibility of air raids, dismissed in 1917, alarmed many officials after Pearl Harbor. Pacific coast blackouts on began on 8 December and "within an hour" a pedestrian was killed by a driver.[83] The next day a report of bombers "roaring in from the sea" prompted an emergency blackout in Washington, DC.[84] After Germany and Italy declared war on the US on 11 December, people from the Atlantic coast to 300 miles inland were asked to disconnect all lights that could not be quickly turned off.[85] These requests from the Army and Navy were just that: requests. Although strongly worded, military officers

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80. "LaGuardia Offers Gas Mask Plan," *Washington Post* (20 December 1941): 17; "Frantic Fiorello and the Dim-Out," *Chicago Tribune* (24 June 1942): 12.

81. United States War Department and Office of Civilian Defense, *Blackouts* (Washington, DC: GPO, August 1941), iii, in Ball State University Digital Media Repository, World War II Government Publications Collection,http://libx.bsu.edu.

82. "Engineer Urges Dim-Outs Instead of Black-Outs," *New York Times* (28 July 1941): 9.

83. "Harbor Area Veiled by Strict Black-out," *Los Angeles Times* (9 December 1941): 8. The pedestrian, Benito Montez, "was believed to be the first blackout death in the [US]."

84. "Cut Down on Lights and Avert Blackout," *Washington Post* (10 December 1941): 12.

85. "Semi-Blackouts Planned for Atlanta Lights," *Atlanta Constitution* (1 March 1942): 2B. "Basic Plan for N. E. State Blackout Procedure: Complete Official Outline," *Daily Boston Globe* (5 January 1942): 4.

and civilian officials admitted they had no authority to compel state and local governments to enforce blackouts. They appealed instead to patriotism and national security but found as little success as their predecessors in WWI.[86]

Public non-cooperation early in the war seems difficult to comprehend today. While many at the time believed WWI blackouts would not work to save coal, early WWII blackouts to hinder a proven threat of attack turned out to be as difficult to enforce.[87] Despite the known presence of hostile submarines offshore, many Americans refused to reduce exterior lighting.[88] That refusal helped create what German seamen called "the happy time," wherein they sank numerous cargo vessels easily seen in silhouette against brightly lighted shores. Part of the problem lay in the fact that people unused to massed city lights did not understand sky glow.[89] A bigger part of the problem lay in pure self-interest. Beach resorts and store owners feared lost revenue, mayors feared crime, and drivers did not want to slow down and dim headlights.[90] Many people ignored blackouts and dim-outs even as debris and casualties washed up on beaches.[91] The military gained authority to

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86. "OCD Here Drafts a Blackout Code," *New York Times* (1 April 1942): 13.

87. Willard Edwards, "Nation Is Warned of Possible Coal Rationing Next Winter," *Chicago Daily Tribune* (March 25, 1942): 27, http://search.proquest.com. Lawrence C. Porter, "Blackout Lighting," *General Electric Review* 45, no. 12 (December 1942): 674-683.

88. "Shore Areas Fail to Cut Off Glare," *New York Times* (1 May 1942): 1.

89. Samuel Eliot Morison, *The Two-Ocean War* (New York: Ballentine Books, 1974), 92-93. "Match in Blackout Visible A Mile Up," *New York Times* (21 February 1942): 10. William Clark, "Why Sky Glow Betrays Ships to Foe," *Boston Globe* (10 May 1942): C2.

90. Driving over fifteen miles per hour in a blackout was "deemed unreasonable and imprudent." United States Office of Civilian Defense, *Traffic Control During Blackouts*, publication 3052, (Washington, DC: GPO, March 1943), 7, in Ball State University Digital Media Repository, World War II Government Publications Collection, http://libx.bsu.edu.

91. Christine Sadler, "Officials Cut 'Blackout' to 10 Hours," *Washington Post* (28 February 1942): 17, for "much criticism" of 6 pm to 6 am blackouts, in response blackouts began at 8 pm instead.

enforce blackouts only after Japanese submarines attacked onshore targets along the Pacific coast.[92]

Even then some people argued against military "regimentation" while special window signs reassured New York shoppers that store windows "[met] the dim-out requirements of the U.S. Army"[93] Civil defense officials realized that enforcing bans on residential lighting would be difficult and that activity would not stop unless an actual air raid was in progress. They had adopted the idea of dim-outs as a compromise and to promote that idea the War Production Board (WPB) authorized limited production of so-called blackout lamps, small incandescent lamps with a black coating and a small colored aperture at one end.[94] The lamps provided just enough light to see by and officials rationed distribution so that people would not install too many and defeat the purpose.[95]

Air raids and the danger to coastal shipping dominated officials' attention early in WWII, but worries about energy supplies remained. Coal still fueled many industrial and electrical plants, a situation that generated fears of an "impending power shortage" due to labor strife in the coal mines.[96] In late 1943, the Army relaxed lighting regulations as the

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92. Bert Webber, *Retaliation: Japanese attacks and Allied countermeasures on the Pacific coast in World War II* (Corvallis: Oregon State University Press, 1975), 30-31, 54-58, for attacks by submarine I-17 (23 February) and I-25 (21 June); 64-78, for bombings by aircraft from I-25 on 9 and 29 September. K. S. Bartlett, "Shades of Night Fall Fast Along the Eastern Coast," *Daily Boston Globe* (May 10, 1942): C2 "U-Boat in Mississippi Area!," *Chicago Tribune* (16 May 1942): 1.William S. Wilson, "Military Area Is Proclaimed On East Coast," *Washington Post* (17 May 1942): 1, 4, all in http://search.proquest.com.

93. James Morgan, "Don't Try to Push Us Around," *Boston Globe* (29 November 1942): B4. "Dim-out Advertisement Reproduced," *Magazine of Light* 11, no. 8 (5 December 1942): 6. GE noted Consolidated Edison's ad would, "bring home an aspect of the war in New York and other coastal cities."

94. Lawrence C. Porter, "The Indoor Blackout Lamp," *Magazine of Light* 11, no. 4 (10 June 1942): 8-9. E. W. Commery, "Blackout Lamps in the Home," *Magazine of Light* 11, no. 5 (20 July 1942): 39-43.
95. "Blackout Fixtures Restricted by WPB," *New York Times* (28 September 1942): 23.

96. L. Mackler, letter to editor, *Electrical Engineering* 61 no. 10 (October 1942): 543-44, recommended

Navy and Coast Guard grew adept at sinking submarines and experts began to question how well blackouts served as a defense against bombers.[97] Policy goals for lighting restrictions shifted to resource conservation despite objections reminiscent of those made during WWI.[98] "The advisability of extending...regulations to inland cities and towns—utilizing fuel conservation as the argument—is questioned sharply by illuminating engineers, the coal industry, and public utilities."[99] They questioned how much coal was actually saved at the cost of more traffic accidents, slowed production flows, and damage to morale. Advocates also made familiar arguments that included curbing unnecessary energy use and symbolically using light to remind people of the ongoing war.

For energy supplies, two big differences stood out between this war and the last. First, major users such as the Navy had shifted to fuel oil, reducing demand for coal. Second, with the issue of scarce railroad cars largely resolved, labor issues created far more problems than transportation. Disturbed by what he considered overly generous concessions to the government, United Mine Workers (UMW) president John L. Lewis ordered a strike in early 1943 despite the war. After failing to mediate a resolution,

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removing street-series lighting circuits, claiming that over 40 percent of input power was lost. A debate ensued with another engineer over the issue. William A. Crow, "Series vs. Multiple Lighting," *EE* 62, no. 1 (January 1943): 48; L. Mackler, response to Crow, *EE* 62, no. 3 (March 1943): 137.

97. "Reappraising Blackouts," *Washington Post* (1 October 1942): 10. "Army Relaxes Dim-out Orders for West Coast," *Chicago Tribune* (10 October 1943): 18. "Light Saving to Follow Dimout," *Boston Globe* (31 October 1943): B1.

98. "Electricity Cut Threatened to End Shortages," *Chicago Tribune* (1 May 1942): 29. "WPB Set to Order Power Rationing," *New York Times* (11 June 1942): 33. "Light Saving," lists "voluntary" lighting restrictions quite similar to those enacted by the USFA in WWI.

99. Thomas P. Swift, "Dimout is Weighed for Whole Nation," *New York Times* (13 February 1943): 19.

Roosevelt nationalized the coal mines in May 1943, but even that did not end the strike.[100] A new round of federal energy restrictions affected all users; bans on exterior signs and advertising again came into force.[101] While the Smith-Connally War Labor Disputes Act and strong public reaction against the miners ended the strike in 1944, the situation remained tense.[102]

As priorities shifted, the War Production Board took the lead on federal lighting policy. Roosevelt and his advisers had set up the WPB in January 1942 to ensure a steady flow of raw materials to defense industries and allocate those materials according to military priorities. Putting war needs ahead of political considerations, they shed their aversion to business leaders and named former Sears executive Donald Nelson to head the agency, and Charles Wilson, CEO of General Electric, as vice-chairman. Critics charged that these "dollar-a-year men" used their authority to further their companies' interests, and several WPB decisions clearly benefitted GE.[103] Over the objections of the Attorney General, antitrust activity was suspended for the duration, putting renewed scrutiny of GE's lamp licensing agreements on hold.[104] WPD actions also allowed GE, Westinghouse,

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100. "U.S. Seizes Strike-swept Coal Mines," *Los Angeles Times* (2 May 1943): 1. "Reject New Lewis Pay Demand," *Chicago Tribune* (2 June 1943): 1. "Total Coal Shutdown is Possible," *Hartford Courant* (31 October 1943): 1.

101. "W.P.B. Ready To Order Nation's Lights Dimmed," *Los Angeles Times* (3 June 1943): 9. "WPB Aide Assails Brownout Cheats," *New York Times* (11 December 1943): 17.

102. Kennedy, *Freedom*, 639-644.

103. Bruce Catton, *The War Lords of Washington* (New York: Harcourt, Brace and Company, 1948).

104. Bijker, "Majesty of Daylight," 260. Heath, "American War Mobilization," 304-309. Thurman Arnold and J. Sterling Livingston, "Antitrust War Policy and Full Production," *Harvard Business Review* 20, no. 3 (Spring 1942): 265-276. United States v. General Electric Company et al., Civil Action No. 1364 (D.N.J. 1941), as cited in Bright, *Electric Lamp Industry*.

and Sylvania to suppress a competing fluorescent lamp design. Cold cathode fluorescent tubes, an extension of European work on neon tubes, predated US hot cathode fluorescent designs and created a competitive threat. Makers of neon signs, worried about the outdoor advertising restrictions, formed the Fluorescent Lighting Association (FLA) and lobbied WPB without success for permission to produce tubes for general lighting.[105] GE and Sylvania made those tubes too but could not patent them or sue association members for infringement. Both companies needed patentable hot cathode devices for strategic reasons. With the assistance of Guy Holcomb in the Justice Department, FLA obtained an order telling WPB to allow competition for war lighting contracts. WPB's Nelson quickly sent a letter to the Attorney General and Holcomb was forced to resign; orders for hot cathode fluorescents remained secure.[106]

Not that GE, Westinghouse, or other lamp makers avoided WPB orders; the Board's activities directly affected lighting manufacturers' operations. The Board enacted restrictions and set priorities for basic materials like copper and brass, as well as esoteric materials like tungsten and molybdenum used in making electric lamps.[107] In response, lamp makers rationalized product lines and sought innovative ways to maximize use of rationed raw materials. They redesigned circuits to use less copper, for example, and

105. Bright and MacLaurin, "Economic Factors," 437, n18.

106. "Holcomb to Fight 'Big Boys' in WPB," *New York Times* (19 September 1942): 21. Holcomb was head of the Small Business Section within the Justice Department's Antitrust Division.

107. "Lamp Production Curtailed by WPB," *New York Times* (25 March 1942): 33. United States Civilian Production Administration, *Industrial Mobilization for War: History of the War Production Board and Predecessor Agencies, 1940-1945*, Vol. 1. *Program and Administration* (Washington, DC: GPO, 1947), 171-184, for a general overview of the different types of Orders issued by OPM and its WPB successor.

produced special products such as the above mentioned blackout lamps.[108] Culling product offerings repeated a step made during WWI. Citing WPD orders, GE took the opportunity to cut their catalog in half, eliminating low volume products and excess ratings such as 50 W incandescents; decisions that might have angered peacetime consumers.

Production efficiency dominated WPB thinking and they considered light just another necessary raw material. They embraced the idea of energy efficient lighting, continuing the pattern set during prewar industrial expansion. According to one journal, as of January 1942 “it is estimated that 12,000,000 tubes are in industry—with...8,000,000 in defense plants,” and another 50 million needed “for high-level lighting in defense industries.”[109] Planners who worried about fuel and energy saw fluorescent lamps as a way to provide light for less input power. Illuminating engineers saw a way to provide more light regardless of power, and argued that high light levels increased production rates and safety.[110] In this case, the different actors’ definitions of efficiency complemented rather than conflicted, though it remains unclear how effective federal lighting policies were in saving energy given the numbers of luminaires installed. Lamp makers took every opportunity to justify increased production and distribution of fluorescent lamps.[111]

During 1944 and 1945 the war’s outcome looked increasingly favorable for the US

108. Lamp Department, “New Sequence Starting Circuit for 65-watt Mazda F lamps,” General Electric Lamp Letter 42-3 (21 January 1942). P. D. Parker, “Regarding Lumiline Lamps,” *Magazine of Light* 11, no. 4 (10 June 1942): 4. “How Will the WPB Lamp Limitation Order Affect You,” *Magazine of Light* 11, no. 8 (5 December 1942): 2. GE made an estimated 9000 lamp types until WPD’s amended Order L-78.

109. “Lighting Review and Forecast,” *Electrical Merchandising* 67, no. 1 (January 1942): 19.

110. Nela Park Engineering Department, “Guide to Planning 50 Footcandles of Fluorescent Lighting,” General Electric bulletin LS-242 (February 1942).

111. “General Electric Wartime Industrial Lighting Recommendations,” Bulletin LM-14, (21 September 1942), although incandescents are included, fluorescents are clearly emphasized.

and its allies, and lighting regulations eased. Military and civil defense authorities gradually relaxed dim-outs and other restrictions as they grew confident that large scale raids on the continental US were unlikely and coal miners went back to work. War production needs continued to take precedence but some materials regulations were loosened and additional lighting fixtures were allowed.[112] Some in the utility industry began to plan "tooling up for peacetime production." "We must not permit our reduced level of living during the war to become a yardstick, even in part, of what is regarded as normal for the future or even a temporary transition period following the war."[113] They wanted to resume widespread promotion of electric appliances and power consumption, although as figure 6.2 (above) shows, residential electric use continued rising throughout the war. It remained to be seen if residential consumers would adopt fluorescent lamps. However, lamp makers had taken full advantage of government policies during the war to push fluorescent lighting to commercial and industrial users, and no amount of postwar utility pressure would remove that product from the market. "Virtually all newly constructed [industrial] plants make major use of fluorescent lighting .... commercial and residential applications will undoubtedly expand tremendously after the war."[114]

Early period, second phase: victory and reconversion

The time between the end of WWI and the end of WWII displayed cycles in US

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112. "Output Expanded in Light Fixtures," *New York Times* (23 November 1944): 41.

113. Hubert M. Langlois, "Public Utility Adjustment to Postwar Conditions," *The Annals of the American Academy of Political and Social Science* 222, no. 1 (1942): 153.

114. Bright and MacLaurin, "Economic Factors," 435.

economic activity, political mood, and lighting policy. The economy boomed, slid into the Great Depression, and then slowly recovered. The political influence of Progressive ideas waned as the nation sought normalcy after WWI, and then waxed as people turned to the New Deal as a way out of Depression. Federal policy makers stepped away from regulating lighting outside of broad areas such as antitrust and tariffs, only to reengage with lighting during the Depression and WWII. When considering wartime policies, (as per the second research question) the interventions were similar in detail, intent, and success: lighting reductions like blackouts to save fuel and to symbolize the existence of a national crisis that largely failed. An intervention that worked, using electric lighting to promote rural electrification was a new policy that largely succeeded. During these cycles some features of the American polity remained evident and contributed to policy makers' troubles, in particular, aversion to central authority and reverence for individual autonomy. As during the WWI-era, people tolerated some federal interventions as supportive of business (NBS research and standards) and resisted other measures as too intrusive (lighting restrictions). Regardless, they expected most lighting specific interventions to be temporary.

Lighting technology and science advanced during the early period as illuminating engineers made lamps of higher efficacy, and learned how to better apply light to specific tasks. As they devised lamps for specific purposes, markets separated into discrete sectors. As with tungsten lamps prior to WWI, the development of fluorescents just prior to WWII gave policy makers a ready tool as they sought to ration electricity use (as per the first research question). By 1945, the fluorescent lamp was firmly established in American commercial and industrial lighting sectors, and in 1952 fluorescents surpassed incandescent lamps in the amount of light produced in this country.[115] As in WWI (and as per the third research question), GE and the other lamp makers had used the WWII emergency to push an expensive, high efficacy light source onto the market in the face of opposition from utilities—opposition that even the utilities realized would be difficult to sustain.[116] With the government encouraging energy efficient lighting to aid war production and Sylvania aggressively promoting fluorescents to escape GE's licenses, power company resistance to fluorescent lamps was not tenable even as they lost revenue due to lighting restrictions.[117] Utility representatives met with GE officials and reached an agreement on how to market fluorescent lamps in a non-threatening way. Sales boomed while a Westinghouse executive wrote that the company would "oppose the use of fluorescent lamps to reduce wattages."[118] As time passed, utilities' aversion to fluorescents faded when they realized that, "even during the first five years..., its great efficiency increases have been employed more in raising levels of illumination than in the reducing of electric energy consumption."[119]

A more significant change occurred in lighting during this period. The definition of

115. Bright, *Electric Lamp Industry*, 410, for 1938 through 1947 sales figures. George E. Inman, "Fluorescent Lamps—Past, Present, and Future," *General Electric Review* 57, no. 7 (July 1954): 34-38, for 1952 figure.

116. *Patents*, (August 1942), 4813, for John E. Mueller, "Today's Fluorescent Lighting Situation," paper read before the Sales Executives Conference of the Association of Edison Illuminating Companies, 30 September to 3 October 1940, https://babel.hathitrust.org. Mueller wrote that with efficacy, life ratings and sales rising, and costs falling, "it is now in the customer's interest in most instances to recommend fluorescent for general lighting."

117. "Dim-out on East Coast Costs Utility $2,600,000," *New York Times* (5 November 1942): 17, refers to a Consolidated Edison report to shareholders.

118. Bijker, "Majesty of Daylight," 238-40; Bright, *Electric Lamp Industry*, 400-404.

119. Bright, "Some Broad Economic Implications," 374-375.

efficiency for lighting professionals evolved significantly during the 1920s. Earlier, the definition centered on energy but as utilities installed more capable generators and illuminating engineers sought to raise light levels, a more expansive definition emerged. The meaning of lighting efficiency included holistic views of lighting systems, including luminaire design and maintenance, and evaluation of the illumination task. Availability of tungsten lamps enabled the push for higher light levels, an idea amplified by the development of fluorescent lamps with even higher efficacy. A mantra of more-light-is-better-light influenced the training of lighting professionals and consumer expectations for years to come. The changing role of efficacy within larger socially constructed definitions of lighting efficiency became a hurdle that later policy makers would need to overcome.

Most people little recognized the scale of the political and economic changes that had taken place. At the end of WWII, the US seemed poised for another return to normalcy, although some feared the Depression might resume. Many lighting restrictions were lifted but some remained for a time. Though unpopular and "isolated within the labor movement," the UMW struck again in 1946, leading to lighting restrictions "more drastic than in wartime."[120] In many ways however, the lighting industry picked up after the war where they had left off. Illuminating engineers and the BLBS continued advocating for higher light levels. Rural electrification resumed. The Justice Department, which never accepted the 1926 decision of the Supreme Court, revived antitrust activity against GE and the company fought to retain control of the US lighting market.[121] One difference

120. Koistinen, "Mobilizing," 478n63. 443-478. Walter H. Waggoner, "Lights Cut Monday," *New York Times* (23 November 1946): 1. "Dim-out to Start Monday," *Chicago Tribune* (23 November 1946): 1.

121. Reich, "Lighting the Path," 331.

however, stemmed from the longer US war involvement—45 months instead of 20 months—that gave wartime research more time to bear fruit. That included projects such as research on quartz and electronics that later fed major changes in lighting technology. Another difference became apparent when, after a brief period of financial retrenchment, federal funding escalated for research and development in the name of Cold War national security.

Chapter Seven: Lighting a Postwar Economy, 1945-1973

[I was told,] the last thing we want is another invention right now.

—Gilbert Reiling, 12 September 1995[1]

Changes in context and new technologies that emerged from the postwar years characterize a transition period between an earlier period of intermittent lighting policy and a later period of sustained interventions. As Historical Institutionalists point out, context plays a critical role in shaping how problems and policy alternatives are defined.[2] Federal officials enacted few lighting-specific policies for nearly three decades after the Second World War. In that respect, those years seemed reminiscent of the time following WWI, when the government lifted specific restrictions and pursued broad policies like antitrust actions wherein lighting was just another technology. Decisions in several of those broader areas contributed to changes in larger, overlapping economic and political contexts within which policy makers worked. Those contextual changes, domestic and international, affected the course of path dependencies built in the years after Edison's 1879 invention. The paths began to slowly shift, resulting in new energy efficient lamps and prompting reevaluation of accepted standards and practices when the US faced a new set of energy challenges in the 1970s.

Immediately after WWII many Americans feared the economy might slide back

1. Gilbert Reiling, telephone conversation with author, 12 September 1995.

2. Orren and Skowronek, *Search*, 113.

into Depression when abrupt cancellation of government war contracts sparked an economic downturn. However, as veterans found or made new jobs, or went to school under the auspices of the G. I. Bill, a sense of economic confidence took hold and domestic spending rose.[3] Along with a growing economy came questions about how the benefits of that growth should be distributed, and renewed union activism brought strikes and reactionary responses from businesses.[4] Internationally, a new bifurcated order emerged characterized by a rift between former wartime allies who embraced different visions of political and economic organization. The US, UK, and others organized institutions that promoted global capitalism, while the USSR, China, and others organized their own institutions that promoted global communism. This ideological competition fueled a military standoff, the Cold War, which led many Americans to support sustained spending on defense and the existence of a large military-industrial complex; a situation that differed from the isolationism that occurred after WWI. Defense spending during WWII and the Cold War enabled scientific and engineering advances that ultimately revolutionized the lighting industry.

One change in the domestic political context included an attempt to limit and institutionalize executive branch regulatory activities. The Administrative Procedure Act of 1946 had little effect on lighting-specific policies at first, but later agencies such as the Environmental Protection Agency and the Department of Energy that pursued such

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3. James Gilbert, *Another Chance: Postwar America, 1945-1968* (Philadelphia: Temple University Press, 1981). Robert Latham, *The Liberal Moment: Modernity, Security, and the Making of Postwar International Order* (New York: Columbia University Press, 1997).

4. David F. Noble, *Forces of Production: A Social History of Industrial Automation* (New York: Oxford University Press, 1984), 154-167.

policies would operate within formal frameworks established by the Act. Another change saw the emergence of a political actor network devoted to environmental regulation. Built on earlier national debates about resource conservation, this network gained strength and created a new policy realm that came to affect the lighting industry. Although lighting-specific policies were few in these decades, one antitrust decision had an important impact. A consent decree that largely settled the Justice Department's antitrust suit against General Electric helped transform the US lighting market.

By 1950, most Americans were connected to central power stations, work to complete rural electrification proceeded, and the country grew dependent on electricity for most energy applications outside the transportation sector.[5] Figure 7.1 shows the extent of the growth in electric power use in the three major lighting sectors during this time. Dependence on electric power was such that utilities faced a capacity shortage that helped them accept fluorescent lamps.[6] As oil and then uranium began displacing coal as fuel in US power plants, advances in generator and plant design helped keep the cost of electricity low for consumers during the first two decades that followed the war.[7] Lighting designers used that cheap electricity to specify blankets of light as high as 100 foot-candles for many

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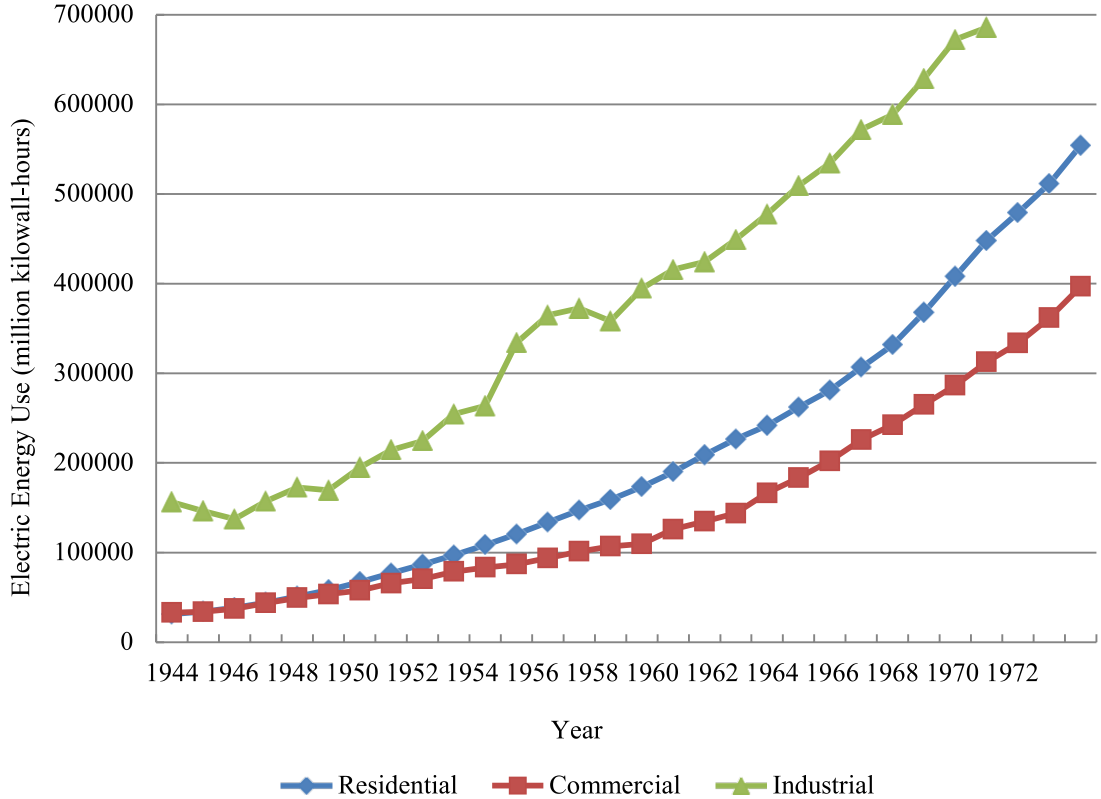
5. Brown, *Electricity for Rural America*. Gavin Wright, "Electrical energy - retail prices, residential use, and service coverage: 1902-2000," Table Db238-240 in *Historical Statistics of the United States, Earliest Times to the Present, Millennial Edition*, eds. Susan B. Carter, Scott S. Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, (New York: Cambridge University Press, 2006), http://dx.doi.org. The 1950 figures for "Percentage of dwelling units with electric service" are: Urban and rural nonfarm - 96.6%; Farm – 77.7%. In 1956 the figures are 99.2% and 95.9%, respectively.

6. Hirsh, *Technology*, 48.

7. Peter H. Lindert, "Consumer price indexes for all urban consumers, for selected items and groups: 1935-1997," Table Cc6-48 in *Historical Statistics of the United States, Earliest Times to the Present*, Millennial Edition, eds. Susan B. Carter, Scott S. Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, (New York: Cambridge University Press, 2006), http://dx.doi.org.

Figure 7.1: Electric energy use in the United States, by sector, 1944-1973[8]



After a post-WWII industrial slump due to cancellation of wartime contracts, all sectors showed an increasing adoption of electric power. This represents the general economic boom at the time and includes expansion of residential use due to the completion of rural electrification and the postwar boom in suburban housing construction. US utilities struggled to keep up with this demand growth.

installations.[9] While most residential customers did not go that far, inexpensive lamps and power led many to add luminaires and revise their expectations of good lighting.[10] Faced

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8. Source: Gavin Wright, "Electrical energy–sales and use: 1902–2000," Table Db229-231 in *Historical Statistics of the United States*.

9. Illuminating Engineering Society, *IES Lighting Handbook: the Standard Lighting Guide*, 1st ed. (New York: Illuminating Engineering Society of North America, 1947).

10. Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York: Basic Books, 1983), for how technology adoption changes users' and society's expectations.

with real competition after years in protected markets, industry managers supported research along a broad front. Researchers at GE and other lamp makers used knowledge gained during WWII to create new lamps, and as Gil Reiling learned, left managers wondering how much invention the company could handle.[11]

Technology: a new burst of innovation

Rationing of materials restricted fluorescent lamp production during WWII to existing devices, but experiments continued and soon after the war manufacturers began producing new lamp types. Researchers found a critical relationship between the distance separating the electrodes (the arc path) and efficacy: the longer the arc path, the more efficient the lamp. Lamps 96 inches long became standard for commercial and industrial consumers.[12] Engineers devised ways of making non-linear arc paths to raise efficacy while keeping lamp sizes manageable: circular tubes, flat panels with serpentine channels, and tubes containing internal structures.[13] Some of these designs sold well while others failed because users adopted fluorescents for reasons other than efficacy. However, experience gained in developing these lamps informed future researchers when they worked to create compact fluorescent lamps.

Research conducted during WWII influenced several important postwar lighting

11. John Waymouth, telephone conversation with author, 20 March 1996. He used the term “golden age” to describe the research environment in the postwar period. Other engineers have expressed similar views.

12. NMAH EC-LRF for manufacturers’ catalogs that show the breadth of postwar offerings.

13. Robert L. Breadner, Henry G. Jenkins and Charles H. Simms, Electric Discharge Envelope, US Patent 2,491,847, filed 21 June 1946 and issued 20 December 1949. Westinghouse, experimental fluorescent lamps with internal structures, ca. 1955, NMAH-EC, accession number 2001.0084, from Daniel Larson.

inventions, one being the surprising development of tungsten halogen lamps by a team at GE's Nela Park. The first radical improvement in incandescent lamps since 1913, tungsten halogens came as a byproduct of a 1953 project to design a new heat lamp.[14] GE mechanic-turned-engineer Elmer Fridrich applied wartime research in quartz fabrication techniques to the task of making a thin, heat-resistant tube.[15] Previous heat lamps needed large glass envelopes and quartz could withstand high temperatures, but evaporated tungsten from the filament darkened the tubes. To keep them clear, Fridrich added iodine to his test lamps, "and Eureka!...instant success."[16] Edward Zubler then identified the chemical cycle at work inside the lamp and Frederick Mosby designed a structure to withstand the high temperatures and pressures. Tungsten halogen lamps showed a 20 percent better efficacy on average over standard incandescent lamps along with longer life ratings, but were expensive and could explode under certain circumstances.[17] Few expected them to become a general lighting product and by 1958 GE began making plans to sell tungsten halogens lamps in niche markets such as for aircraft marker lights.[18]

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14. J. N. Aldington, "Lamps and Lighting—A Vision for the Future," *Illuminating Engineering* 48, no. 2 (February 1953): 82-90. Aldington noted that future progress on incandescent lamps would need "vigorous and fresh" thinking. Frederick Mosby, interview by Harold D. Wallace, Jr., 8 March 1996, in NMAH EC-LRF. Mosby said other companies "had worked on halogen lamps just like we had, for years, and had given it up because of the horrendous problems that they saw."

15. Philip K. Devers, "Fused Quartz...An Unusual Material Offers Suggestions for New Applications," *Magazine of Light* 12, no. 2 (February 1943): 18.

16. Gilbert Reiling and Elmer Fridrich, interview by Harold D. Wallace, Jr., 1 March 1996, in NMAH EC-LRF.

17. General Electric Company, "Large Lamp Price Schedule," form 9200 (16 February 1970), 38-40, in NMAH EC-LRF. Edward G. Zubler and Frederick A. Mosby, "An Iodine Incandescent Lamp with Virtually 100 Per Cent Lumen Maintenance," *Illuminating Engineering* 54, no. 12 (December 1959): 734-7.

18. Carl J. Allen and Ronald L. Paugh, "Applications of the Quartz Lighting Lamp," *Illuminating Engineering* 54, no.12 (December 1959): 741-748. Early applications included aircraft lights, runway guide lamps and automotive headlamps.

At that same time, physicist Gilbert Reiling at GE's Schenectady research laboratory invented an improved type of mercury vapor lamp called the metal halide lamp.[19] By the mid-1950s, mercury vapor lamps were a mature technology primarily used in street lighting and high-bay interior installations, but their poor color output limited their use. Several producers introduced improved mercury lamps that gave better color and longer life at the cost of lower efficacy (as seen in the figures in table 7.1).[20] Though researchers knew that adding metallic salts (halides) to the fill gas would improve the quality of the light, they lacked necessary materials and a good understanding of the complex chemistry involved.[21] Reiling, like Fridrich, used wartime quartz research to design an arc tube and then analyzed various metallic compounds, devising an indium-iodide mix that produced white light with much higher efficacy than mercury vapor lamps.[22] Reiling recalled industry enthusiasm after GE announced his lamp in February 1962.[23] "[Nobody] had seen 100 lumens per watt of white light."[24]

That drive for new white light sources brought yet another novel design from GE

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19. Gilbert H. Reiling, "Characteristics of Mercury Vapor - Metallic Iodide Arc Lamps," *Journal of the Optical Society of America* 54, no. 4 (April 1964): 532-540. Independent metal halide work was done in Germany by Bernhard Kühl and Horst Krense.

20. William S. Till and Melvin C. Unglert, "New Designs for Mercury Lamps Increase Their Usefulness," *Illuminating Engineering* 55, no. 5 (May 1960): 269-281.

21. Charles P. Steinmetz, Electric Lighting, US Patent 1,020,323, filed 25 April 1900 and issued 12 March 1912, for an early attempt to use halide salts in a mercury lamp.

22. Reiling and Fridrich interview, 1 March 1996.

23. New electrodes were required as were new marketing strategies as engineers came to realize that the new lamps could not directly replace mercury vapor lamps. Metal halide lamps required specially-designed ballasts that could give a high-voltage surge for ignition, making retrofits more expensive than anticipated.

24. Reiling and Fridrich interview, 1 March 1996. GE initially used indium-iodine and Sylvania, once they learned of the development, turned to thallium-iodide.

during this period when another team invented the high pressure sodium (HPS) lamp. As known since the 1920s, sodium produces light more efficiently than mercury at equal pressures. Experiments showed that the light's color improved as pressure increased but so did the corrosive effects of the sodium gas. In early 1957, GE ceramicists Joseph Burke and Robert Coble made aluminum-oxide discs that transmitted over 90 percent of incident light. At Nela Park, William Louden and Kurt Schmidt made a HPS lamp using an aluminum-oxide tube.[25] The difficult development process took far longer than expected; premature announcement of the lamp in 1962 and problems found after commercial introduction in 1966 led even the inventors to question the product's viability.[26] A redesign in 1968 gave a good life rating (>6000 hours) and efficacy (100 lpW) while the golden yellow color marked a big improvement over the monochromatic yellow of 1930s LPS lamps. Philips responded by introducing a new LPS lamp that gave 180 lpW and sold well in Europe, but the US lighting market cared more about color than efficacy and began adopting HPS.[27]

That point bears emphasis: by the 1950s and 1960s efficacy was only one, and not the most important, motivation for inventing and marketing new lamps. Reasonably well defined market sectors meant that expensive new lamps competed against lower cost

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25. Charles I. McVey, "High-pressure sodium lamp technology," *IEE Proceedings A-Physical Science, Measurement and Instrumentation, Management and Education-Review* 127, no. 3 (April 1980): 158 for redirected research. William C. Louden and Kurt Schmidt, "High-Pressure Sodium Discharge Arc Lamps," *Illuminating Engineering* 60, no. 12 (December 1965): 696-702.

26. Rodney E. Hanneman, William C. Louden, and Charles I. McVey, "Thermodynamic and Experimental Studies of the High-Pressure Sodium Lamp," *Illuminating Engineering* 64, no. 3 (March 1969): 162. Louden recounted being discouraged in 1966 and asking his supervisor if HPS would be cancelled.

27. Willem Elenbaas, H.J.J. van Boort, and R. Spiessens, "Improvements in Low-Pressure Sodium Vapour Lamps," *Illuminating Engineering* 64, no. 2 February 1969): 94. "Norelco looks to the future," *Lighting Design & Application* 7, no. 3 (March 1977): 16, for a note that GE dropped LPS around 1971.

predecessors during a period of cheap electricity. As seen in table 7.1, the improved efficacy of the new lamps did not yet exceed existing designs by much. Certainly not by enough to arouse the ire of electrical utilities, in part due to growth in power demand, but

Table 7.1: Lamp efficacy comparison (lpW), 1945-1970[28]

Date	Regular incandescent	Tungsten halogen	Mercury vapor	Metal halide	Linear fluorescent	Low pressure sodium	High pressure sodium	Light emitting diode
1945	13.9		35		58	72		
1950	13.9		40		58	72		
1955	13.9		50		65	79		
1960	14		44.5*		63	100		
1965	14.25	19.9	44.5	63	72.5	137	105	
1970	14.25	19.9	44.5	67	68.5**	157	107	3

During the 1950s and 1960s, lamp makers offered two new, higher efficacy versions of existing products. These parings were tungsten halogen / incandescent, and metal halide / mercury vapor. At first, efficacy gains were modest; other advantages led to adoption of the new lamps as niche products in some markets. A third new lamp, high pressure sodium, never matched the efficacy of its low pressure predecessor, but did exhibit better color and competed against mercury vapor and fluorescents. LPS efficacy rose as improved products were introduced. Light emitting diodes, introduced in 1968, would later be made with efficacies in excess of 300 lpW.
*Lower efficacy reflects introduction of an otherwise improved product.
**Lower efficacy due to revised testing standards.

also due to expectations of very limited markets. Tungsten halogens filled a niche for small bright lamps with good color characteristics and the electrical simplicity of an incandescent source. Metal halide lamps competed against low cost mercury vapor lamps until the rapid adoption of color television during the 1960s created demand for a high output, white light lamp to illuminate evening sports broadcasts. Early technical problems slowed HPS sales and only slowly did the lamp’s higher efficacy begin attracting

28. Source: product catalogs, NMAH EC-LRF. Values cited are representative examples.

customers already confused by the plethora of new large lamps.[29] One more GE invention from this period, light emitting diodes (LEDs), were seen as an even more specialized product, and will be discussed in more detail in chapter nine. Suffice for now to note that GE sold LEDs as miniature indicator lamps and never devoted a high level of funding to refining them.

The reemergence of efficacy as a major factor occurred only later, after the economics of electric power changed. When that happened, the lamps developed in the 1950s and 1960s gave federal policy actors ready alternatives as they responded to national energy problems.

1945-1960: shifting contexts

The late 1940s was a time of uncertainty in the US when people recognized quite clearly that their world had changed but could not yet see what the changes meant. That uncertainty carried over to the lighting industry. WWII destroyed much of Europe's and Asia's industrial capacity and also ended the Phoebus cartel's control over international trade in electric lamps. Leaders of the capitalist countries developed postwar policies of open trade and competitive markets that they hoped would preclude the economic issues that contributed to the global war. Those policies helped prevent reestablishment of the cartel.[30] Leading lamp makers such as Philips and Osram began rebuilding their facilities with the idea of reviving Phoebus, but as the 1950s progressed that possibility faded. They

29. Ernest C. Martt, telephone conversation with author, 26 February 1996, for "initial confusion among customers" as result of introducing three new lamps within just a few years.

30. Robert Jones and Oliver Marriott, *Anatomy of a Merger*, 172-174.

and other companies in formerly well meshed actor networks started to view former colleagues as future competitors and phased out technical exchange agreements.[31]

With Philips already in the US market via its Norelco brand, the prospect of competition from former international partners meant General Electric faced changes in two sets of networks. Resumption of the antitrust suit marked the beginning of the end for GE's half century fight to maintain control of the US lamp market. Negotiations and a series of consent decrees among GE and other defendants (Corning Glass, for example) began opening the market to competition. The Justice Department charged that GE and its licensees had restrained trade and prevented competition through use of restrictive agreements and participation in the Phoebus cartel. They proposed, among other remedies, undoing the 1911 absorption of the National Companies by forcing GE to split its lighting operations in two, spinning one off into a competing company. Though Chief Judge Phillip Forman declined to go that far, and also deferred to the 1926 Supreme Court decision on the matter of retail price fixing via agency, he voided the old system of patent licensing agreements and ordered the Mazda trade name severely restricted. GE was required to "dedicate to the public existing patents on lamps and parts," make new patents available for license until 1958, and license patents for production equipment.[32] The company quickly adapted and, taking a calculated risk, delayed filing for patents on Fridrich's 1953 tungsten halogen breakthrough until 1958 to keep the invention free of the decree. What real

31. Louden, interview, 8 March 1996, NMAH EC-LRF. "I made a trip to Europe [about 1975] after those [agreements] ran out, met with some of my old friends, ... All we could do was talk about the old times."

32. United States v. General Electric Company, 115 F. Supp. 835 (D.N.J. 1953), https://law.justia.com. See also, Reich, "Lighting the Path," 305-34, 331-332. Robert P. Rogers, *Staff Report on the Development and Structure of the U.S. Electric Lamp Industry*, prepared for the Federal Trade Commission (Washington, DC: GPO, February 1980), 113-120.

competition might mean and how long it might take to achieve was anyone's guess. However, everyone in the actor networks saw that fundaments conditions had changed.

Another change in postwar contexts quickly became apparent; the role of science and technology would be substantial and receive generous government support. Victory in WWII, the high technology "Wizards' War," drove an infatuation with science and engineering research among a polity and policy makers anxious to avoid another surprise attack, especially as relations with the USSR deteriorated.[33] GE's Joseph Burke recalled that, "After the war there was great wonder at the results of basic research."[34] Vannevar Bush, director of the wartime Office of Scientific Research and Development, proposed a postwar science policy later published as *Science: the Endless Frontier*. Many of his ideas were later modified or dropped, but the report laid out a plan for federal scientific research, including establishment of the National Science Foundation (NSF).[35]

As it turned out, much of the funding for scientific research came not from the civilian NSF but rather from the new Department of Defense and the armed forces. Determined to build US leadership in military technology, the services funded work to invent specific devices, so-called applied research, and also the study of fundamental principles with no immediate application, so-called basic research.[36] Supporting university

33. Winston Churchill used this phrase as a chapter title in volume two of his history of WWII in reference to radar and other advanced technologies used in the war.

34. Joseph E. Burke, telephone conversation with author, 8 January 1998.

35. Daniel J. Kevles, "The National Science Foundation and the Debate Over Postwar Research Policy, 1942-1945: A Political Interpretation of Science–The Endless Frontier," *Isis* 68, no. 1 (1977): 4-26.

36. Purported differences between basic and applied research are critical to understanding how researchers identify and organize themselves. Suffice here to say the difference mattered to NBS and NSF, far less so to the Defense Department. Paul Forman, "Behind Quantum Electronics: National Security as Basis for

and industrial researchers, the infusion of military funds generated important new knowledge in physics, chemistry, electronics, and the social sciences. Effects of that funding carried over into many fields, including the lighting industry where it created a hiring boom, as one Westinghouse engineer recalled.[37] Military purchases provided a profitable market for expensive components like transistors, and transferring those technologies to lighting later brought unintended but important changes.

Unexpectedly, the national emphasis on scientific research resulted in the exit of the Bureau of Standards from much lighting research. Retirements and a reorganization spurred by Congress and the Truman Administration led to "an almost complete turnover of the top echelon" at NBS in the late 1940s. New director Edward Condon, a theoretical physicist and former Westinghouse employee, considered industrial research as pursued by NBS redundant given the capabilities of US industrial labs.[38] Some lighting research continued. William Meggers's work on mercury-198 lamps helped define a new standard of length, but these exceptions proved the new rule as the Bureau emphasized service to science.[39] One of the few lighting tasks left from the earlier era lay in quality assurance testing of light bulbs purchased by the government.[40]

Letting private sector labs handle research on commercial products seemed a

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Physical Research in the United States, 1940-1960," *Historical Studies of the Physical and Biological Sciences* 18, part 1 (1987): 220-221.

37. Robert G. Young, telephone conversation with author, 26 October 1995.

38. Cochrane, *Measures*, 443 for retirements, 448 for Condon.

39. Cochrane, *Measures*, 463 for Meggers' work, 489 for new direction.

40. Cochrane, *Measures*, 500.

reasonable policy. Major lighting inventions like tungsten halogens and metal halides leveraged wartime advances made with federal funding, but the government did not deliberately pay for those inventions.[41] Lasers constituted the most significant area of lighting research that relied heavily on defense money but potential military uses drove early work, commercial applications followed later. No one intended to use lasers for general lighting anyway; the first three lasers came from defense and communications labs at Hughes Aircraft, IBM, and Bell Telephone, respectively.[42] GE's early laser work stemmed from solid state physics research and was important for the invention of light emitting diodes but, as discussed in chapter nine, the company lost interest and inventor Nick Holonyak left the company for academia.

Lighting devices had known military utility on and off the battlefield, but the technology was mature and the effect of government research funding mostly indirect and tangential. The experience Gil Reiling gained designing a new switch tube for nuclear research at Los Alamos in the mid-1950s, for example, later helped him understand physical reactions inside his experimental metal halide lamps.[43] One scientist declared "about 1950 a new age in the science of materials was born;" Manhattan Project-veteran Joseph Burke's ceramics research at GE led to the high pressure sodium lamp.[44] As William Louden struggled to invent seals for the HPS lamp, he found that colleagues

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41. "Lighting," *General Electric Review* 49, no. 2 (February 1946): 57-61 notes several applications of wartime research for postwar lighting technology.

42. Joan Lisa Bromberg, *The Laser in America, 1950-1970* (Cambridge, MA.: MIT Press, 1991).

43. Reiling and Fridrich interview, 1 March 1996. "I learned a lot of things about [solid-state] discharge."

44. Andreas L. Stuijts, "Renaissance in Ceramic Technology," *Philips Technical Review* 31, no. 2 (February 1970): 44. Manhattan Project was the code name for the successful US effort to develop an atomic bomb.

working on classified aerospace devices had similar problems with sodium's reactivity, so they "compared notes" and helped each other's projects.[45] These are not the only examples. The effect on the lighting industry of this indirect and often intangible military research funding was profound.

As a matter of policy, the military decided that lamp makers could field new products without direct funding although they made exceptions for special projects. GE, for example, developed an automated system to make miniature lamps that "the Air Force [procured] by the millions" for aircraft panel and indicator lighting, resulting in a "$10-to-$25 per plane saving...."[46] That particular project may have stemmed from deeper concerns however. A strike in 1946 closed GE plants across the country and encouraged the company to participate in Air Force efforts to promote automated manufacturing technology to circumvent organized labor. On the civilian side, a few government programs promoted lighting. The REA continued to use lighting as an enticement as they resumed promoting rural electric cooperatives. The Department of Agriculture worked with GE physicist John Campbell in 1951 to test a high-frequency fluorescent lighting system they hoped might reduce the cost of accelerating plant growth.[47] While successful, GE chose not to pursue the product, but Campbell and his research surfaced again twenty years later when the high efficacy of his system attracted renewed attention.

The actor networks built up over decades also changed when affiliated groups like

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45. Louden interview, 8 March 1996.

46. "Lighting" *General Electric Review* 55, no. 1 (January 1952): 49, for the Air Force project. Noble, *Forces of Production*, 154-167, for the 1946 GE strike.

47. "Lighting" *GE Review* (January 1952): 47.

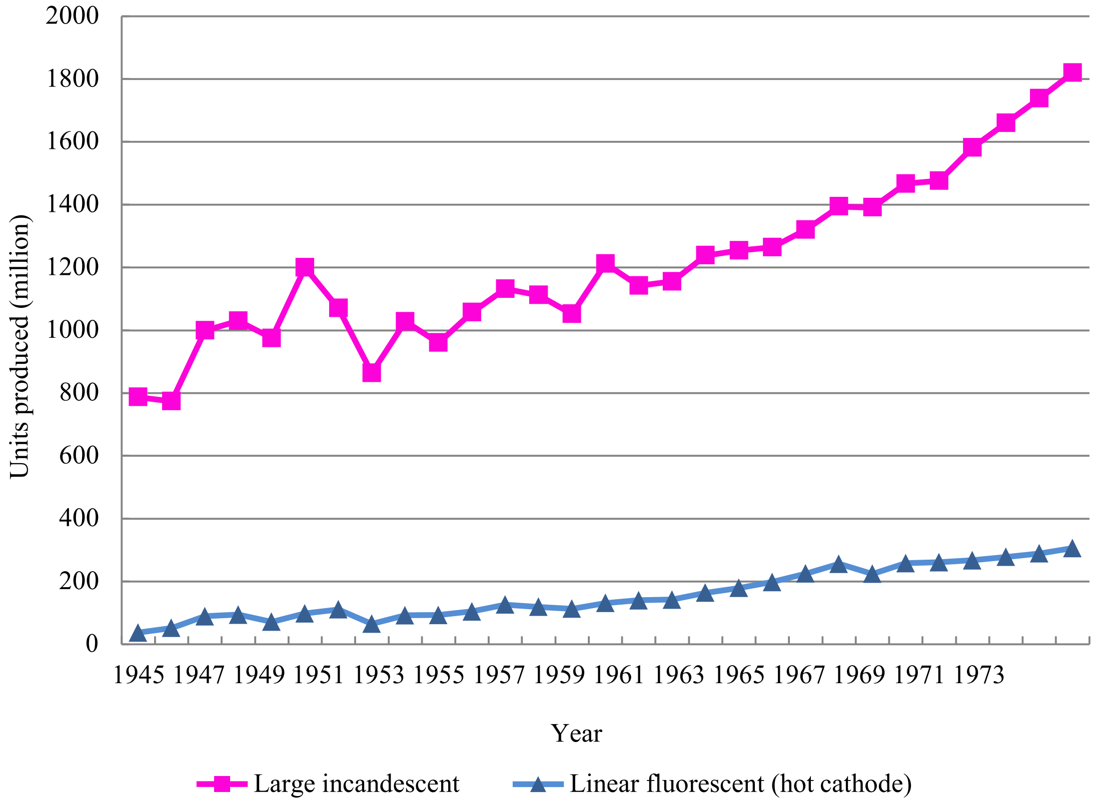
electrical utilities dealt with their own postwar challenges. By the 1950s, central power systems dominated the supply of electric power in the US, and a complex network of transmission lines spanned the continent.[48] The anticipated advent of civilian nuclear generators and repeated references to electricity "too cheap to meter" concerned utilities more than fluorescent lamps giving a few more lumens per watt. That incandescent lamp sales grew at a faster pace than fluorescents starting in the mid-1950s, as seen in figure 7.2, helped assuage their concerns about the new lamp's effect on their power sales. Struggling with a capacity shortage and continuing to shift fuels from coal to oil and uranium, utilities failed to recognize the depth of the problems that would beset them during the 1960s. The end of GE's market control seemed a small event, but it forced the company to compete for lamp sales and made their traditional link with utilities more tenuous. By this time, most people purchased lamps and luminaires from retail stores, not utilities, and market participants like Sylvania and Norelco had no power equipment products to worry about.

To illuminating engineers seeking higher light levels, the company that made and sold the lamps seemed irrelevant. Their goal of creating high light levels could be met by anyone's product. All of the inventive activity and lighting research prompted the Illuminating Engineering Society in 1958 to boost "recommended lighting levels for various tasks," including some "marked increases."[49] At that time, energy efficiency carried weight only in the commercial and industrial lighting sectors because energy expended on lighting figured into lighting cost calculations, but only as one factor among

48. Hirsh, *Technology*, 20.

49. William F. Little and E. H. Salter, "Lighting of the Past 25 Years and the Future," *Electrical Engineering* 78, no. 5 (May 1959): 523.

Figure 7.2: Production of incandescent and fluorescent lamps, 1945-1973[50]



Production of large incandescent lamps fluctuated in the 1950s but settled into an upward trend during the 1960s that resulted in annual production more than doubling. Fluorescent lamp production showed less fluctuation; the low initial numbers reflect the lamp's market introduction in 1939. The rising sales of energy inefficient incandescents helped utilities overcome their initial aversion to fluorescents but contributed to the general rise in US electricity and energy consumption.

several.[51] The higher IES standards continued prewar efforts to define lighting quality in terms of quantity with more light being better light. The Better Light Better Sight Bureau in the Edison Electric Institute, the trade association of investor owned utilities, supported

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50. Source: Atack and Bateman, "Physical output of selected manufactured products: 1860-1997," *Historical Statistics of the United States*, Tables Dd412\30, 422\30.

51. Examples of cost advice to commercial-industrial users include: Phelps Meaker, "The Unit Cost of Light," *General Electric Review* 55, no. 7 (July 1952): 36-37, 61; Elton A. Linsday, "Let's Reduce the Cost of Lighting," *Electrical Engineering* 73, no. 7 (July 1954): 632-635.

that goal. Federal policy makers took little notice of this approach to lighting design at that time. To them, energy policy meant increasing supplies rather than efficient use, with a particular emphasis civilian nuclear power.

Lighting for federal policy actors, as for many users, receded from conscious view and policy decisions that involved lighting returned to state and local levels. “More and more Americans have the concept that light is bountiful and so low in cost...that there is no longer the question of ‘how little light can I get by with’.”[52] The 1958 merger of General Telephone and Sylvania into GTE triggered no federal objections. Lighting was a minor concern in that merger and federal prosecutors were otherwise occupied with a major investigation of power equipment manufacturers.[53] In 1960, the Justice Department charged about 40 companies, including GE and Westinghouse, with fixing prices and rigging bids on power equipment in an antitrust case that saw senior managers fined and some sentenced to brief jail terms.[54] The lamp divisions of GE and Westinghouse played no apparent part in the collusion. Company executives knew that part of the 1953 antitrust settlement included allowing the Justice Department access to their books, in part to verify compliance with an order prohibiting collusive bidding.[55] For the most part, the lighting industry’s relationship to the federal government going into the 1960s looked much as it

52. “Lighting Progress in 1962,” *Illuminating Engineering* 58, no. 1 (January 1963): 1.

53. “Sylvania Plans Merger with General Telephone Corp.,” *Illuminating Engineering* 53, no. 12 (December 1958): 15A.

54. John Herling, *The Great Price Conspiracy: The Story of the Antitrust Violations in the Electrical Industry* (Westport, CT.: Greenwood Press, 1974).

55. *US v. GE*, 115 F. Supp. 835, Section VI, Section X. Rogers, “Development and Structure,” 124, 140. Rogers believed that “the lamp firms seem to take precautions not to involve themselves in [collusive price fixing],” but based his belief on “two anecdotes” rather than hard evidence.

had in the 1890s, that of a product vendor and occasional research partner. However, the economic, social, and political contexts within which electric lighting actor networks and policy makers operated had changed, and would change more in the new decade.

1960-1973: changes and choices

The embodiment of corporate America's vision of a technological utopia opened in April 1964 on 650 acres of Flushing Meadows, New York. Although the Bureau of International Expositions opposed this World's Fair, organizers moved forward with plans for an event they hoped would attract tourists and showcase technical marvels.[56] For GE and Westinghouse, the World's Fair served as a marketing opportunity akin to expositions as far back as Edison's day, although in this case it gave them a chance to rebuild public relations damaged by the bid rigging scandal. GE in particular, aided by the showmanship of Walt Disney, presented their newest inventions in a rationalist, linear view of history and technological development idealized as progress.[57] As with the introduction of fluorescents at the 1939 fairs, company managers now rushed their new tungsten halogen and metal halide lamps into public view.[58] As before, this ran counter to engineers' better judgment; although ongoing problems did keep high pressure sodium lamps out of the

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56. Joseph Tirella, *Tomorrow-land: the 1964-65 World's Fair and the Transformation of America* (Guilford, Ct: Lyons Press, 2014).

57. Tirella, *Tomorrow-land,* 53-55. The Carousel of Progress still presents Disney's positivist message in Orlando's Disney World today. Lighting is mentioned but only as one technology and GE's presence is subtly evident in the appliances displayed.

58. Mosby interview, 8 March 1996, for GE's use of special fixtures on the Unisphere to minimize the visual effect of failed tungsten halogen lamps. Ernest Martt said of metal halides: "We struggled to meet that deadline. The lamps were as green as could be, but they worked."

fair.[59] GE and Westinghouse illuminated the Fair with their most current products and presented a futurist vision of lighting tailored to user needs.

By the time the Fair opened though, the era of optimism had already started to wane. John F. Kennedy's assassination brought Lyndon Johnson to the presidency a few months before, and US involvement in the Vietnam War was growing. Johnson's support for civil rights and Great Society agenda of social programs began generating political opposition. The publication of *Silent Spring* in 1962 and *Unsafe At Any Speed* in 1965 raised questions about a technological utopia untainted by negative externalities and unintended consequences.[60] Rachel Carson's *Silent Spring* in particular sparked a discussion about technology's impact on environmental quality and fueled a growing actor network around that issue. Environmental considerations later led to federal policy interventions such as regulating mercury that directly affected the lighting industry.

Less than a month after the Fair closed, New Yorkers and about 20 million others learned a lesson about life without electric power when a malfunctioning relay resulted in a regional power failure.[61] The 1965 blackout exposed the larger problems within the electrical power industry and demonstrated the "technological stasis" that affected the central generating paradigm, as Richard Hirsh later observed. Long held technical and economic assumptions about the power industry failed, investors became wary as costs soared, especially for nuclear plants, and network participants began to reevaluate the

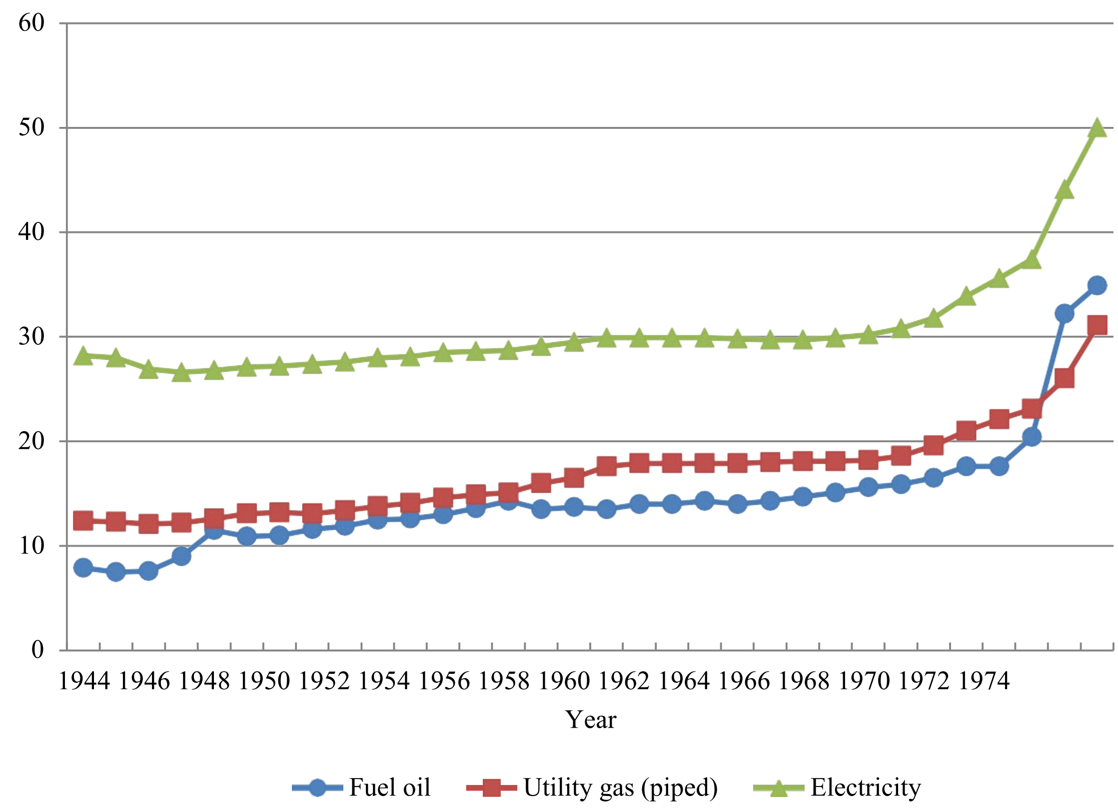
59. Co-inventor Louden could not recall any talk of using HPS at the Fair.

60. Bruce L. R. Smith, *American Science Policy Since World War II* (Washington, DC: The Brookings Institution, 1990), 73-77.

61. Nye, *When the Lights Went Out,* 84-94. Hirsh, *Technology*, 56-57, 132-133 for responses to the 1965 blackout by the power industry.

electric power infrastructure.[62] As demand for power grew, electricity prices reversed their traditional downward trend and began rising. As figure 7.3 shows, ordinary consumers began to see their electric bills rise, and as the decade advanced those rises grew more pronounced. Growing awareness of pollution from generating plants and public unease about proliferating high voltage transmission lines were examples of negative externalities

Figure 7.3: Consumer price index for all urban consumers, selected energy types, 1944-1975[63]



CPI: 1984 = 100.
This chart shows a slow rise in electricity prices during the 1950s that reversed decades of declining prices. Rises in fuel oil, utility gas, and electricity occur throughout the 1960s. That predates the 1973 oil embargo that added upward pressure to prices.

62. Hirsh, *Technology*, 1-11.

63. Source: Lindert, “Consumer price indexes,” Tables Cc25, Cc27, Cc29 in *HSUS*.

that affected the entire industry. Dealing with those issues would increasingly occupy regulators and utilities during the following decades, with renewed demand for high efficacy lamps as one consequence.

As federal regulators worked to understand the 1965 blackout, load building programs that promoted lighting demonstrated the persistence of utility perceptions that demand growth for their product was perpetual. In the mid-1960s, lamp makers offered special purchasing deals to electrical utilities in support of programs designed to sell more electricity. In 1966, for example, Westinghouse sold Baltimore Gas & Electric a batch of 150 W incandescent lamps in special BG&E 150th anniversary packages for free distribution to customers in commemoration of the company's founding. According to Westinghouse, if 80 percent of the customers replaced a 60 W lamp with the 150 W lamp BG&E would see a net revenue gain of almost $115,000 from increased electricity sales.[64] Continuation of load building programs of this type in the face of obvious system stress shows that utilities thought their problems were temporary and subject to solutions that would allow them to resume business as usual. For now, federal policy actors paid little attention to this type of lighting program and gave priority to promoting adequate power supplies and system reliability.

Federal involvement with lighting in the 1960s generally came in the form of disconnected policy initiatives that happened to include lighting. Sometimes these initiatives were designed to address real problems and sometimes they simply made for

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64. Westinghouse Electric Corporation Lamp Division, *Four Residential Load Building Programs*, form A-8010, February 1968, NMAH EC-LRF. Westinghouse, 150 W incandescent lamp in BG&E package, 1966, NMAH-EC, catalog number 1997.0387.19.

catchy headlines. An example of the former can be seen in state and local government applications for federal funding that supported infrastructure and urban renewal projects and included lighting upgrades as part of the proposal.[65] Typically these proposals had less to do with improving energy efficiency than with ideas about increasing public safety and making the "blighted" area more attractive.[66] An example of the symbolic use of light for political purposes appeared in highly publicized investigations of lamp life and labeling conducted between 1964 and 1967 by the Federal Trade Commission and the House Committee on Government Operations. The investigations stemmed from complaints that incandescent lamps burned out too quickly and that manufacturers, in the name of profit, refused to make longer life lamps readily available. While GE had certainly manipulated lamp life for the sake of profit (as noted in chapter 6), the results of the hearings indicated political theater along with differences in definitions and values.[67]

All parties accepted the technical constraint that longer life meant lower light output and lower efficacy. Producers sold 130 V lamps for hard-to-reach and hazardous places but only through specialty outlets that charged a premium price.[68] Placing a higher

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65. "Redevelopment agency asks for $4 million," *Hartford Courant* (16 February 1965): 8A, http://search.proquest.com, for one example. A search using the terms "federal government" and "lighting" in major newspapers archived on ProQuest returned reports of a variety of these proposals.

66. Thomas Buck, "Upgrading of Public Housing Slated at Cost of 27.5 Millions," *Chicago Tribune* (18 May 1968): N2, http://search.proquest.com. $2 million of this money was to be spent "for greater security [including] new exterior lighting of projects ... "

67. Committee on Government Operations, Government Activities Subcommittee, *The Short Life of the Electric Light Bulb*, H. R. Rep. No. 69-620 [*sic*] (October 1966) (Committee Print).

68. Ann Wood, "Brooks Blows Fuse; Bulbs to Last Longer," *Washington Post* (30 December 1967): C2. The headline refers to Rep. Jack Brooks, chair of the subcommittee who started the investigation. Using a 130 V incandescent lamp on a 120 V circuit can double the life but cuts the efficacy and light output by about 15%. This is an approximation; exact figures depend on the lamp size and rating.

value on convenience (and political points) than energy, the Committee decided that doubling life ratings would reduce lamp replacement costs enough to offset the higher energy costs, and directed that government lamp purchases be made accordingly. Aside from that, "the major result of the report was probably the promulgation in 1971 of the [FTC] Trade Rule Relating to Incandescent Lamps...that set forth labeling requirements for...lamps sold to consumers."[69] Lamp makers agreed to sell more lamps with long life ratings, though they warned that utilities would need to supply more electricity as a result, an admission that shows the growing divergence of lighting and power interests.

Westinghouse researchers seem to have sensed that circumstances were changing for engineers and business people alike. After a contentious meeting, one engineer recounted some history of the company's lighting work and then wrote:

> Here in 1969, after all this concerted effort,...,our most efficient lamp...is little better than a 25% efficient device ....With lower profits on all time high sales as reported this norming [*sic*],...,our costs are too high and our price realization disappointingly inadequate. <u>Do we need any further challenge</u>?[70]

Concerns about slowly rising electricity prices spurred new research to meet a potential demand for energy efficient lamps not only at Westinghouse but other lamp makers as well. GE's John Anderson began working on a small fluorescent lamp without electrodes, while his colleague John Campbell designed a small fluorescent lamp that used advanced electronic switching. William Roche at Westinghouse patented a small screw-in

69. Rogers, "Development and Structure," 33, 137; as of 1980, "The effect ofthe rule has not yet been ascertained."

70. John W. McNall, "Historical Notes on the Lamp Division and Its Technical Activities," (unpublished memo: Westinghouse Research Laboratories, 1969): 7, in NMAH EC-LRC, emphasis in original.

fluorescent lamp. Tungsten halogen co-inventor Fred Mosby patented a lamp for general residential use that contained a small halogen capsule, and then tried to convince managers to put it on the market.[71] These experimental efforts resulted in no new products at that time, but did begin building a knowledge base that the companies later tapped when demand for efficient residential lamps could no longer be ignored.

Although this renewal of efficacy oriented research would play a role in the 1970s and beyond, a quest for higher efficacy did not drive development of GE's three successful new lamps: tungsten halogen, metal halide and high pressure sodium. Though all three achieved market success and ultimately played significant roles in subsequent federal policies, they addressed some problems while simultaneously raising others. For example, adopting metal halide and HPS lamps wrought profound effects on exterior environments.[72] Both types gave equal or better color and higher efficacy than older mercury vapor lamps, making exterior lighting more energy efficient, but they encouraged more outdoor installations. This provides an example of an unintended consequence called the rebound effect. Even though individual lamps were more efficient than earlier models, using more of them raised total energy consumption.[73] As urban nightscapes became lost in a haze of sky glow from reflected and wasted light, a new set of actors began to make

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71. John M. Anderson, "Electrodeless Fluorescent Lamps Excited by Solenoidal Electric Fields," *Illuminating Engineering* 64, no. 4 (April 1969): 236-244. John H. Campbell, Fluorescent Light Source with a Plurality of Sequentially Energized Electrodes, US Patent No. 3,609,436, filed 21 April 1971 and issued 28 September 1971. William J. Roche, Integrated Fluorescent Lamp Unit, US Patent No. 3,753,036, filed 3 May 1971 and issued 14 August 1973. Frederick A. Mosby, Electric Lamp and Support, US Patent 3,243,634, filed 23 April 1963 and issued 29 March 1966.

72. Kate Bolton, "The Great Awakening of the Night: Lighting America's Streets," *Landscape* 23, no. 3 (1979): 41-47.

73. Lee Schippera and Michael Grubb, "On the rebound? Feedback between energy intensities and energy uses in IEA countries," *Energy Policy* 28, no. 6–7 (June 2000): 367–388.

their presence felt in federal policy circles. Environmentalists, aided by astronomers, voiced concern about a negative externality they called light pollution.[74] Questions about lighting's environmental impact joined growing concern about energy efficiency, starting debates about how lighting policies might address these issues.

Environmental politics and policies in general gained strength at the federal level during this period.[75] In reviewing this era, Bruce Smith identified a "change in attitude toward technology [that marked a clear distinction of] the second from the first phase of postwar science policy."[76] The first phase consisted of the optimism apparent at the 1964 World's Fair. The second phase reflected recognition of the increasingly obvious side effects, like light pollution. Federal concern with conserving resources traced a lineage to Theodore Roosevelt's administration, but the new environmental activism took on added urgency. Some products could clearly harm the environment, DDT being a prime example as Carson showed in *Silent Spring*, and federal regulators began to take an adversarial and skeptical approach to industrial claims about product safety and effects.[77] The obvious problems of atmospheric smog, rivers that caught fire, and growing piles of solid wastes became so obnoxious that environmental advocates could garner popular support for a series of new laws. These included the National Environmental Policy Act, the Clean Air Act, and the Clean Water Act. The first Earth Day and establishment of the Environmental

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74. There is a rich literature dealing with light pollution. A recent overview is, W. Scott Kardel, "Into the Dark: Reclaiming the Night Skies," *Planetary Report* 32, no. 2 (June 2012): 7-11.

75. Hays, *The History of Environmental Politics*.

76. Smith, *American Science Policy*, 98.

77. Anthony J. Nownes, "Interest Groups and the Regulation of Pesticides: Congress, Coalitions, and Closure," *Policy Sciences* 24, no. 1 (1991): 1-18.

Protection Agency (EPA) in 1970 by "policy entrepreneurs within Congress" also served to bring new policy actors into the mix.[78] Though light pollution and the effects of lamp manufacturing did not yet generate as much discussion as other issues such as chemical and radiation hazards, these new laws and actor networks laid the foundation for an entire new area of lighting policy.

Transition period: setting the stage

In 1949, as he completed his in-depth analysis, Arthur Bright wrote: "My own conclusion is that General Electric's control over the lamp industry has not provided an ideal environment for the rapid development and introduction of major new *light sources*."[79] Bright spent years studying an industry he felt provided, "an interesting case of modified competition, based on extensive cross-licensing agreements under a highly developed patent structure."[80] He died in 1953 but would doubtless have interpreted the new lamps of the 1950s and 1960s as evidence in favor of his argument. GE's strengths remained evident after the consent decree when the promise of real competition forced them into action. Only they pursued early commercialization of all three new sources simultaneously. Sylvania chose to focus on metal halides while Westinghouse pursued HPS development.[81] Only later did those companies offer full product lines. The increase

78. Bruce L. R. Smith, *The Advisers: Scientists in the Policy Process* (Washington, DC: Brookings Institution, 1990), 74.

79. Bright, *Electric Lamp Industry*, 456, emphasis in original.

80. Bright and MacLaurin, "Economic Factors," 429.

81. Louden, Reiling, and Waymouth interviews. Also Gerald Meiling, telephone conversation with author, 4 February 1997. GE pushed metal halide as a direct replacement for mercury vapor lamps while HPS was sold

in research activity and introduction of significant new products constituted the private sector's response to the federal policy that reshaped the industry (as per the third research question). The plethora of new lamps and improved older lamps combined to give lighting designers many more tools to uses, to the point that "a definitive guide [to which source should be used] cannot be provided." The range of capabilities and tradeoffs left such decisions to "the personal preference of the designer and the economics involved."[82]

Not that all new research in this era immediately resulted in profitable products. Westinghouse in particular pushed a line of solid state lamps based on electroluminescent technology that succeeded in niche applications but never found broader markets. Sylvania and GE pursued electroluminescents to the same ends.[83] Like the other new lamps of this era, electroluminescent lamps took advantage of materials research and scientific advances made during WWII, but in this case intractable difficulties kept energy efficiency low. Another type of solid state lamp, GE's light emitting diodes (LEDs), likewise served in niche applications in the years following its invention. Commercially introduced by GE in 1969, other companies like Texas Instruments and Hewlett Packard adopted colored LEDs for use as indicator lamps and alphanumeric displays. Only later, after those and other companies outside the lighting industry invested more heavily in the technology, would

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as a new system. Sylvania sold metal halide as a new system and later offered HPS as a direct mercury lamp replacement. Westinghouse followed GE in pushing HPS as a new system but (with Corning) designed a lamp using a different arc tube material to avoid GE patents.

82. Light Sources Committee, Illuminating Engineering Society, "Choosing Light Sources for General Lighting," *Illuminating Engineering* 62, no. 5 (May 1967): 320.

83. McNall, "Historical Notes," reported EL research started at Westinghouse in 1949 and reached "peak effort" in 1957-58. Elmer C. Payne, Eric L. Mager, and Charles W. Jerome, "Electroluminescence - A New Method of Producing Light," *Illuminating Engineering* 45, no. 11 (November 1950): 688-693, for Sylvania. Mary S. Jaffe, Flexible Electroluminescent Laminated Panel, US Patent 2,774,004, filed 8 April 1953 and issued 11 December 1956, for GE..

LEDs become the white light product that revolutionized the lighting industry.

Improved efficacy had no direct effect on federal policy during the transition period (as per the first research question), and federal attention to lighting largely waned in the immediate postwar era (the second research question). After addressing market distortions caused by the Phoebus cartel and GE's de facto monopoly, federal policy makers turned their attention to larger issues of electricity affordability and reliability, rather than this one application of electric power. Beyond that, simmering issues of civil rights and workers' prerogatives remained to be dealt with, as people struggled to reconcile stated American ideals with deeply-held beliefs about social, cultural, and economic norms. Add in Cold War fears and a hot war in Vietnam, and federal agendas had little room for issues identified as low priority conditions. As John Kingdon points out, a condition changes to a problem when people decide to address whatever the subject may be, and that decision can occur for reasons external to the subject itself.

The decades-old condition of low efficacy lamps became redefined as a problem when emerging concerns about environmental quality added to urgent concerns about energy supplies, and put electric lighting back on federal agendas.[84] As early as the summer of 1971, the Office of Emergency Preparedness warned about the need to conserve electricity in the face of possible power shortages. Announcing a voluntary campaign to save energy, OEP's director George A. Lincoln offered advice that could have been written in 1917 or 1941: "We could have less ostentatious and wasteful lighting in many places."[85] The situation did not yet seem that dire, although (as seen in figure 7.3, above) energy

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84. Kingdon, *Agendas*, 109-110.

85. "US Opens Campaign to Save Energy," *New York Times* (18 May 1971): 23, http://search.proquest .com.

prices in general had been rising for over a decade. When that view changed two years later in 1973, the postwar burst of lighting innovation provided near-term policy alternatives and a starting point for another round of long term federal action. However this time, though the immediate crisis soon passed, federal action never receded accordingly. The political and economic contexts within which policy makers worked had shifted enough to allow a sustained policy effort to commence. The four decades that followed represented a new period in electric lighting policy marked by coordination between agencies, enrollment (not always willingly) of private sector actors, enforcement of a particular definition of lighting efficiency, and accommodation of wildly alternating political agendas.

Chapter Eight: Lighting an Energy Crisis, 1973-1990

When President Nixon stood on the White House steps and shut off the lights, the world of lighting changed at that date.

—Gilbert Reiling, 1 March 1996[1]

The second major period of federal lighting interventions began in 1973. After the chaos of the 1960s, many Americans lost confidence in formerly respected social, political, and technical institutions. Divisions over core values came to the fore as civil rights actions and the divisive Vietnam War continued to set people against each other, sometimes violently. Richard Nixon's abrupt resignation from the presidency in 1974 exemplified political turmoil that roiled both major parties. The memory of moon-walking astronauts still stirred pride and Edison's lamp would soon serve in the nation's bicentennial as a symbol of American inventiveness.[2] But as the decade proceeded, more people came to view federal policy as inadequate to the task of addressing complicated problems, such as ensuring energy supplies and correcting electrical system failures bound up in competing values. Pollution, unintended consequences, and inequitable distribution of costs and benefits led some to question how technology was used to solve problems. They sought approaches that minimized environmental impact and encouraged decentralized decision making. Others pursued market-based solutions, rather than government interventions.

1. Gilbert Reiling, interview, 1 March 1996, NMAH EC-LRF.

2. Baltimore Museum of Industry, Hugh F. Hicks Lighting Collection, Archives of the Mt. Vernon Museum of Incandescent Lighting, series 4, box A, folder 7, "Loans: Freedom Train & Moscow 1976."

An unwelcome jolt that defined the decade came in October 1973 when an international cartel, the Organization of the Petroleum Exporting Countries (OPEC), embargoed oil shipments to the US. Increased demand, outdated regulations, and stagnant domestic production made the US dependent on imported oil.[3] As oil prices soared, motorists lined-up to buy gasoline, adding to a sense of national dysfunction. US utilities generated about 16 percent of the nation's electricity with oil and higher oil prices accelerated rising electricity rates.[4] Figure 8.1 shows oil and electricity prices spiking together, along with the upward trend in electricity prices throughout this period. Rising electricity prices prompted policy interventions that included lighting restrictions. In late November, Nixon asked Americans to curtail Christmas lighting and Congress to approve "the elimination of all [outdoor] commercial lighting except that which identifies places of business."[5] As metal halide inventor Gilbert Reiling recalled in the above quote, Nixon's symbolic action conveyed a clear message of national crisis.

Many lighting professionals saw the curtailment of exterior lighting as an unwelcome step backwards.[6] Some treated the problem as temporary but others saw basic issues as longer term and called for new energy efficient products and designs. That task was complicated by tensions within the industry over appropriate standards as well as core definitions of lighting quality. Executives of one company accepted that government

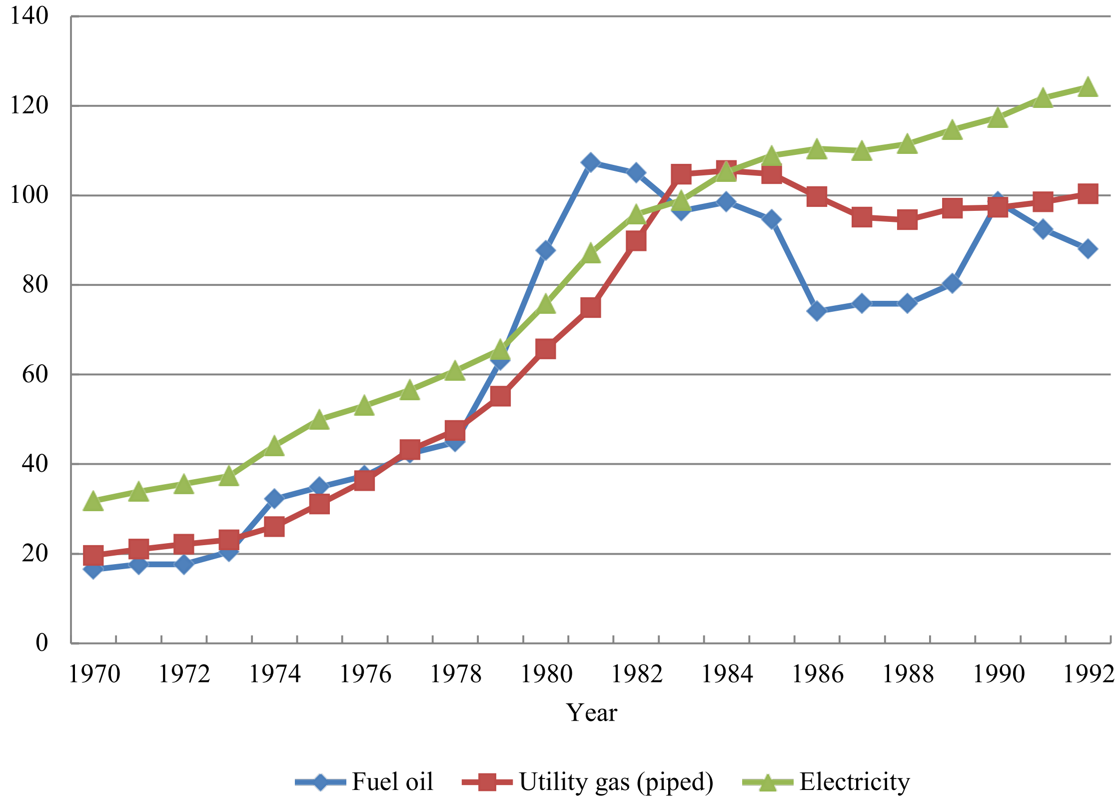
3. Meg Jacobs, *Panic at the Pump: The Energy Crisis and the Transformation of American Politics in the 1970s* (New York: Hill and Wang, 2016), 4-5.

4. Energy Information Agency, *Annual Energy Review 1996* (table 8.4, "Electric Utility Net Generation of Electricity by Prime Mover, 1949-1996"), 233.

5. Richard Nixon, "Address to the Nation About National Energy Policy," 25 November 1973. The American Presidency Project, http://www.presidency.ucsb.edu.

6. "Energy Notes," *Lighting Design & Applications* 3, no. 12 (December 1973): 5.

Figure 8.1: Consumer price index for all urban consumers, selected energy types, 1970-1992[7]



CPI: 1984 = 100.
A spike in oil prices in 1973 and another in 1978 stem from OPEC embargoes. Policy changes during the Reagan years stabilized oil and gas prices but electricity continued rising for other reasons as generators abandoned oil in favor of coal and uranium fuels.

intervention would probably be needed to achieve results. "Any expectations that material progress in energy conservation will accrue from voluntary efforts on the part of the merchant, the landlord, or the consumer will be doomed to failure or at best to mediocrity."[8] That stance would have been familiar to government and industry actors who had failed in attempts to restrict lighting use during both world wars. Unlike those

7. Source: Lindert, "Consumer price indexes," Tables Cc25, Cc27, Cc29 in *HSUS*.

8. Excel Energy Paper #2, May 1977, 2, Lighting Program Files, Department of Energy, Washington, D.C. (Hereafter cited as LPF-DOE.)

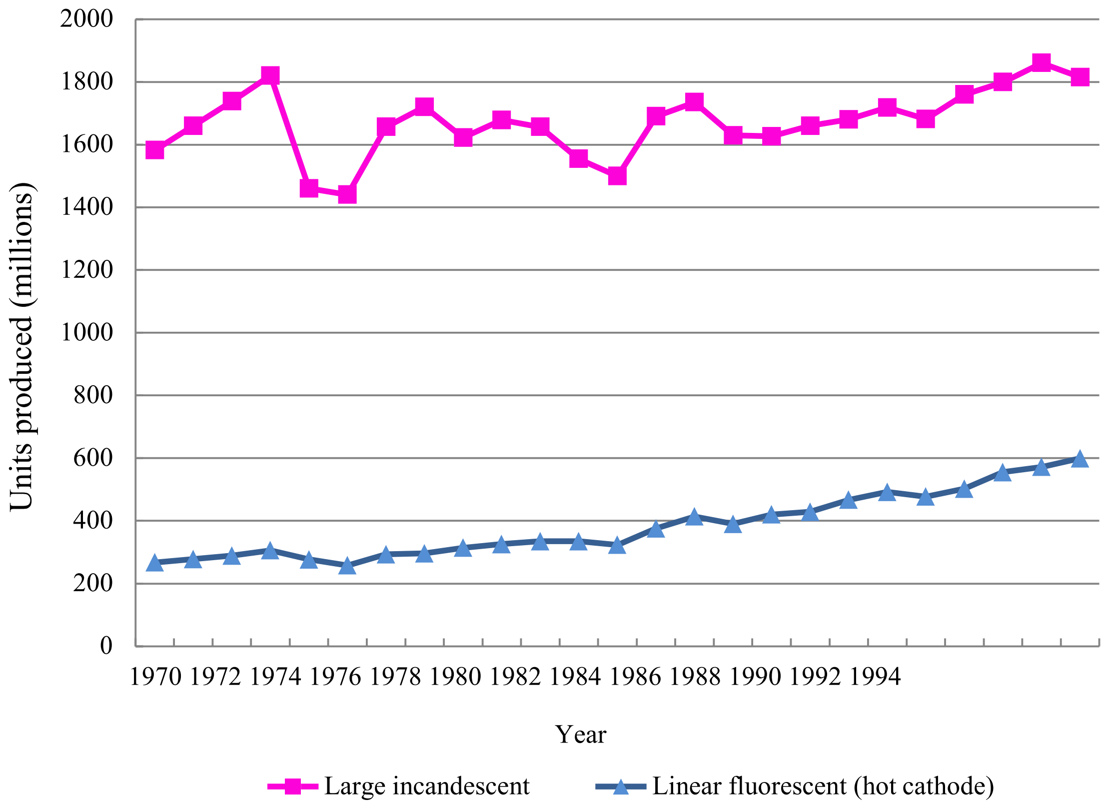
instances however, the political and economic contexts of the nation had fundamentally changed, enabling a different approach to lighting policy. Federal actors took a new look and rather than try to enforce restrictions, chose to direct public funds to a sustained research and development effort to advance efficient lighting. The Department of Energy and the private sector cooperated on programs that stimulated efficacy increases in lamps and energy conscious lighting designs. Persuading consumers to look at life cycle costs rather than lamp purchase prices would be critical, so initiatives included education and market preparation. Some parts of the subsequent efforts succeeded, other parts failed, and still other parts carried over into a new century. Regardless, the federal lighting programs helped move the industry to a path that emphasized the importance of energy efficient lighting devices and designs.

Technology: inventing for a new era

As seen in figure 8.2, production of incandescent lamps dived in the immediate aftermath of the embargo as people yanked lamps from sockets and governments passed ordinances that cut outdoor lighting.[9] Producers responded to the sudden demand for energy efficient products by taking known but previously uneconomic steps that required little new equipment. For example, they added krypton gas to incandescent and fluorescent lamps, a technique long known to improve efficacy but not worth the cost in a time oflow

9. Robert Rawitch and Celeste Durant, "How California Cities Are Responding to Energy Shortages," *Los Angeles Times* (21 December 1973): A2, http://search.proquest.com, for cutbacks in that state. Richard Nixon, "Address to the Nation About Policies To Deal With the Energy Shortages," 7 November 1973, American Presidency Project, http://www.presidency.ucsb.edu. Nixon mentioned lighting only briefly in his Project Independence address.

Figure 8.2: Production of incandescent and fluorescent lamps, 1970-1994[10]



Incandescent and fluorescent lamp production declined in the wake of the 1973 oil embargo, though the former declined more sharply. Production of fluorescents nearly tripled during this period while incandescent production reached an approximate plateau after more than doubling in the preceding thirty years (figure 7.2).

electricity prices. As noted in chapter seven, two makers already sold krypton-filled incandescent lamps for longer life and only needed to alter their packaging to emphasize high efficacy.[11] Another fast response, phantom tubes, emitted no light but matched the electrical characteristics of a fluorescent tube. Replacing one fluorescent tube with a

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10. Source: Atack and Bateman, "Physical output of selected manufactured products: 1860-1997," Tables Dd412\30, 422\30 in *Historical Statistics of the United States*. Data for both tables stops in 1994.

11. George S. Evans, "Fluorescent lamps, krypton, and the conservation of energy," *Lighting Design & Application* 4, no. 7 (July 1974): 10-13.

phantom tube in a two-tube luminaire meant that the user could cut energy use by almost half while keeping the luminaire in service.[12]

Responding quickly to market demand, some actions backfired. As described in chapter six, fluorescent lamps need a ballast to control current flow and a starter to overcome high initial resistance; changing one component alters the electrical interactions within that system. When manufacturers introduced krypton-filled 35 W fluorescent tubes as a direct replacement for 40 W tubes, the altered electrical characteristics caused lower lumen output, starting problems, and ballast failures.[13] Manufacturers hurriedly made a completely new product, even as the effort was criticized for perpetuating light levels seen as too high.[14] As one architect complained, a “20 percent [energy] reduction is advanced as the answer to systems that are 60 percent overdesigned.”[15] For policy makers, the failures underlined the need for special care in specifying technical details in their alternatives.

As a second step in responding to the demand for efficiency, producers intensified research on new devices such as compact fluorescent lamps (CFLs) that would take time to create. Uncooperative physics and a lack of suitable materials had thwarted engineers’

12. Duro-Test model 420-RS “Enersave Pow-R-Shunt” Fluorescent Lamp Substitute, ca. 1982, NMAH-EC, catalog number 1997.0062.15.

13. Edward E. Hammer, David H. Riesland, Quentin D. Dobras, “Improved 35-W Low Energy Lamp-Ballast System,” *Journal of the Illuminating Engineering Society* 9, no. 3 (April 1980): 181-187. George V. Preston III, “A T-10 Energy Saving Rapid Start Fluorescent Lamp,” *Journal of the Illuminating Engineering Society* 11, no. 7 (July 1982), 200-203. Brooke Stauffer, “Low-wattage fluorescent lamps: a low first cost approach to energy conservation,” *Lighting Design & Applications* 9 no. 7 (July 1980), for GE’s Watt-Miser & Watt-Miser II, Westinghouse’s Econ-O-Watt & Econ-O-White and Sylvania’s Super Saver & Super Saver II.

14. GE’s Watt-Miser appeared in their January 1975 Form 9200 lamp catalog; the 1979 catalog added the Watt-Miser II. By 1982 the hardware store in which I worked could no longer obtain the original product.

15. Richard G. Stein, *Architecture and Energy* (Garden City, NY: Anchor Press, 1977), 290.

attempts to shorten fluorescent lamps and only a few special products existed.[16] Short lamps lacked the most important feature needed for high efficacy in regular tubes, a long arc path between electrodes. To lengthen arc paths, engineers typically used elaborate glass envelopes that would require expensive new production equipment. Work was just beginning on miniaturizing electronic components for ballasts and starters. Phosphor coatings inside thin tubes darkened very quickly due to their close proximity to the electrical discharge. Scientists at Philips working on a new red phosphor for color television tubes solved that part of the problem with a rare-earth aluminate mixture that could tolerate high energy flux while converting ultraviolet to visible light.[17] An example of technology cross-pollination, rare-earth phosphors met demands in two huge markets, television and lighting, and could be adapted to existing production machinery. They represented a critical breakthrough in making a successful CFL.

Lamps designed to retrofit exterior installations received attention given Nixon's symbolic targeting of outdoor lighting. Many municipalities used mercury vapor street lamps little changed from the 1930s, and higher energy costs made these older systems increasingly expensive to operate. Industrial and street lighting customers accepted mercury vapor's low efficacy and deficient color due to the low purchase price rather than switch to more expensive metal halide. But a 1974 report noted:

> a recent major development [in metal halide] has been interchangeability

16. General Electric flat "Mazda F" lamp, ca. 1942, NMAH-EC, catalog number 1997.0388.45, is a short tube used to backlight aircraft instrument panels during WWII.

17. A. Bril, W.L. Wanmaker, C.D.J.C. de Laat, "Fluorescent Properties of Red-Emitting Europium Activated Phosphors with Cathode Ray Excitation," *Journal of the Electrochemical Society* 112, no. 1 (January 1965), 111. J.M.P.J. Verstegen, "A Survey of a Group of Phosphors, Based on Hexagonal Aluminate and Gallate Host Lattices." *Journal of the Electrochemical Society* 121, no. 12 (December 1974), 1623.

> with some types of mercury systems. This has improved the economics of utilizing this source as well as providing the user with the opportunity to upgrade the lighting system, *perhaps as much as doubling the initial lumination level with no increase in power consumption*.[18]

As seen in the quote, even immediately after the embargo many people in the industry did not speak in terms of reducing power consumption, rather the goal remained maintaining or increasing light levels. "Don't cut back lighting...switch to energy saving products and lighting techniques," declared one GE marketer who then detailed "nine ways to cut costs without cutting light."[19] This language reflected the ongoing controversy within the lighting profession about lighting levels, as discussed later in this chapter.[20]

The energy situation gave GE's troubled high pressure sodium lamp a much needed boost when some industrial and municipal users adopted that product to replace their older street lighting.[21] The golden-yellow color seemed less objectionable than low pressure sodium's monochromatic yellow despite LPS's higher efficacy; though LPS did make inroads in the US market.[22] Westinghouse stepped up sales efforts on HPS lamps, and Sylvania introduced a retrofit product.[23] Philips improved the already high efficacy of their LPS product while developing HPS. The emphasis on energy efficiency accelerated

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18. Terry K. McGowan, "Sources—Today and Tomorrow," *Lighting Design and Application* 4, no. 1 (January 1974): 25-26. Emphasis mine.

19. Henry G. Williams, "The How and Watt of Energy-Efficient Lighting," reprint from *Buildings Magazine* (February 1977), in NMAH EC-LRF.

20. Stein, *Architecture*, 142-153.

21. Bea Tusiani, "Lilco Getting Out of the Street-Lighting Business," *New York Times* (2 October 1988): 2, http://search.proquest.com, for one example of the shift.

22. In 1984, the author worked in a Rite Aid store wherein the only lamp on after closing was a LPS security light. The stark yellow light illuminated the entire store while reducing energy consumption.

23. John Waymouth, telephone conversation with author, 20 March 1996.

work on lower wattage HPS and by 1975, 70 to 250 W lamps were in production. The smaller lamps worked well in a new street light design that recessed the lamp into the fixture. Without a protruding glass cover, the unit emitted no light above the horizontal. Called a full-cutoff fixture, the design minimized waste by directing light downward and, using smaller lamps, saved energy while also reducing light pollution.

As seen in table 8.1, manufacturers improved efficacy in almost all product lines during this period. They also instituted process changes during this time such as adopting

Table 8.1: Lamp efficacy comparison (lpW), 1970-1990[24]

Date	Regular inc.	Tungsten halogen	Mercury vapor*	Metal halide	Linear flu.	CFL	LPS	HPS	LED
1970	14.25	19.9	44.5	67	68.5		157	107	3
1975	14.25	21.2	47.75	68	81.4		183	112.5	3
1980	14.5	21.2	40.5	75	79		183	112.5	3
1985	15.38**	27.14	37.5	80	86.25	40	183	112.5	6
1990	15.38	27.14	43.75	80	87.5	46.6	183	112.5	20

During the 1970s and 1980s, lamp makers offered higher efficacy versions of almost all products and continued improving. Compact fluorescent lamps entered the market in 1981 with more than twice the efficacy of the incandescent lamps they were meant to replace. The examples in this table are representative, selected to show efficacy improvements. An attempt was made to keep parameters such as wattage equivalent within each type, but changes in makers' product offerings and inconsistent data between manufacturers make comparisons approximate.
* Rating fluctuations reflect changing test standards. **Krypton-filled lamp.

computer technology. Lamp engineers in labs used automated test equipment. Designers used software that helped them visualize spaces and determine appropriate light levels. Marketing personnel digitized product comparisons that included energy saving vs.

24. Source: product catalogs, NMAH EC-LRF. Values cited are representative examples.

traditional lighting devices.[25] A few people recognized that "miniature circuits" could make automated lighting controls, "reasonable and relatively inexpensive. .. [and ultimately] could be responsible for saving millions of kilowatt hours of energy."[26]

Effects of the energy crisis on lighting technology varied from creating new markets for existing products to spurring new inventions and techniques that helped to fundamentally alter path dependencies. Much of this era's lighting technology already existed as niche products (tungsten halogens, for example) or previously uneconomical solutions to low priority problems (krypton additives). Some products may ultimately have been adopted to meet concerns aside from energy conservation (full-cutoff fixtures also cut light pollution). Certainly the question of how much light was too much had been debated for years, and the lighting industry was not alone in adopting computers. As one might expect, altering long travelled paths would not happen quickly but take years to accomplish. Federal policy helped lamp makers with several products by providing research funds, market studies, and early purchases, however. In the case of new ballasts for fluorescent lamps (detailed below), it played a critical role in creating the product. As per John Kingdon's model of policy making, these different products and approaches represented alternatives floating along in the policy stream waiting for a window to open. War in the Middle East threw open that window.

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25. General Electric Lighting Co., "Data Light I" and "Retro" software, ca. 1984, NMAH EC-LRF. The former program helped "GE lighting specifiers and users" adopt new MR-16 incandescent lamps; the latter was an "economic analysis" program for use in designing a system retrofit for higher efficiency.

26. Stein, *Architecture*, 153.

1970s: shocks to the systems

The energy crisis provided a good example of the federal government's limited ability to prepare people for slowly developing situations. In late 1973, a coalition of Arab states attacked Israel, starting the Yom Kippur War. The oil producing nations in the region embargoed shipments to countries that supported Israel, including the US. Oil prices spiked and Americans perceived a sudden crisis. By then however, as seen in chapter seven, energy costs had been rising for over a decade, while US oil consumption outpaced domestic supplies.[27] Official concern about energy rose to the Presidential level as early as 1971, indicating that policy makers recognized the seriousness of the issue and were developing alternatives.[28] Yet they failed to capture people's attention or lay the groundwork for a clear response, so the embargo's suddenness surprised average citizens and seemed to catch officials off-guard.[29] The latter scrambled to be seen as taking action and that included reviving a well-worn symbolic policy—turn off electric lights and call for dousing "wasteful" exterior lighting. As in both world wars, leaders called for patriotic cooperation with voluntary lighting restrictions but rejected mandatory measures, and as before many people resisted symbolic acts perceived as an "absurdity."[30]

Using lighting policy to advance energy conservation proved no more effective in

27. Jacobs, *Panic*.

28. Richard M. Nixon, "Special Message to the Congress on Energy Resources," *Public Papers of the Presidents: Richard M. Nixon, 1971*, (University of California, Santa Barbara, American Presidencies Project, June 4, 1971); Richard M. Nixon, "Special Message to the Congress on Energy Policy," *Public Papers of the Presidents: Richard M. Nixon, 1973*, (University of California, Santa Barbara, American Presidencies Project, April 18, 1973). Both at http://www.presidency.ucsb.edu.

29. Nye, *Consuming Power*, 220.

30. Jack Mabley, "Dark Yule: Stupid by any Measurement," *Chicago Tribune* (9 December 1973): 4, http://search.proquest.com.

1974 than it had in the earlier crises. Congress debated a federal energy tax, sponsored educational projects to raise awareness about energy conservation, and established the Federal Energy Administration (FEA).[31] Many citizens did cooperate, especially cost-conscious business people and municipal authorities. A survey of municipalities in California reported that all but one (citing a high crime rate) reduced outdoor lighting.[32] FEA's projects were hindered however when several directors were fired for advocating conservation mandates, and also by the general commotion surrounding Nixon's resignation.[33] Industry success in raising light levels became embarrassingly evident when photographers covering an FEA initiative to voluntarily lower levels to 50 foot-candles reported that their meters indicated 100 fc in the room.[34] Even seeming victories for some policy makers could work at cross-purposes for others. In 1973, GE lost its fight to dictate retail lamp prices and those prices dropped by as much as 50 percent, making it more difficult to persuade users to buy expensive energy efficient lamps.[35]

In another similarity with earlier war experiences, the prospect of a 1974 coal strike

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31. "Excess Energy Use Tax Studied," *Atlanta Constitution* (23 December 1973): 4A, http://search.proquest.com.

32. Rawitch and Durant, "How California Cities ..."

33. William Simon took over FEA on 4 December 1973 when John Love "was forced out because he advocated too hard a line in dealing with the energy crisis." James Elsener, "Profile: The Things That Bill Simon Says," *Chicago Tribune* (6 January 1974): A9, http://search.proquest.com. Simon's successor James Sawhill lost the post for similar reasons. Thomas O'Toole, "Energy 'Blueprint' Urges Mandatory Cut in Demand," *Washington Post* (13 November 1974): A3, http://search.proquest.com.

34. Ken Botwright, "US Warns, Asks 5000 N.E. Firms to Reduce Heat, Lights," *Boston Globe* (19 November 1974): 3, http://search.proquest.com.

35. United States v. General Electric Company, 358 F. Supp. 731 (S.D.N.Y. 1973), https://law.justia.com. The form 9200 Large Lamp Catalogs (NMAH EC_LRF) document GE's attempts to keep up with a price freeze and the court settlement and by 1975 pricing information was deleted. Gerald Gold, "G.E. Light-Bulb Price Falls Sharply," *New York Times* (9 May 1974): 53, for 50% price cut. "General Electric Ends Court Plea, And Agency System of Lighting Bulb Sa1es," *Wall Street Journal* (22 April 1974): 22.

led to calls for voluntary holiday lighting cuts that year.[36] This pointed to another, larger problem bound up with increasing US energy supplies, the stress on the nation's electric power infrastructure. As figure 8.3 shows, US dependence on electric power continued the rise seen in previous decades. The Nixon administration supported converting oil-fired power plants to coal, building an oil pipeline across Alaska along with more nuclear plants in a commitment to increasing energy supplies rather than using energy more efficiently.[37] To Nixon and many others conservation meant sacrifice, reduced economic growth, and lower living standards.[38] The idea of doing more with less did not enter official conversations though that idea received attention from people concerned with troubles apparent in the electric power industry such as air pollution and proliferating transmission lines. Recognition of negative externalities that affected the entire electrical infrastructure led to calls for a new approach by those in the Appropriate Technology Movement.[39]

Physicist Amory Lovins wrote of a "soft path" for energy issues in an influential 1976 paper that recommended, in part, locating small generators near their loads. That would encourage modular plant designs better suited to meet local needs, as well as requiring less capital investment than large power plants, whatever their fuel. Lovins's soft path also called for conservation of resources and high efficiency electric devices,

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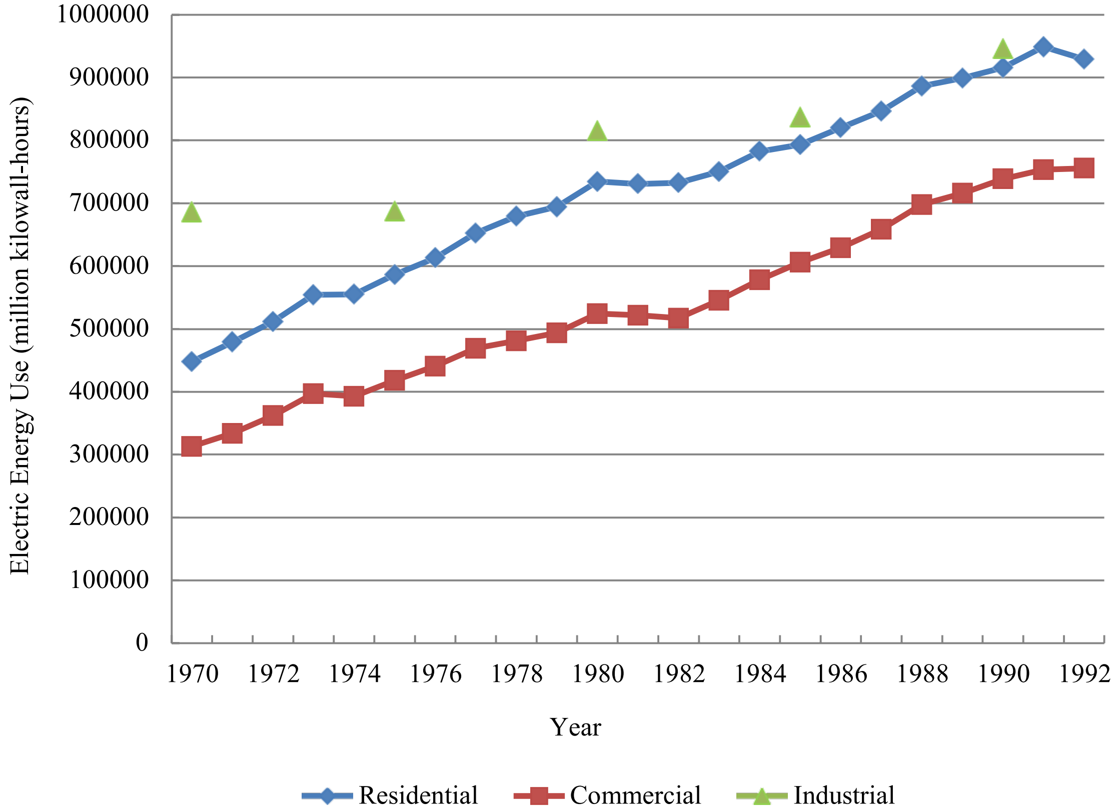
36. Chicago Tribune Press Service, "White House Issues Warning to Coal Miners, Firms," *Chicago Tribune* (29 September 1974): 40, http://search.proquest.com. Sharon Bailey, "FEA Is Requesting Cutbacks on Energy," *Atlanta Constitution* (19 November 1974): 2C, http://search.proquest.com.

37. Nixon, Special Message, April 18, 1973.

38. Robert Stobaugh and Daniel Yergin, eds., *Energy Future: Report of the Energy Project at the Harvard Business School* (New York, N.Y.: Random House, 1979), 136-145.

39. Carroll Pursell, "The Rise and Fall of the Appropriate Technology Movement in the United States, 1965-1985," *Technology and Culture* 34, no. 3 (July 1993): 629-637.

Figure 8.3: Electric energy use in the United States, by sector, 1970-1992[40]



Electrical energy use continued trending upward throughout the 1970s and 1980s.
Note: HSUS data for the Industrial sector stops in 1970 but continues in the Annual Energy Review at 5-year intervals. HSUS and AER data do not match exactly but are close.

including lamps and luminaires.[41] Unlike many in industry and the administration, Lovins and his supporters did not perceive the ongoing energy crisis as a temporary problem of tight supplies but rather as a long term problem of unrestrained growth that would require long term solutions.

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40. Source: Gavin Wright, "Electrical energy–sales and use: 1902–2000," Table Db229-231 in *Historical Statistics of the* United States. US Department of Energy, Energy Information Agency, "Electricity End Use," table 7.6 in *Annual Energy Review 2016* (January 2016), https://www.eia.gov.

41. Amory B. Lovins, "Energy Strategy, The Road Not Taken?" *Foreign Affairs* 55 (October 1976): 65. Anthony J. Parisi, "'Soft' Energy, Hard Choices," *New York Times* (16 October 1977): 123, http://search.proquest.com.

While the private sector accelerated research into efficient lighting, the efforts received only modest support from managers convinced that high energy prices were a temporary inconvenience. Many US lighting professionals remained wedded to an idea of high light levels, muting the call for efficient designs like task-lighting that could reduce electrical consumption. The Energy Reorganization Act of 1974 provided an opportunity to promote lighting research at the federal level with the creation of the Energy Research and Development Administration (ERDA). A Constitutional rationale for federal support of research and development programs lay in the private sector's inability or refusal to support projects "to promote the general welfare." Though clearly intended to emphasize energy production, ERDA's authorizing language included the enabling statement that:

> The Congress hereby declares that the general welfare and the common defense and security require effective action to develop, and *increase the efficiency and reliability of use of*, all energy sources to meet the needs of present and future generations, to increase the productivity of the national economy and strengthen its position in regard to international trade, to make the Nation self-sufficient in energy, to advance the goals of restoring, protecting, and enhancing environmental quality, and to assure public health and safety.[42]

ERDA identified lighting as one area where efficiency could be increased and established research programs that included the 1976 "Windows and Lighting" project.[43]

ERDA undertook two major electric lighting projects as part of this effort. Both

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42. Energy Reorganization Act of 1974, Pub. L. No. 93-438, 88 Stat. 1233, (1974), Title I, Sec. 2(a). Emphasis mine. Richard G. Hewlett and Bruce J. Dierenfield, *The Federal Role and Activities in Energy Research and Development, 1946-1980: An Historical Summary* (Springfield, VA: National Technical Information Service, 1983), 102.

43. Lawrence Berkeley Laboratory, "A National Plan for Energy Conservation Research and Development Related to Windows and Lighting," 27 August 1976, Energy Research and Development Administration, 4, 23, 31 for quotes, LPF-DOE. The windows project promoted use of daylighting, important but not electric and therefore outside the scope of this dissertation.

projects affected major producers and aimed to improve lighting efficiency, but they targeted different market segments, received different levels of publicity, and clearly differed in outcomes. One supported development of a solid-state, electronic replacement for core-coil magnetic ballasts used widely in commercial sector fluorescent systems.[44] The other project supported development of efficient lamps "near market readiness" to replace incandescent lamps in residential applications.[45] As seen in figure 8.4, the commercial and residential sectors accounted for two-thirds of electric power used for lighting the US. When ERDA merged into the Department of Energy in 1977, both projects continued as part of President Jimmy Carter's conservation oriented approach to energy policy. They provide a useful look at federal market interventions in the recent past, given that the legacy of both programs is evident in current lighting policies.

The solid-state electronic ballast program (SSEB) led to the creation of a new product and cultivated a market years before that probably would have occurred absent the intervention.[46] Lighting accounted for up to half of the electricity used in commercial buildings (including schools and offices), and by the 1970s fluorescent lamps dominated that market. Despite the relatively high efficacy of fluorescent tubes compared to incandescent lamps, energy losses within the ballast lowered overall system efficiency. Engineers had improved ballasts and circuits since the 1930s but the basic design, a coil of

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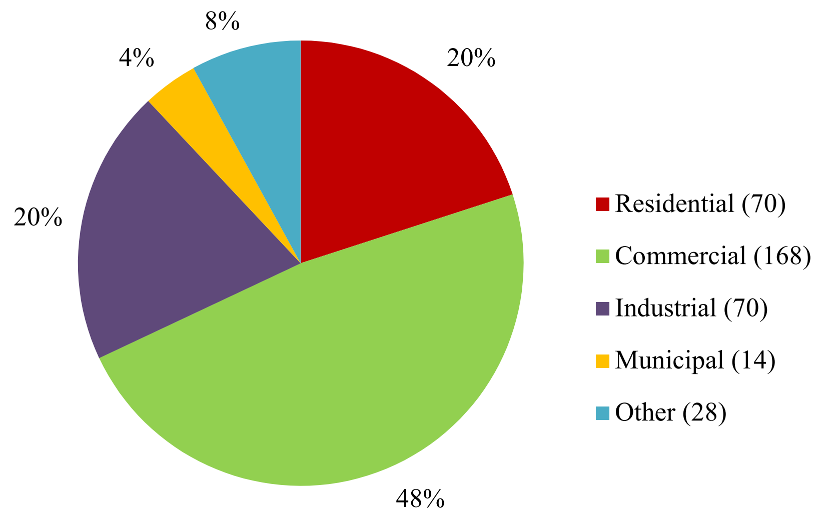
44. Verderber, Cooper and Ross, "Testing of Energy Conservation."

45."Should DOE Pursue Further Development and Commercialization ofthe Electrodeless Fluorescent Lamp?," (internal report, Department of Energy, September 1978), NMAH-LRF.

46. Program Proposal, "A National Plan," 31. US Department of Commerce, Bureau of the Census,Current Industrial Reports, Fluorescent Lamp Ballasts, MQ36C(92)-5, "Summary for 1992," (1992): 1. Richard H. Dowhan, "The Impact of EPACT." *Electrical Contractor* 60, no. 4 (April 1995): 40.

Figure 8.4: US electricity consumed for lighting, by sector, 1973[47]



By 1973, US electrification was complete and the lighting market sectors well defined. The two main ERDA lighting programs affected the commercial sector (solid-state ballast) and residential sectors (incandescent lamp replacement) that together accounted for 68% of lighting electricity. The BLBS Bureau estimated that lighting consumed 349 billion kilowatt-hours, about 20 percent of all electricity generated. Electricity use figures are in billion kWh. The commercial figure includes stores, offices, schools, and commercial outdoor lighting. The municipal figure includes street and highway lighting.

wire wrapped around an iron core, remained the industry standard because they were easy to mass produce at low cost and gave a long service life. Advanced components such as transistors and silicon controlled rectifiers, though expensive, gave engineers the ability to generate high frequency currents while reducing the energy wasting side effects, as John Campbell's work in the 1950s demonstrated. But experimental systems using the new components could not compete on price with low cost core-coil ballasts. While feasible, a new type of ballast required significant research and development funding, and would have to displace an established product in a mature market.

47. Source: Memorandum, "Facts about lighting and electric energy," 28 January 1974, Edward A. Campbell,, Better Light Better Sight Bureau, NMAH EC-LRF, 2.

ERDA managers saw this as a prime opportunity for federal research dollars to have a significant impact. The oil embargo altered the economics of energy, and the auto industry's adoption of power transistors drove component prices down.[48] The program ran into serious opposition from the private sector, however, "pie in the sky," in the words of one executive.[49] Another rebuked the idea that ballast manufacturers sought to keep a competing technology off the market: "the concern...that we...would attempt to discredit a semi conductor [*sic*] ballast program because of our investment [in existing technology] is sheer nonsense." Technical challenges and economic risk led them to "...maintain a watch and wait attitude...," and their concerns were real.[50] As seen by the fiasco with krypton-filled fluorescent lamps, new ballasts had to be compatible with existing products or developed as part of a new system. Either option would require new production equipment, more space on dealers' shelves, and new standards for safety and comparative tests. Though better than older ballasts, SSEBs still generated heat and electromagnetic interference that could degrade circuit performance and disrupt other electronic devices. Early research raised questions concerning power factor, noise, and flicker that initially gave the new technology a "bad name."[51]

48. Sam Berman, Rudy Verderber, Oliver Morse, Al Arthur and Francis Rubinstein, "Techniques and procedures for On-Site Demonstrations of Energy Efficient Technology," (letter of invitation and course material for seminar given at Lawrence Berkeley Laboratory, 26 June 1980), 2, LPF-DOE.

49. Kenneth C. Meinken (President, Advance Transformer Co.) to Frank M. Coda (Executive Vice President, Illuminating Engineering Society), 15 March 1977, LPF-DOE.

50. A. E. Fienberg (Vice President, Product Design, Advance Transformer Co.) to Samuel Berman (Lawrence Berkeley Laboratory), 6 June 1977, LPF-DOE.

51. IOTA Phase I report, amendment 1, (project report, November 1977), 8, LPF-DOE. GE's John Campbell, retired by this time, assisted with the project in October 1977. Stevens Luminoptics to Lawrence Berkeley Laboratory (October Monthly Report, December 14, 1977), LPF-DOE. Lee Anderson (Lighting Program Manager, Department of Energy), conversation with author, August 1995, for the recollection of early

While older manufacturers objected, new, small companies saw the program as an opportunity to overcome market entry barriers and eagerly sought the federal support.[52] In 1977, Stevens Luminoptics Corp. and IOTA Engineering, Inc., received contracts "for technical research, product development, prototype demonstration and testing."[53] Despite some failures and assembly problems, both companies' designs demonstrated positive results that proved a profitable ballast was possible.[54] With little public fanfare, the SSEB project stimulated industry research and investment. IOTA, with Beatrice Foods's Excel division, Sears Roebuck, and GE, expanded its design to include a new ballast for residential fixtures.[55] Stevens Luminoptics also owned designs for dimming and emergency lighting systems, and in 1981 ballast maker Universal Manufacturing bought the company.[56] In 1977, an ERDA report cited an industry source that tied "Universal's increased interest *directly to our activities in this field*," and noted "that GE has revived and

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electronic ballasts having a "bad name".

52. P. Franson, "Solid-State Fluorescent Ballasts Could Be $1 Billion Business," *Electronic Business* (July 1980): 84, 87.

53. Subcontract 2253202 between The Regents of the University of California and Iota Engineering, Inc., signed April 6, 1977; Subcontract 2019702 between The Regents of the University of California and Stevens Luminoptics Corp., signed 25 April 1977, both in LPF-DOE. Lawrence Berkeley Laboratory ran the program under contract from ERDA.

54. Lawrence Berkeley Laboratory, "Test Results for IOTA Ballasts," nd., circa August 1977. Lighting Research Laboratory, report 378-8, March 24, 1978, for Stevens Luminoptics data. James E. Jewell, Stephen Selkowitz, and Rudy Verderber, "Solid-state Ballasts Prove to be Energy Savers," *Lighting Design and Application* 10, no. 1 (January 1980): 36. Bill Jones to Rudy Verderber, memo regarding "Additional Findings," dated July 21, 1978, and IOTA Phase II Report, dated July 1978. All in LPF-DOE.

55. IOTA subcontracted Excel Corp. to produce test units, giving IOTA access to capital and stability when costs began to escalate. Purchase requisition 457138 from Iota Engineering to Lawrence Berkeley Laboratory, May 23, 1978, for phase II cost overruns. David Cooper to Rudy Verderber, "Excel Monthly Report," September 27, 1978, LPF-DOE, for the Sears-GE-Excel deal.

56. Stevens Luminoptics, press release dated December 3, 1981, for Stevens-Universal deal. See also *Energy User News* 7, no. 1 (January 25, 1982): 4.

accelerated their activities on the [SSEB], and *again attributes this directly to our activities*."[57] The small private sector actors, later assisted by larger companies, used the DOE program to overcome entry barriers, cultivate a market, and introduce an expensive product into the commercial lighting sector. In this instance, technology creation and diffusion occurred together, the DOE program supporting both. The perceived urgency of the energy situation led program staff to risk early introduction of the nascent ballasts rather than wait for prices to fall.[58] Traditional ballasts makers were forced to follow suit or risk being left behind. SSEB constituted a resounding success for DOE.

Rather than create a new technology, ERDA's second electric lighting program aimed to accelerate ongoing private sector efforts and, unlike the SSEB program, ended with mixed results at best. Incandescent lamps consumed 178 billion kilowatt-hours of electricity in 1974, almost 43 percent of total electricity used for lighting the US, and accounted for 95 percent of lamps in the residential sector. ERDA planners identified an energy efficient residential lamp as a potential source of significant energy savings.[59] The Energy Efficient Light Bulb (EELB) program initially supported an independent inventor but later changed into a test and evaluation effort for seven companies' designs. The program's impact is questionable given that most of the lamps never made it to store shelves or only lasted in the market a short time. The design that did succeed probably

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57. Kurt Riegel to Stephen Selkowitz, July 26, 1977, emphasis in original. "CFLs Get Dimmer," *Home Energy* 12, no. 5 (September/October 1995): 63, for Universal-Stevens problems.

58. Stoneman and Diederen, "Technology Diffusion," 919.

59. Edward A. Krupotich, "The Market Potential for the Litek Lamp", chapter 3 in *Market Statistics for Lighting*, SRI Project MEC 5670 (Menlo Park, CA., Stanford Research Institute, December 1976), in NMAH EC-LRF.

needed little help from DOE. The area where EELB contributed most lay in raising awareness about the need for a residential lamp replacement, and helping to prepare the market for CFLs and, later, LEDs.

In February 1974, California engineer Donald Hollister invented a small, screw-based fluorescent lamp he called Litek. Most fluorescent lamps pass an electric current between two electrodes that waste energy and wear out. Hollister used a small radio frequency generator to energize Litek's gases with an electromagnetic field, an electrodeless design that would be more efficient and longer lasting—if it worked.[60] Hollister expected that energy savings and a ten year life would make his expensive Litek economical, and in June 1975 submitted an unsolicited proposal to ERDA for funds to finish development and market the lamp. After successful NBS tests of a prototype, ERDA issued a $353,000 contract for ten lamps and gave Litek a public debut in March 1976. A newspaper editorial quipped, "[w]hy he seems to have been able to do what the giants of the electrical industry have not done is a question we can't answer."[61]

Few development programs run smoothly and the Litek was no exception as excess heating and electromagnetic interference slowed the work.[62] But apparent progress led ERDA to issue Hollister a Phase II contract for $185,000 in February 1977 to resolve

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60. Chuck Beardsley, "And Now, The Hollister Lamp," *Lighting Design & Application* 6, no. 4 (April 1976): 48. See also NMAH catalog #1992.0466.01, experimental Litek compact fluorescent lamp, 1979.

61. John M. Anderson, P. D. Johnson, C. E. Jones, and T. H. Rautenberg, "Electrodeless HID Lamp Study, Final Report," (project report, 1 April 1984), 2; Donald D. Hollister to Maxine Savitz, June 27, 1975; Rockwell International to Lighting Technology Corp., (proposal) December 5, 1975; Donald A. McSparron (NBS) to Kurt Riegel (ERDA), September 11, 1975; all in LPF-DOE." Editorial, "Flicking on the Idea Switch," *Los Angeles Times* (10 March 1976): D6.

62. Steve Weitzner, "What Ever Happened to the Screw Base Fluorescent Lamp?" *Electronic Products Magazine 21* (June 1978): 31-34. John M. Anderson, "Electrodeless Fluorescent Lamps Fields," 236.

problems, set specifications, "and secure commercial support."[63] The project seemed on track as Hollister received a patent and produced working prototypes, but by fall he faced bankruptcy.[64] The demands of being engineer, project manager, administrator, and promoter proved too much for the lone inventor competing against large companies that employed specialists for those functions. The new Department of Energy worked to save Litek, recognizing that "withdrawing support from a small company with a good idea," risked political backlash, but in late 1978 recommended against renewing the contract.[65]

Unwilling to give up on a residential lamp replacement, staff at DOE headquarters and Lawrence Berkeley Laboratory recast the program.[66] In 1979, seven companies agreed to supply ten prototype lamps for initial testing, followed by one hundred "commercially packaged" lamps for more tests.[67] Duro-Test and MIT partnered on a special incandescent lamp. Philips, Westinghouse, Interlectric, and Spellman Electronics all proposed compact fluorescent designs. GE submitted a miniature metal halide lamp,

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63. "Should DOE Pursue...?," is a frank evaluation of the Litek project. Stanford Research Institute, "Business Development Strategy and Market for a New General Purpose Lamp," both in NMAHEC-LRF.

64. Donald D. Hollister, Light Generation by an Electrodeless Fluorescent Lamp, US Patent 4,010,400, filed 13 August 1975 and issued 1 March 1977. Application File, US Patent 4,010,400, United States Patent and Trademark Office. Karen J. Bowland, Patrick J. and Donald D. Hollister, Richard Hurney, Douglas Moore, Paul Reedy, "Litek Lamp Optimization Study, Final Report: V2, Market Analysis and Commercialization Plan," April 1977, NMAH EC-LRF.

65. Robert H. Ragan (Chief of Contracts Operations Branch, Procurement Division, DOE) to Donald Hollister, June 27, 1978; Lighting Technology Corp., Twelfth Monthly Report, July 13, 1978; inLPF-DOE. John Cuttica (DOE) to Donald Hollister, August 4, 1978. "Should DOE Pursue...? ," 9.

66. Memorandum, Leighton to Cuttica, 6 November 1978. The Carnegie-Mellon Energy Productivity Center and McKinsey & Co, Inc., *Shaping Substitute Incandescent Strategy, Department of Energy*, 23 April 1979, see chart on page 7.

67. *Commerce Daily*, August 10, 1979. Sam Berman to John Cuttica, et.al., memo dated May 7, 1979, includes a sample RFP. Rudy Verderber to Review Committee, "Proposed Scoring Schedule, Energy Efficient Light Bulb Project," November 28, 1979, LPF-DOE.

and a reorganized company continued with the Litek. The new company brought an infusion of private capital and gave most of the legal, management, and administrative functions to others leaving Hollister free to focus on technical issues.[68] Unfortunately for him, while a 1984 report stated that Litek's efficacy and life rating exceeded that of most other program designs, it was too late.[69] The industry had already settled on a compact fluorescent design and left the DOE program behind.

Raising lighting efficiency was a small part of the Carter Administration's work on energy, although technical and policy actions taken at that time set the stage for later advances. Federal tax rebates that encouraged weatherization and energy efficiency did not, for example, include lighting upgrades.[70] After a political struggle with his own party, Carter signed the National Energy Act in 1979, a mammoth five piece attempt to set energy policy. Despite its symbolism for conservation, the only lighting-specific policy did not involve electricity but rather a limited ban on using natural gas for outdoor lighting. As with past lighting restrictions, the limits called into question the ban's practical effect.[71] One among several technologies in the National Energy Conservation Policy Act, schools,

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68. Litek International, Response to RFP 4502710, November 29, 1979. Robert I. Christopherson, *Electrodeless Fluorescent Lamp System: Coil/Plasma Impedance Measurement* (Adelphi, MD: Harry Diamond Laboratories, January 1980). Colin S. Willett and Robert M. Curnutt, *Technical Evaluation of Output Characteristics of Litek Corporation rf-Excited Light Bulbs* (Adelphi, MD: Harry Diamond Laboratories, September 1980), 13, for comparison to GE and Philips lamps. All in NMAH EC-LRF.

69. Rudolph R. Verderber and Francis M. Rubinstein, "Comparison of Technologies for New Energy-Efficient Lamps," *IEEE Transactions on Industry Applications* IA-20, no 5 (September/October 1984): 1185-1188.

70. Gayle Pollard, "Tax rebate for Energy Savers," *Boston Globe* (11 September 1979): 29, http://search.proquest.com.

71. Powerplant and Industrial Fuel Use Act, P.L. 95-620, 92 stat 3315, National Energy Policy Act, Committee Print, 96-1 (January 1979), 201. The ban exempted memorials, places of historical significance, and use "for commercial purposes,...of traditional nature, and [that] conforms with [its surroundings]."

hospitals, and local governments could seek federal grants to improve energy efficiency that included lighting fixture upgrades. However, in an important policy opening, another part of NECPA defined electric lighting as industrial equipment, subject to standards and labeling requirements.[72] Lighting was not included with standards enacted then, but regulators later used their new "discretionary authority to set efficiency standards for [other] products," to bring lighting into energy policies.[73]

The presidential administrations and Congresses of the 1970s had difficulty enacting energy policies partly due to differences over ideas like the role of markets and the private sector in policy alternatives. They faced resistance from a polity riven by competing values and skeptical of experts, government, and corporations. For example, many people held that no oil shortage existed and oil companies' schemes caused high prices, a perception that record industry profits did little to assuage.[74] Environmental pressures that forced utilities to internalize waste disposal costs and political pressures to allow markets to set prices raised energy costs and hindered compromise. People used to cheap, plentiful energy did not support policies that endorsed conservation (defined as less use) or price deregulation (leading to higher costs) to alleviate shortages. Societal values of perpetual growth and abundance complicated efforts to promote efficient products, including lighting products for the residential sector.[75]

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72. National Energy Conservation Policy Act, P.L. 95-619, 92 stat 3239, National Energy Act, Committee Print, 96-1 (January 1979), 87, for grants; 92 stat. 3268, 116, for lighting as industrial equipment.

73. National Energy Conservation Policy Act, Committee Print, 161, for discretionary authority.

74. Jacob, *Panic*, 73, 211, 221. Robert A, Rosenblatt, "Oil Profits—Are They Obscene or Vital to Industry?," *Los Angeles Times* (28 May 1974): 3A, http://search.proquest.com.

75. "Energy: Voluntarism or Controls?," *Los Angeles Times* (11 October 1973): B6; "Saving Energy: More

1980s: changing politics and paradigms

Federal policies involving lighting faded into the background during the 1980s although for external and internal reasons the industry continued along the path started during the prior decade. The oil shortage ebbed as new fields outside the Middle East began producing and OPEC lost solidarity, but the embargos highlighted US dependence on imported oil. Ronald Reagan's administration began promoting policies to increase oil production and other energy supplies while the definition of dependence began to change from one of a problem to be solved to one of a condition to be managed. Oil entrepreneur George H. W. Bush, first as vice-president and then as president, accepted imports as a tool to augment domestic oil production.[76] Budget cuts forced DOE's Lighting Program to adopt a "more generic" approach to research and development projects.[77] Underlying structural problems in the electric power industry continued as well but in that arena, state policies often played a more important role than federal policy due to state oversight of electricity rates.[78] Faced with mounting and sometimes violent opposition to costly new power plants and intrusive transmission lines, utilities implemented demand-side management programs that included promoting new, efficient lamps to residential and commercial customers.[79] Industry debate about the importance of energy added to external

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Needed," *Boston Globe* (9 November 1973): 14, both in http://search.proquest.com.

76. Jacob, *Panic*, 293-296.

77. Maxine L. Savitz, telephone conversation with author, 28 November 1995. Dr. Savitz was director of the Division of Building and Industry at ERDA.

78. Lindert, "Consumer price indexes," Table Cc6-48 in *HSUS*.

79. "Commercial-Sector Demand-Side Management Activities," *EPRI Journal* 10 (November 1985): 63. Casper and Wellstone, *Powerline.* Hirsh, *Power Loss*. "Northwest Utilities Subsidize CFLs," *Home Energy* pressures as lamp makers began introducing the fruits of research started years earlier.

At synchronized press conferences in March 1980, Philips introduced European and American audiences to a CFL designed to replace incandescent lamps. Using their rare-earth phosphors and miniaturized electronics, Philips promised “70% savings in energy savings [and] 5 to 10 times” the life of incandescents without the problems that plagued competing technologies. Philips made this CFL for the residential sector but soon followed with a smaller commercial product.[80] Within a few months EELB participants Westinghouse and Interlectric also unveiled residential CFLs. Manufacturers targeted different sectors simultaneously with designs that shared the basic technology while optimizing particular features, thus allowing marketers to identify profitable niches while spreading costs over a wider base.

The introduction of competing designs for new efficient lamps gave policy makers technical options, although which if any of these lamps might find success would take a few years to discover. In the meantime the nation’s shifting political orientation wrought uncertainty about lighting policies just as a significant paradigm shift within the lighting profession created confusion about the expert advice policy makers relied upon to craft alternatives. Arguments over standards, practices, and identity hampered consumer education and may have contributed to lighting’s low profile in the National Energy Act.[81]

13, no. 2 (March/April 1996): 45.

80. Steve Goldmacher, “New Light Bulb Advance,” press release (North American Philips Lighting Corp., 28 March 1980), in NMAH EC-LRF. Steven Goldmacher, interview with Harold D. Wallace, Jr., 28 October 1996, NMAH EC-LRF.

81. National Energy Conservation Policy Act , 92 Stat 3268. Electric lights appears 6th on a list of 14 “types of [industrial] equipment...in addition to electric motors and pumps” that are to be studied, tested, and labeled for energy information for that sector.

Illuminating engineers had worked hard to gain the respect that led policy makers to seek their advice, as when the IES participated in wartime committees and state legislators wrote codes that incorporated IES standards. For nearly a century lighting experts drafted standards based on the idea that low light levels damaged eyesight, and reduced productivity and safety; problems correctable with higher light levels. Outside of special situations, the idea that one could have too much light provoked acrimonious exchanges between "quasi-professional[s]...dominated by and financially dependent on the lighting industry," and design "'chefs' who apply lighting recipes [but do not] know the tradeoffs involved in resource optimization."[82]

One engineer observed, "as the Seventies got underway someone shouted 'energy' in the bright theater of Lighting Design… All of a sudden, the Lighting Designers and Engineers found themselves together out of work."[83] Debates over who qualified as a lighting professional and the basic nature of the profession, qualitative art or quantitative science, made expert advice appear ambiguous, something not welcomed by policy makers, as both Grahams pointed out.[84] Prior debates such as rating lamps by lumens or watts generally stayed within the industry but now quarrels appeared in mainstream newspapers and on television. Designer William Lam stated,

Designers, faced with an extraordinary rapid turnover of products and a

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82. Stein, *Architecture*, 123, his comment refers to the IES as a whole; Robert T. Dorsey, "Interior Lighting Based on Resource Optimization," *Lighting Design & Application* 4, no. 5 (May 1974): 36.

83. Laurence J. Maloney, "The State of the Profession...As an Engineer Sees it," *Lighting Design & Application* 10, no. 1 (January 1981): 24-25. Saul Goldin, "The State of the Profession...As a Designer Sees it," *Lighting Design & Application* 10, no. 1 (January 1981): 25.

84. Neustadt and May, *Thinking In Time*. Also, H. D. Graham, "Stunted Career", 20; O. Graham, "Uses and Misuses," 16.

> fast, fragmented process of design and construction which has taken root in this electronic age, have yielded the control which they once exercised over the luminous environment to others [including] misguided government officials, who have been brainwashed by propaganda from the lighting and power industry into adopting and enforcing irrelevant and obstructive codes in the name of progress.[85]

PBS's 1977 broadcast "We Will Freeze in the Dark" helped bring the debate into the open. As lighting designer Howard Brandston later recalled, "the [IES] did not fare well... Pseudo-science led to some...preposterous recommendations. The defensive posture and the technical arrogance of our leadership and some of the poor, perhaps tainted, research was brought to light in that PBS broadcast."[86]

The debate came down to a seemingly simple question: how much light was too much? The participants in the debate recognized this as a cultural issue with deep roots.[87] Matthew Luckiesh wrote in 1935 that "the greatest opportunity in serving human beings through lighting at the present time lies in greatly increasing foot-candle intensities."[88] Luckiesh and his colleagues endorsed a definition of good lighting that required high light levels and aligned with producers' desire to sell lamps, luminaires, and electricity. That definition came to permeate actor networks although tensions began emerging before energy costs spiked. In 1963, the IES and BLBS Bureau recognized, "increasing the

85. Carter B. Horsley, "Let There Be Less Light, Experts Tell Office Workers," *New York Times* (2 April 1978): R1, http://search.proquest.com.

86. Paul Tarricone, "Good Grief, It's Howard Brandston," *Lighting Design and Applications* 33, no. 8 (August 2003): 62.

87. M. Clay Belcher, "Cultural Aspects of Illuminance Levels," *Lighting Design & Application* 14 (February 1985): 49-50.

88. Matthew Luckiesh and Frank M. Moss, "Quality of Lighting," General Electric Company, form LS-1013 (August 1935), 4. This is a reprint from *Transactions of the Illuminating Engineering Society* 30, no. 7 (July 1935).

quantity of light, with little consideration for its quality, [often] resulted in extremely unfavorable visual conditions."[89] The surging cost of energy and the willingness of people to accept lower light levels confirmed for some that those levels were excessive. At the same time, the problem of light pollution began receiving public recognition, which brought another set of actors into the discussion.[90] When ophthalmologists spoke out against the idea that low light levels damaged eye sight, high levels became even more difficult to defend.[91] Designers who faced the reality of customers disabling light fixtures needed to illuminate work areas while minimizing light levels in the entire room.

A clear signs that times were changing came in 1979 when the Depression-era Better Light Better Sight Bureau folded. The Bureau's last director waxed nostalgic but acknowledged that BLBS's programs were "thought by many to be load-building activities...."[92] An even clearer sign of a paradigm shift came in 1981when a new system that recommended ranges of light for given tasks appeared in a revised *IES Handbook*, replacing the very precise recommendations of past editions. "This new procedure will accommodate a need for flexibility in determining illuminance levels so that lighting

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89. Paul W. Seagers, *Light, Vision and Learning* (New York: Better Light Better Sight Bureau, 1963), 67.

90. John McCarron, "Light Pollution Foes Plead for Right to Night," *Chicago Tribune* (27 August 1978): 42, http://search.proquest.com. Fred Pilot, "Light Pollution Dims the View of the Universe for Astronomers," *Los Angeles Times* (26 June 1978): E1, http:// search.proquest.com.

91. Russell D. Hamer, Velma Dobson and Melanie J. Mayer, "Absolute Thresholds in Human Infants Exposed to Continuous Illumination," *Investigative Ophthalmology & Visual Science* 25, no. 4 (April 1984): 381-388, found no evidence for concern. Joseph L. Calkins and Bernard F. Hochheimer, "Retinal Light Exposure from Ophthalmoscopes, Slit Lamps, and Overhead Surgical Lamps: An Analysis of Potential Hazards," *Investigative Ophthalmology & Visual Science* 19, no. 9 (September 1980): 1009-1015, http://iovs.arvojournals.org, found that special light sources could cause damage and recommended process and technology changes.

92. Ed Campbell, letter to the editor, "Lights Out for BLBS Bureau," *Lighting Design & Applications* 9, no. 11 (November 1979): 55.

designers can tailor lighting systems to specific needs, *especially in an energy conscious era*.[93] The editors recognized that energy costs might remain high. The new handbook included a section on "Energy Management," a "concept [that] has gained in importance since the early 1970's, [*sic*] when energy conservation became a concern, resulting in a close examination of the way buildings have been lighted and the criteria for future designs to use energy resources effectively and efficiently."[94]

The actor networks associated with lighting thus broadened in response to the demand for energy efficiency. Illuminating engineers found themselves coordinating and compromising with other professionals, heating and air conditioning engineers, for example, to meet user needs within the confines of holistic energy budgets and codes that segregated building systems.[95] Policy makers were able to pursue alternatives that used lighting to lower energy consumption, aided by lighting designers intent on the same goal. As Kingdon pointed out, many policy actors lack technical expertise, something the federal civil service bureaucracy provides.[96] As DOE gained more experience working with lighting, illuminating engineers on staff and under contract brought their expertise and the new, energy conscious culture to the task of crafting policy alternatives.

Global actor networks also realigned during this time. With the demise of the Phoebus cartel, lamp makers entered each other's markets. The world's largest lamp

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93. John E. Kaufman, ed., *IES Lighting Handbook : the Standard Lighting Guide*, 4th ed. (New York: Illuminating Engineering Society, 1966), 9-81. John E. Kaufman and Howard Haynes, eds., *IES Lighting Handbook, Application Volume* (New York: Illuminating Engineering Society, 1981), 2-3 to 2-5, emphasis mine.

94. *IES Handbook, Application*, 1981, 4-1.

95. Stein, *Architecture*, 14-17, noted the issues that discouraged cooperation between systems professionals.

96. Kingdon, *Agendas*, 32-33.

maker, Philips purchased Westinghouse's Lamp Division in 1983, an acquisition that pooled the companies' CFL inventions. It also gave the Dutch company access to a recognized brand, established distribution channels, and advanced research facilities.[97] The global reshuffling brought new players like China's Feit Electric and Japan's Matsushita into the US market; both companies introduced CFLs in the 1980s. In response, GE acquired Hungarian lamp maker Tungsrad when the Soviet policy of Glasnost opened Eastern Europe to western influences, thus gaining access to European markets and relatively modern, un-unionized facilities.[98] GE also bought into the British market with the purchase of Thorn Lighting's lamp factories in 1991.[99] GTE Sylvania faced rising costs in producing the new efficient fluorescents and CFLs. As the deregulated telephone industry became competitive, GTE executives decided lighting lay outside their scope and sold Sylvania to Germany's Osram (part of Siemens) in 1993.[100]

New technologies, the global corporate shuffle, the professional paradigm shift, and the market's focus on energy costs combined to create a turbulent time in lighting. Older federal agencies that routinely interacted with the industry (such as the Patent Office and NBS) were joined by new entities such as DOE and EPA. Though NBS (reorganized in 1988 as the National Institute of Standards and Technology), assisted with research and

97. "Philips of Eindhoven," *Fortune* (June 1945): 126-129, 197-206, for Philips during the war. "North American Philips," Industry News, *Lighting Design & Applications* 12, no. 2 (February 1983): 64.

98. John Burgess, "Hungarian Firm, GE In Venture," *Washington Post* (16 November 1989): E1, http://search.proquest.com.

99. Daniel F. Cuff, "G.E. Sets Thorn Deal," *New York Times* (22 January 1991): D4, http://search.proquest.com.

100. "Osram Acquires Sylvania," *Lighting Design & Applications* 21, no. 11 (November 1992): 20.

agencies like the FCC and the Public Health Service occasionally pursued lighting policies, DOE and its national labs became major points of contact between public and private sectors.[101] Parallel to these technical, market, and social changes, the policy whiplash that resulted as US political power swung between administrations with distinctly different political philosophies only added to the uncertainty of the era.

Later period, first phase: nudging paths

Federal policy makers undertook significant research programs and enacted efficiency standards for some lamps during this period with the intent of reducing the amount of electricity used to light the US (as per the second research question). Policy changes initiated during the 1970s altered lighting paths by creating one new technology, assisting another, and providing a legal opening for future interventions. The consequences of the changes took years to emerge as new technologies vied for public acceptance, lighting professionals wrestled over definitions, and a restructuring lamp market shook off the inertia of a century. Energy issues no longer constituted just one of several factors in lighting system efficiency; they became the driver of innovation and the focus of policy. Policy makers used the high efficacy inventions of the 1950s and 1960s and pushed for new advances in lamp efficacy, to develop alternatives that would help reduce energy consumption in a time of perceived national crisis (as per the first research question).

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101. The FCC was concerned with radio interference from new lighting devices. In 1976 the Bureau of Radiological Health received reports of people burned by ultraviolet rays from damaged mercury lamps and required lamp makers to devise a way of extinguishing the arc within 2 minutes of a break. Herbert Strauss and Dick Neubert, interview with Harold D. Wallace, Jr., 1 November 1996. B. L. Collins, Steven J. Treado, and M. J. Ouellette, "Performance of Compact Fluorescent Lamps at Different Ambient Temperatures," *Journal of the Illuminating Engineering Society* 23, no. 2 (Summer 1994): 72-85, provides one example of NIST lamp research conducted in concert with Canadian researchers.

Federal research support became more important as market competition reduced private sector managers' time horizons for realizing investment returns on difficult programs like tungsten halogen and high pressure sodium lamps.[102] DOE pushed and augmented private sector efforts to develop technologies that did not fit into near term plans or were considered disruptive, a generally accepted role for federal research. As demonstrated by the solid state ballast program, some private sector actors resisted policy efforts in order to protect existing markets, but others embraced the federal support as a way of overcoming market entry barriers and gaining access to advanced research facilities. That provides part of the answer to the third research question, the other part being the use of federal policy to help cultivate markets for new energy efficient lamps. Like tungsten lamps in the 1910s and fluorescents in the 1940s, lamp makers needed help diffusing expensive compact fluorescents and improved linear fluorescents in the 1980s.

By the end of the 1980s, petroleum prices were low and deregulation brought new supplies of natural gas into the market. A telecommunications infrastructure long viewed as a natural monopoly gave way to a competitive market that resulted in lower costs, and new products and services like cell phones. The deregulation bandwagon began to roll in the direction of electric utilities after the successful integration of non-utility generators into the power infrastructure, enabled by the Public Utilities Regulatory Policy Act, part of the National Energy Act.[103] Although energy concerns receded from many Americans'

102. When asked in our 1996 interview if he thought tungsten halogen would be invented at that point, co-inventor Fred Mosby replied "I doubt it," citing increased competition. Bill Louden made a similar comment about HPS based on economic considerations. Other researchers active in that time period noted in interviews and conversations the phenomena of shrinking horizons for research payback.

103. Public Utility Regulatory Policies Act of 1978, P.L. 95-617, 92 stat 3144, National Energy Policy Act, Committee Print, 96-1 (January 1979), 304.

thoughts, electricity demand continued to grow as did technical and economic pressure on the electric power infrastructure. As the electrical industry began contemplating restructuring, a new set of regulations designed to improve energy efficiency began working through executive and legislative offices. Those regulations proposed significant changes in lighting, built on the successes of the federal electronic ballast program and the private sector's work on advanced phosphors.

The new proposals were enabled by policy makers' ability to convert the old definition of lighting efficiency that emphasized high light output to a new definition that prioritized reduced energy consumption. Some lighting professionals complained that, "[after] working 10 or 15 years to develop rational standards...the states and [federal] government bypass us and listen to the NRDC."[104] Those professionals little appreciated that 15 years represented nearly four presidential election cycles, a time frame perceived differently by policy makers than by engineers. Professional debates about energy, however socially or technically necessary, took too much time and gave other actors in policy networks a chance to make their voices and positions heard. Industry writer Karl Ruling described the message that came out of conversations at a 1990 meeting of the IES: "The lighting industry in North America has to wake up—its future is being decided by others."[105]

Some of the critics of energy legislation say that it can fail its purpose

104. Karl G. Ruling, "Lighting Legislation: Government Tries for Component Regulation," *Lighting Dimensions* 15, no. 1 (January/February 1991), 98. Quote is from a letter to the editor from three lighting designers that Ruling excerpted for his article. NRDC is the National Resources Defense Council, an environmental advocacy group known for using economic arguments to advance their causes.

105. Karl G. Ruling, "IESNA Conference: 'Lighten Up' Addresses Heavy Topics," *Lighting Dimensions* 14, no. 8 (November 1990), 162.

> because it considers only the efficacies of lamps and luminaires and does not consider the overall efficacy of a lighting system......[Critics] feel that the legislation drafted by people who are not in the lighting industry misses the point of lighting. *Lighting is not designed to consume energy. It is designed to help people do things*..... Lighting does indeed use energy, but the increased productivity that good lighting makes possible is worth far more than what it costs in energy. Of course, the above argument begs the question: What is good lighting?[106]

What indeed? Nearly twenty years after the oil embargo and after a century of debate, lighting professionals in 1990 still could not clearly answer the question, and expressed dismay that the issue was being taken out of their hands. Part of the problem lay in the refusal to accept that lighting was designed to do both: "consume energy .... and help people do things." Indeed, lighting for decades played a major role in promoting electricity consumption, as seen in the chapters above. Sustained attention to energy policy provided the necessary impetus to take real steps to lower the denominator of the lpW equation, something that had never happened before. That is what designer Brandston meant when he noted that, "[IES] was forced to change; it never would have happened without the energy crisis."[107]

In May 1990, GE unveiled a revamped manufacturing facility in Winchester, Virginia that could produce 400 million incandescent lamps annually with a labor force of just over 400 people. The investment of "$1 billion in the lighting division" since 1985 and the acquisitions of Tungsrad and Thorn, announced that GE still saw lighting in general and incandescent lamps in particular as a major source of profit.[108] Modernizing facilities

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106. Ruling, "IESNA Conference," 162, emphasis mine.

107. Tarricone, "Good Grief," 62.

108. Frank Swoboda , "GE's Shining Factory of The Future," *Washington Post* (21 May 1990): 1,

to make the most energy inefficient lamp while simultaneously importing CFLs from its new Hungarian subsidiary typified the conflicted nature of the lighting industry as the century’s final decade opened. However, as CFLs gained market share, full-cutoff luminaires sprouted along highways, and automated controls did what many people would not—turn lights off—an unexpected revolution in lighting was brewing in North Carolina, Germany, and Japan. Another Middle East war loomed that would again boost energy costs and rekindle American concern about energy, providing new incentive for continued federal policies to promote efficient lighting.

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http://search.proquest.com.

Chapter Nine: Restructuring Light, 1990-2016

We did not think that [lighting standards] would be as controversial a thing as it turned out to be. But we just got reamed.

—Eric Noble, December 1990[1]

The second part of the later period of federal lighting intervention began like the first, with war in the Middle East. In August 1990, Iraq invaded Kuwait and four months later a US-led coalition intervened to expel the Iraqis. Oil prices spiked nearly 30 percent on average, reminding Americans of their tenuous energy supplies, but soon returned to prewar levels.[2] Electricity prices, however, continued rising as they had since the 1960s and several states enacted legislation that imposed minimum energy efficiency standards on electrical appliances, extending earlier federal efforts that included the National Appliance Energy Conservation Act of 1987.[3] As states debated regulating individual components like lamp ballasts, industry stakeholders often felt left out. Regulating components irritated many lighting designers who wanted holistic energy budgets that

1. Ruling, "Lighting Legislation," 103. Noble was a Program Manager in the New York State Energy Department.

2. US Department of Energy, Energy Information Agency, *Annual Energy Review 1998* (Washington, DC.: GPO, July 1999), 149, table 5.16. This 1989-90 comparison is representative.

3. National Appliance Energy Conservation Act of 1987, Pub. L. No. 100–12, 101 Stat. 103 (1987). Earlier laws included the Energy Policy and Conservation Act of 1975, Pub. L. No. 94–163, 89 Stat. 871 (1975), and the National Energy Conservation Policy Act, Pub. L. No. 95–619, 92 Stat. 3206, (1978). Maura Dolan and Richard Paddock, "'Big Green' Battle Centers on Cost of a Cleaner State," *Los Angeles Times*, 17 October 1990, OCA1, http://search.proquest.com. California's debate mirrors other states'.

enabled tradeoffs to achieve savings. As Eric Noble recalled in the above quote, he and his colleagues learned that regulating lighting could ignite political controversy. The Gulf War opened a policy window that gave federal actors an opportunity to reconcile differing state energy regulations while trying to calm the public.

Despite objections, the invention of practical electronic ballasts had allowed policy makers to use the opening provided by NECPA in 1979 to add ballast standards to the National Appliance Energy Conservation Amendments of 1988.[4] Just as the little-noticed section 210 of the Public Utility Regulatory Policies Act of 1978 (PURPA) led to major changes in power generation, so the small steps in NAECA88 wrought changes in all segments of the lighting industry. Over the twenty years that followed, gradual expansion of energy standards affected each lighting market sector in turn as discussed below, and helped move lighting to a new path that emphasized energy efficiency.

Aside from rationalizing state energy regulations, these standards advanced environmental goals. As larger political and economic contexts in the US shifted, a series of presidential administrations pursued alternating agendas that oscillated between stressing energy policy (George H. W. Bush and George W. Bush) and environmental policy (Bill Clinton and Barack Obama). Enacting lighting policies during this period required balancing opportunities and challenges, forcing compromise among actors who held conflicting values. Events like war in the Middle East, failures in restructuring electric power markets, and the events of 11 September 2001 complicated those efforts by reshuffling national priorities. Policy makers in this later period shared one reality with

4. National Appliance Energy Conservation Amendments of 1988, Pub. L. No. 100-357, 102 Stat. 671 (1988). Hereafter NAECA88. This amended the 1987 NAECA.

their earlier period forebears however; private sector actors still used energy policies to push new, expensive products to market sectors reluctant to embrace those devices.

In 1990, lighting consumed 515 billion kWh in the US, representing 19 percent of total electricity at a cost of $36 billion.[5] Though lighting consumed more electricity in absolute terms, that percentage had changed little since 1950. Without efficiency standards, projections indicated commercial and residential lighting demand alone could rise to 613 billion kWh by 2030 at a cost of $52 billion.[6] With electricity costs trending upward as deregulation uncertainties and environmental concerns inhibited capacity growth, making better use of electricity seemed vital.[7]

During this period public and private sector actors used compact fluorescent lamps to achieve energy savings. Technical breakthroughs in light emitting diodes raised efficacy to levels previously thought unattainable and started an unprecedented lighting revolution. By the early 2010s, federal regulations effectively banned general purpose incandescent lamps, sparking protests from consumers and politicians, even as policy makers and the lighting industry built new partnerships based on LED technology.[8] The availability of very high efficiency lamps started another paradigm shift within the industry as lighting professionals adjusted to two unexpected ideas: efficacy might be approaching theoretical

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5. Barbara A. Atkinson, et al., *Analysis of Federal Policy Options for Improving US Lighting Energy Efficiency: Commercial and Residential Buildings* (Berkeley, CA: Lawrence Berkeley Laboratory, December 1992), 1-1.

6. Atkinson, et al., *Analysis*, S-2.

7. Steven Stoft, *Power System Economics: Designing Markets for Electricity* (New York: John Wiley & Sons, Inc., 2002).

8. IES Policy Director Robert Horner noted that his position was established around 2010. Conversation with author, 3 March 2016.

limits, and luminaires might need to accommodate non-lighting functions. Both ideas promised radical changes for illuminating engineers and policy makers alike.

Technology: adaptive and creative responses

Economist Joseph Schumpeter differentiated between episodes of change as either an "adaptive response" that worked within existing paradigms or a "creative response," arising from "something...outside the range of existing practice."[9] Technology changes during the transitional period (tungsten halogen, metal halide, high pressure sodium) and the first phase of the later period (solid state ballasts, compact fluorescents) fit his definition of adaptive response well. Policy makers used efficacy gains made in the 1950s and 1960s to nudge the industry toward a path of higher energy efficiency in the 1970s and 1980s. Existing lamps makers adapted, with varying degrees of enthusiasm, to changing energy economics by adding higher efficacy products and expanding markets. Those innovations allowed policy makers to promote additional goals, such as pollution control.

New innovations during this period also led to a creative response. Schumpeter characterized such changes as: apparent only in hindsight, affecting "the whole course of subsequent events," and arising from creative individuals.[10] An unexpected breakthrough in solid-state physics made outside the traditional lighting industry triggered a revolution in high efficiency lighting whose ultimate consequences remain to be seen. Choosing whether to adopt the new technology required people to consider tradeoffs based on differing values. Higher efficacy led to increased use of lighting that fed concerns about a

9. Schumpeter, "Creative Response," 150.

10. Schumpeter, "Creative Response," 150.

rebound effect and negative externalities such as light pollution, but also resulted in a substantial drop in the amount of energy used to light the US, as discussed in detail below.

The most efficient descendants of Edison's incandescent lamps, tungsten halogens, illustrate value tradeoffs. As discussed in chapter seven, halogens originally filled a niche demand for small, bright, lamps with good color rendition. During the 1980s several user groups adopted them to save energy, as when retailers made extensive use of small, low voltage MR-16 units to light store displays. But for residential lighting, halogen's expense, tendency to explode unpredictably, and high temperature offset gains from higher efficacy. Their use in popular fixtures called torchieres failed when they caused fires.[11] Tungsten halogens run at high temperature, about 730° C (1340° F), hot enough to ignite curtains or debris that settled in the open top torchieres, leading to a ban from that application in 2005.[12] In the 1990s, producers encased a small halogen capsule inside a heavy glass envelope that would not shatter if the capsule exploded. In time, they discovered the problem's cause and designed a safe capsule suitable for use inside a thin glass envelope, lowering costs. Policy makers used halogen capsule lamps in legislation enacted in 1992 and 2007, to provide a somewhat more efficient alternative to regular incandescent lamps.

In the 1980s, engineers demonstrated practical rare-earth phosphor fluorescent lamps coupled to solid-state electronic ballasts, as discussed in chapter eight. DOE's successful SSEB program stimulated the ballast's introduction into commercial lighting

11. Mosby, US patent 3,243,634. A. L. Hart, "Incandescents: New Role, Growth in Tungsten Halogen," *Lighting Design & Application* 2, no. 12 (December 1972): 19-20.

12. Barbara Mayer, "Halogen Lights: the Good and the Bad," *Hartford Courant*, 27 March 1988, J16. Brooke A. Masters, "Fires Turn Up Heat On Halogen Lamps," *Washington Post*, 20 April 1998, B5.

sooner than would otherwise have occurred and carried over to other lighting sectors. Metal halide and high pressure sodium lamps used in industrial and street lighting also needed ballasts, and the fluorescent ballast work led to new ballasts for those lamps.[13] As described below, that work helped address the unexpected need to replace millions of ballasts that contained toxic polychlorinated biphenyls (PCBs). Replacing contaminated units boosted demand for expensive electronic ballasts because they contained no PCBs, and gave building owners the double incentive of eliminating a safety hazard and saving energy.[14] Market diffusion proceeded rapidly, with sales of electronic ballasts rising from about 3 percent of total in 1990 to 13 percent in 1992. By 1995, at least 73 companies worldwide made electronic ballasts.[15]

By 1990 commercial and industrial markets accepted compact fluorescent lamps as a replacement for incandescent lamps in fixtures that ran continuously, such as exit signs. A building might have dozens of exit signs, and long-lived CFLs cut energy and labor costs, "a powerful economic incentive to purchase CFLs."[16] Commercial and industrial acceptance helped justify investment in CFLs, but residential consumers could not so easily be convinced. Unfamiliar shapes, a noticeable starting delay, and deficient color

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13. J. C. Engel, R. T. Elms and R. E. Hanson, "An Energy Efficient Solid-State Controlled Ballast for HPS lamps," *Journal of the Illuminating Engineering Society* 10, no. 2 (January 1981): 81.

14. General Electric Lighting Technical Support, Application Information Note 103, "PCB's in Ballasts," (September 1985) and Note 104, "Disposal of Ballasts with PCB Capacitors," (October 1985), NMAH EC-LRF.

15. "1995 Lighting Equipment & Accessories Directory," *Lighting Design & Application* 25, no. 2 (February 1995): 88, for list of ballast producers.

16. Karl Johnson, "Energy Policies in Action," *Lighting Designs & Applications* 26, no. 6 (June 1996): 12, compares cost figures for incandescents, CFLs, and LEDs. Howard Geller and Steven Nadel, "Market Transformation Strategies to Promote End-Use Efficiency," *Annual Review of Energy and the Environment* 19 (November 1994): 314.

output, led many people to reject the lamps. Many CFLs would not fit in old fixtures. Dedicated luminaires that accepted plug-in bases rather than traditional screw-in bases addressed that concern, (and prevented “snap back” that occurred when dissatisfied users reinstalled incandescent lamps), but few people wanted to replace old fixtures.[17] Only in the late 1990s did producers offer CFLs whose size, shape, and color became palatable to many residential users. Rising sales augmented utilities’ demand side management programs and lowered prices. Though concerns about mercury still made some people uncomfortable, by the early 2010s CFLs could be purchased for under $1.

Also in the 1990s, discoveries in material science led researchers to create new, efficient light emitting diodes, bringing another expensive lamp to market. Invented in the early 1960s, LEDs are essentially transistors that emit light when electrons move from one substance to another across an intervening junction. Reliable and consuming little electricity, by the 1970s LEDs became familiar to most people as digital displays on calculators and watches. Companies not known for lamps, such as Texas Instruments and Hewlett Packard competed against traditional lamp companies such as GE, opening new markets for LEDs in communications and consumer electronics. That spurred research to raise the efficacy of red, green, and yellow LEDs, as well as to make a blue LED that in combination with others could emit white light.[18] In 1993, Shuji Nakamura in Japan

17. Victoria Eisen and Kelley Griffin, “Fluorescents at Home: A Cheap, Well-Lighted Place,” *Energy Auditor & Retrofitter* 4, no. 2 (March/April 1987): 11-19. Bruce Manclark, “How to Keep 'Em DownHome in the Socket,” *Home Energy* 11, no. 6 (November/December 1994): 36-38. Michael Siminovitch and Evan Mills, “Dedicated CFL Fixtures for Residential Lighting,” *Lighting Design & Application* 25, no. 3 (March 1995): 28-32.

18. J. W. Hall, II, “Solid State Lamps: How They Work and Some of Their Applications,” *Illuminating Engineering* 64, no. 2 (February 1969): 88-93.

invented a bright blue LED using gallium nitride.[19] As will be detailed below, Nakamura's breakthrough ignited a technical revolution that changed the entire industry. Other firms outside the traditional lighting industry including Mitsubishi and Siemens raced to make a white LED, as did Cree Inc., a small startup company in North Carolina. Engineers at Cree developed a way of processing very pure silicon carbide crystals and had already made dim, blue LEDs when they learned of Nakamura's work. Cree and others adapted techniques from the integrated circuit industry and pushed LEDs along a developmental path that more closely resembled something from Intel rather than GE.

That LEDs are solid-state devices like transistors had two noteworthy consequences. Unlike Edison, who needed to invent new production techniques, LED makers could build on years of research and capital invested in computer chip fabrication, Cree's approach. They created new knowledge, as Nakamura did with blue LEDs, but they could then adapt that knowledge to existing fabrication techniques. Such leveraging saved time and money, and wrested control of intellectual property from traditional lighting companies that could no longer use production patents to limit market entry. Secondly, the technical affinity shared by LEDs and computer chips made it easier to connect the two. In Massachusetts, Color Kinetics surprised the lighting industry in 1997 with color shifting, programmable lamps that contained from fifteen to one hundred individual LEDs.[20] Architectural and theatrical lighting designers swiftly adopted the energy saving, low voltage lamps. Since then, the merger of LEDs and computers has expanded to include

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19. Johnstone, *Brilliant!*

20. Color Kinetics color shifting LED devices, accession 2001.0165, NMAH-EC. Robert Wolsey, "Interoperable Systems: The Future of Lighting Controls," *Lighting Futures* 2, no. 2 (January 1997).

communications, a convergence with important ramifications for lighting policy and society in general, as will be discussed in chapter ten.

When the Gulf War reminded Americans of their society's dependence on energy, four decades of research and market preparation brought new lamps into service and new players into actor networks. Calls to conserve energy, slow the growth in demand for electricity, and mitigate pollution and climate change, combined with unexpected technological convergence, to propel a solid-state revolution in lighting that by 2016 pushed all other lamps toward obsolescence.

1990s: stresses and compromises

The 1990 Gulf War elevated the place of oil imports and energy in the political and economic contexts within which policy makers operated. The George H. W. Bush Administration took the opening of this policy window as an opportunity to advance new legislation that would increase private sector control over energy. Committed to increased supplies rather than conservation, Bush proposed looser regulations and tax incentives to boost fossil fuel production.[21] His administration also supported expanding the electrical power infrastructure, along with electricity deregulation modeled on recent efforts in other infrastructures.[22] Residential expenditures on electricity doubled over the course of the

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21. George H. W. Bush, "Remarks at a Briefing on Energy Policy," *Public Papers of the Presidents: George H. W. Bush, 1991* (Washington, DC: GPO, 20 February 1991), https://www.gpo.gov. This two-page talk about increasing energy supplies compares to one paragraph of substance in a 1989 signing statement for a bill on efficiency. George H. W. Bush, "Statement on Signing the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989", *Public Papers of the Presidents: George H. W. Bush, 1989* (Washington, DC: NARA, 11 December 1989), https://bush41library.tamu.edu.

22. Andrew Davies, *Telecommunications and Politics: The Decentralized Alternative* (London: Pinter Publishers, 1994). Kahn, *Economics*.

1980s, a continual rise that reflected an electrical infrastructure under growing technical and economic stress.[23] PURPA forced utilities to purchase electricity from industrial power plants rather than build new plants and suggested that power generation might be amenable to competition.[24] Restructuring and continued demand growth influenced utilities' approaches to energy efficiency programs. Sponsoring efficient lighting became palatable and potentially profitable.

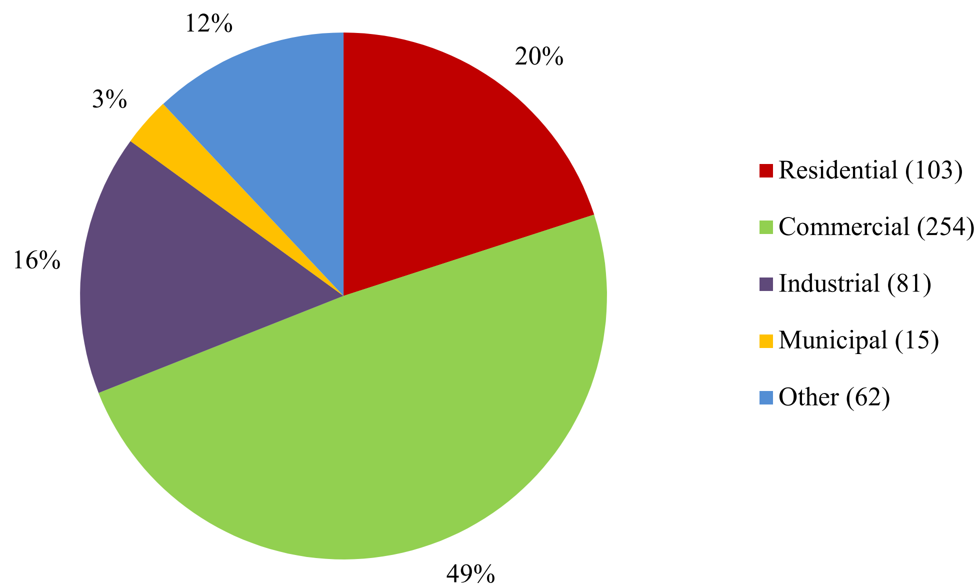
Many states were engaged with lighting policy at this time. Public service commissions and utilities used coupons, rebates, and other incentives as part of Demand Side Management (DSM) programs to encourage consumers to install efficient lamps so as to slow demand growth and delay building power plants and transmission lines. Many of these programs were designed for commercial and industrial customers who, as seen in figure 9.1 used much of the electricity devoted to lighting the US. For example, Wisconsin Electric Power offered rebates to the Milwaukee Public School System to install 175,000 electronic ballasts in nearly 150 buildings. The utility saved around 78 MW of lighting energy over a two year period, savings that "offset the entire cost of the job in five years."[25] Such programs appealed to business customers used to thinking about life cycle costs and return on investment, but most residential consumers gave priority to initial lamp purchase costs. Reversing earlier load building programs, lamp makers worked with utilities to subsidize CFLs to overcome consumer objections to high lamp prices, although as noted

23. Lee A. Craig, ed., "Consumption expenditures by type: 1929-1999," Table Cd187 in *Historical Statistics of the United States*, Millennial Edition On Line, eds. Susan B. Carter et al., (New York: Cambridge University Press, 2006), http://hsus.cambridge.org.

24. *Public Utility Regulatory Policies Act*, Section 210.

25. Leslie Lamarre, "Lighting the Commercial World." *EPRI Journal* 14 (December 1989): 8.

Figure 9.1: US electricity consumed for lighting, by sector, 1990[26]



The percentage of electricity used for residential lighting in 1990 had changed little since the 1950s. But other sectors used still more, despite adoption of fluorescent and discharge lighting. Electricity consumption figures are in billion kilowatt-hours.

above, not all liked what they saw.[27] Still, the programs played a major role in pushing CFLs and solid state ballasts into markets. By the late 1990s costs had dropped and many DSM programs scaled back for a time.[28] Reduced costs let to increased adoption and

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26. Atkinson, et al., *Analysis*, 1.1

27. Michael Arndt, "Energy Misers, Your Day May Be Back," *Chicago Tribune* (28 August 1988): F3. Susan E. Kinsman, "Utilities generate renewed interest in saving energy," *Hartford Courant* (4 November 1990): B1. Martha Groves, "PG&E Launches $2-Billion Energy-Saving Program," *Los Angeles Times* (31 January 1991): SDD1. Louis Rasky, "Consumers and Compact Fluorescents," Home Energy 10, no. 6 (November/December 1993): 11-13.

28. Marvin J. Horowitz, "Electricity Intensity in the Commercial Sector: Market and Public Program Effects," *Energy Journal* 25, no. 2 (2004): 117, http://www.jstor.org. William J. Roche interview with Harold D. Wallace, Jr., 31 October 1996, NMAH EC-LRF. Asked about the importance of DSM programs Roche replied, "...a couple of years ago, ... , I would have said very important, but that has really dried up....; it's a very small factor right now."

higher production, making both products readily available. That made them attractive for new federal energy policies.

While the Bush administration showed little interest in energy conservation, they understood well the political need to work with Democrats who controlled Congress. Neither party relished seeing gas lines return so they compromised; the Energy Policy Act of 1992 (EPAct92) was the result. As noted above, amendments in 1988 to the NAECA added a few fluorescent lamp ballasts to a list of appliances covered in that legislation.[29] Bush's proposed National Energy Strategy tried to remove those standards from the amendments, but compromise meant that the standards not only stayed in place but were augmented.[30] One columnist wrote:

> Unpopular or not, it does not seem likely that component regulations are going to go away..... In case anyone had forgotten that energy—the availability and the cost of it—has a severe impact on the life of the nation, recent events in the Middle East have reminded us of that fact.[31]

Much state and federal energy policy focused on large appliances like heating and cooling equipment, and many agreed that HVAC standards adopted in collaboration with ASHRAE in 1980 "worked remarkably well." Lighting designer Hayden McKay noted that, "the [1980 HVAC] standard got numbers for equipment efficiencies so low that the entire industry retooled. And it was a huge savings in energy! They think the same thing will happen in lighting."[32] That thought turned out to be correct. Mandating minimum

29. NAECA88.

30. National Energy Strategy Act of 1991, H.R. 1301, 102nd Cong. (1991), https://www.congress.gov.

31. Ruling, "Lighting Legislation," 103.

32. Ruling, "Lighting Legislation," 98. The 1980 standard referred to was ASHRAE/IES 90-1980.

standards with delayed implementation allowed producers time to conduct research and conveyors time to clear old inventory. Commercial and industrial consumers could replace expensive equipment with new, efficient units in a cost effective manner at end of service life. While slower than some advocates wished, this approach accomplished the goal without the economic and political risks of an outright ban. Lighting could consume half a commercial building's energy, by the lamps themselves or through higher air conditioner loads, making the potential savings for this one sector alone substantial.

EPAct92 included efficacy standards that fluorescent lamps with expensive rare-earth phosphors could meet but that lamps with inexpensive halophosphors could not.[33] Ballasts in several fluorescent systems were subject to the 1988 standards, now the tubes themselves were affected.[34] The standards removed the low price product and cleared the market of older lamps, forcing the new, high efficacy products into wider service.[35] Lamp prices rose at first but dropped over time as supply increased.[36] The legislation also replaced cheap incandescent spot and flood lamps with expensive, higher efficacy tungsten halogen versions. The few residential consumers who used these

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33. Bril et al., "Fluorescent Properties." Energy Policy Act of 1992, Pub. L. 102-486, 106 Stat. 2776 (1992). Hereafter EPAct92. One of the most common commercial fluorescent lamps, an 8' long unit designated F96 was also affected. Lamps for aiding plant growth and colored lamps were exempt.

34. NAECA88 set energy efficiency standards for the ballasts while EPAct92 set standards for the lamps used in those fixtures.

35. EPAct92. Lindsey, "Green Lights + EPACT," 11. Dowhan, "The Impact of EPACT," 40. See also: Jack Lindsey, "EPACT: Bad News for Some, Good News for Contractors," *Electrical Contractor* 60, no. 4 (April 1995): 41.

36. Russ Liddle, "Are Cool-White and Warm-White Phosphor Colors Extinct?" *Lighting Design & Application* 25, no. 1 (January 1995): 12. During EPAct92 rollout I worked in a Baltimore hardware store. Customers reacted negatively to the intervention; objecting to higher prices and government mandates. In 1995, older F40 lamps sold from 99¢ to $1.99. New F40 lamps sold from $5.99 to $12.99.

products noticed the change but the transition mostly affected commercial and industrial users.[37] The law also required development of, but did not set, standards for the discharge lamps often used in street lighting that many state and local governments were already replacing. As seen in table 9.1, EPAct92 was designed with a level of technical detail that reflects the close involvement of lighting experts, some of whom now worked within the Department of Energy. Relationships between actor networks dating from past ERDA and DOE programs allowed policy makers to design very specific regulations and ensured that industry concerns were heard.

The incremental adjustments to the earlier legislation proved effective in several ways. Dividing the markets along technical lines muted potential resistance and allowed manufacturers to adjust production in stages rather than across entire product lines. Targeting lamps used mostly in commercial and industrial lighting allowed policy makers to make economic arguments about life cycle costs that business people would likely find appealing. Drafting discharge lamp standards for later enactment allowed local governments to make budget preparations, and avoided penalizing early adopters by ensuring their systems would be compliant. The legislation hardly affected residential consumers; few used spot and flood lamps and they tended to operate cheap 40 W fluorescent tubes in only a few locations like garages. By avoiding general purpose incandescent lamps, policy makers minimized political resistance while achieving measurable energy savings. Later legislation did affect general purpose lamps, as discussed below, but policy makers would not have to face resistance from home owners and

37. Halogen reflector lamps debuted in the 1965 GE product catalog. They were still about twice the retail price of regular incandescent reflector lamps in the 1980s. Author's recollection from the hardware business.

Table 9.1: EPAct92 table showing standards for targeted lamps.[38]

"FLUORESCENT LAMPS

"Lamp Type	Nominal Lamp Wattage	Minimum CRI	Minimum Average Lamp Efficacy (LPW)	Effective Date (Months)
4-foot medium bi-pin	>35 W	69	75.0	36
	≤35 W	45	75.0	36
2-foot U-shaped	>35 W	69	68.0	36
	≤35 W	45	64.0	36
8-foot slimline	65 W	69	80.0	18
	≤65 W	45	80.0	18
8-foot high output	>100 W	69	80.0	18
	≤100 W	45	80.0	18

"INCANDESCENT REFLECTOR LAMPS

"Nominal Lamp Wattage	Minimum Average Lamp Efficacy (LPW)	Effective Date (Months)
40–50	10.5	36
51–66	11.0	36
67–85	12.5	36
86–115	14.0	36
116–155	14.5	36
156–205	15.0	36

This table from the EPAct legislation conveys the complexity of component level regulation. Four types of fluorescent tubes are specified, in two wattage ranges each. The 4-foot tubes >35 W affected residential users, the others much less so. CRI is color rendition index in which incandescent lamps = 100. There were several types of reflector incandescent lamps, typically residential consumers purchased either 75 W or 150 W units. Many exemptions appear in the legislation, as well as specific discharge lamps.

business owners simultaneously.

Lighting companies objected only mildly to the EPAct92 standards. Their trade organization, the National Electric Manufacturers Association, argued in favor of adopting holistic building standards rather than component standards, but noted that "significant energy savings are possible through intelligent lighting design, efficient components and

38. EPAct92, 106 STAT. 2824.

control."[39] No lighting producers submitted separate statements similar to Whirlpool's that "vigorously opposed" new washing machine and dryer standards.[40] Standards negotiated with lighting industry actors like ASHRAE, IEEE, and IES that attended to industry concerns and focused on low-profit lamps that producers could live without partly accounts for the muted response.

As with carbon lamps in WWI and fluorescent lamps in WWII, the industry used EPAct92 as cover. They pushed expensive new lamps into a reluctant market, leaving policy makers to face public ire.[41] GE, embroiled in legal action with the FTC and thirty-two states over their "Energy Choice" lamp packaging, had extra motivation to avoid public attention.[42] EPAct92 permitted wholesalers and retailers to sell existing stock to avoid loss, but banned production and importation of the affected fluorescents in 1994 and the other lamps in 1995. The law also pushed federal agencies to adopt efficient technologies in government operations; an action that lured manufactures the prospect of GSA and Post Office contracts.[43] Replacing older lamps with newer lamps did make the US more energy efficient. In this case, the policy goal complemented business goals.

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39. *National Energy Strategy (Part 5), Hearings on Energy Efficiency, H.R. 776, H.R. 1301, H.R. 1543, H.R. 2220, Day 2, Before the Subcommittee on Energy and Power*, 102nd Cong., 295 (1991), https://babel .hathitrust.org. Statement of Daniel K. Shipp, Vice President, Public Affairs, National Electrical Manufacturers Association.

40. *National Energy Strategy (Part 5)*, statement of Michael Thompson, Manager, Government Relations, Whirlpool Corporation.

41. Peter Passell, "Economic Scene: Energy standards aren't as oppressive as they may seem," *New York Times* (July 27, 1995): D2, http://search.proquest.com.

42. Ted Rieger, "False Advertising Ceases, Bum Deal Continues," *Home Energy* 10, no. 2 (March/April 1993): 8-9. GE changed the packaging and paid court costs without admitting wrongdoing.

43. EPAct92, Title I, subtitle F, "Federal Agency Energy Management."

As we have seen, energy-related policies in some form have long affected electric lighting, but environmental policy was a relatively new area for lighting regulation. As people redefined pollution as a problem rather than a condition, they supported banning hazardous materials such as the pesticide DDT and setting waste disposal standards. The lighting industry's need to deal with two materials, polychlorinated biphenyls (PCBs) and mercury, directly affected high efficiency lamps. In 1976, the Resource Conservation and Recovery Act laid out policy to mitigate the effects of hazardous waste, and the Toxic Substances Control Act gave the Environmental Protection Agency authority to regulate PCBs.[44] First made in the 1880s, PCBs were chemically stable, non-flammable, and widely used in electrical devices as a cooling and insulating fluid.[45] Many core-coil lamp ballasts contained PCBs, although newer magnetic ballasts and electronic ballasts lacked the PCB-laden capacitors of the older designs. As described above, building owners installed new ballasts to rid themselves of PCBs while saving energy.

Though PCBs proved manageable, mercury posed a more difficult problem and the lighting industry paid close attention to regulatory proposals. Designated a pollutant in a 1990 Clean Air Act amendment, no suitable alternatives existed.[46] Fluorescent and discharge lamps required varying amounts of the toxic metal to function, as did sunlamps found in many homes. To cut costs, producers had already reduced the mercury in their

44. Toxic Substances Control Act of 1976, Pub. L. No. 94-469, 90 Stat. 2003 (1976); Resource Conservation and Recovery Act of 1976, Pub. L. 94-580, 90 Stat. 2795 (1976).

45. Environmental Protection Agency, Office of Toxic Substances, "EPA's Final PCB Ban Rule: Over 100 Questions & Answers To Help You Meet These Requirements," Document 560R80002 (June 1980): 2-3, https://nepis.epa.gov.

46. Clean Air Act Amendment of 1990, Pub. L. No. 101-549, 104 Stat. 2538 (1990).

lamps from over a pound to mere milligrams, but the quantity of lamps entering the waste stream alarmed people.[47] CFLs and new very thin linear tubes used less mercury than old designs, and new fabrication techniques more precisely dosed each lamp.[48] Recyclers and the lighting industry worked with state governments to add lamps to recycling programs and by 2000, "over sixty businesses [operated] in 33 states to collect and recycle lamps."[49] The presence of mercury, even in minute amounts, still troubled some consumers however and later contributed to demand for a substitute product: LEDs.

Mercury played another role in lighting policy that turned out to have fortuitous consequences for policy advocates. In 1991, the EPA set up the Green Lights program to promote efficient commercial and industrial lighting. They reasoned that efficient lamps needing less electricity would reduce emissions of mercury and other pollutants from power plants. Program managers decided to "[let] the market work… Voluntary action based on clear incentives plus flexibility in approach equals tangible rewards for both the environment and the economy," recycling Herbert Hoover's idea.[50] Green Lights used "non-binding agreements" between EPA and participants, mostly large corporations, to

47. Cooper Hewitt Vapor Lamp Co., mercury vapor lamp, ca. 1904, NMAH-EC, catalog number 1998.0005.10, contains about one pound of mercury. H. H. Whitmore, "Mercury Content ofFluorescent Lamps," (12 May 1977), NMAH EC-LRF, lists 93 lamp types with dosages from 40 to 350 mg each.

48. Philips, "Alto" lamp electrode flares with dosing capsule, 1995, NMAH-EC, catalog number 1997.0389.01, shows one technique for precise dosing of lamps.

49. John Chilcott, "Lamp Disposal in the New Millennium," unpublished conference paper, (2000), 1, NMAH EC-LRF.

50. William K. Reilly, "Green Light for Green Lights," US EPA Communications and Public Affairs bulletin A-107, 17 January 1991, 15, in US EPA Green Lights Decision Support System, document no. 000R91101, https://nepis.epa.gov. Reilly was EPA Administrator.

increase market penetration of efficient lighting products.[51] The program acted as a hub for technical and financial information, and featured advertisements to recognize partners as environmentally responsible. That latter aspect may have moved GE to participate. Absent from the first year's list of Green Lights "Allies" that included most of their competitors, GE appears on the second year's list.[52]

Positive results impressed Clinton Administration officials who, in mid-1994, rolled Green Lights into the Energy Star Buildings initiative, a larger voluntary effort.[53] A later Government Accounting Office review quibbled with some of EPA's numbers but found that the program had succeeded and was viewed positively by former participants.[54] Later studies found that Green Lights significantly contributed to solid-state ballast adoption and showed the value of publicizing socially beneficial activities.[55] The addition of EPA to lighting actor networks gave energy and environmental policy advocates flexibility to shift strategies during this and subsequent political transitions. Policy

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51. Matthew L. Wald, "E.P.A. Urging Electricity Efficiency," *New York Times* (16 January 1991): D6, http://search.proquest.com.

52. "Green Lights Allies as of May 2, 1991," in US EPA Green Lights Decision Support System, document no. 000R91101. "Green Lights Allies as of March 2, 1992," in Green Lights Program: the First Year, document no. 400192003, https://nepis.epa.gov. Elizabeth Chrun, Nives Dolšak and Aseem Prakash, "Corporate Environmentalism: Motivations and Mechanisms," *Annual Review of Environment and Resources* 41 (2016):351.

53. Environmental Protection Agency, "Green Lights Update," EPA 430-N-95-001 (January/February 1995): 3. Environmental Protection Agency, "Building On Our Success," EPA 430-R-97-002, May 1997, for merger of Green Lights and Energy Star Buildings programs.

54. General Accounting Office, Resources, Community, and Economic Development Division, "Information on the Results of Four of EPA's Voluntary Climate Change Programs," Report no. GAO/RCED-97-163, June 1997, 5-7, http://www.gao.gov.

55. Marvin J. Horowitz, "Economic Indicators of Market Transformation: Energy Efficient Lighting and EPA's Green Lights," *Energy Journal* 22, no. 4 (Fall 2001): 95-122, http://www.jstor.org. Geller and Nadel, "Market Transformation Strategies," 310-11.

advocates could tailor their arguments as needed to fit preferred agendas by stressing how efficient lighting addressed either goal. This helped sustain their engagement with lighting during decades of turmoil as political polarization in the US grew.

While EPA used efficient lighting to support pollution control, the Department of Energy continued to support research on lighting devices to advance energy conservation. Two inventions supported by DOE at this time illustrate the limits of federal research funding, even when programs are well designed and implemented. The first invention, a new incandescent lamp that used a silicon carbide filament instead of tungsten, attracted modest support from the Electric Power Research Institute.[56] NIST tested samples and found that the "concept seems scientifically sound but requires further development to demonstrate its performance and implementation potential."[57] In 1993, NIST and DOE jointly provided a $100,000 grant but technical difficulties were intractable and, in hindsight, the idea came too late.[58] The same year NIST and DOE made their grant, Nakamura made his blue LED and incandescent lamps began sliding toward obsolescence.

The second project supported a new discharge lamp that did reach the market. Featuring a golf ball size quartz globe containing sulfur energized by microwaves, the

56. John V. Milewski and Peter D. Milewski, Single Crystal Whisker Electric Light Filament, US Patent 4,864,186, filed 29 March 1988 and issued 5 September 1989. John Milewski, telephone conversation with author, 16 April 1996.

57. Jogindar S. Dhillon, *Single Crystal Whisker Electric Light Filament, Energy-Related Inventions Program Recommendation No. 579* (National Institute of Standards and Technology report, 27 July 1992), in NMAH EC-LRF. EPRI provided $150,000.

58. Milewski, telephone conversation, 16 April 1996. A.H. Gomes de Mesquita, "The Polytypism of Silicon Carbide," *Philips Technical Review* 30, no. 2 (February 1969): 36.

lamp emitted a very bright light with good color properties.[59] After failing to interest traditional lamp makers, the inventors at Fusion Lighting contacted DOE staff who "immediately grasped the potential benefit."[60] Tests appeared promising with system efficacy near 65 lpW and a life rating of 100,000 hours. Consultants helped Fusion with UL standards and FCC regulations, and in 1994 the company unveiled the product in two risky demonstrations. Two sulfur lamps outside DOE's headquarters and three more in a gallery in the Smithsonian's National Air & Space Museum would be visible but politically embarrassing in case of failure.[61] The lamps worked well however and Fusion began making sales; an improved version gave nearly 100 lpW.[62] Success seemed assured as technologists, entrepreneurs, and public servants had all done their jobs, yet by 2003 the sulfur lamp was gone.[63] DOE's Lee Anderson, whom Kingdon might call the lamp's policy entrepreneur, had died in 1999. With more time lingering technical problems might have been resolved but like incandescents, discharge lamps were becoming obsolete.[64]

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59. US Patent Office, Technical Seminar "Fusion Lighting," 17 October 1995, notes in NMAH EC-LRF. Donald M. Spero, Bernard J. Eastlund, Michael G. Ury, Method and Apparatus for Generating Electromagnetic Radiation, US Patent 3,911,318, filed 4 February 1974 and issued 7 October 1975.

60. *Federal Technology Transfer Policies and our Federal Laboratories: Methods for Improving Incentives for Technology Transfer at Federal Laboratories: Joint Hearing Before the House Subcommittee on Technology and the Subcommittee on Basic Research of the Committee on Science*, 104th Cong., 218 (27 June 1995), https://babel.hathitrust.org. (Testimony of Michael G. Ury, 217-227, written statement 247-250).

61. Ury interview, 20 March 1996.

62. Curt Suplee, "A New Kind of Illumination That Burns Brightly, but Not Out," *Washington Post* (October 24, 1994): A3. Staff, "Sunlight In A Bulb," *Discover* (June 1995): 77. For ratings see, B. P. Turner, Michael G. Ury, Y. Leng and W. G. Love, "Sulfur Lamps—Progress In Their Development," (Paper presented at meeting of the Illuminating Engineering Society, August 1995). They also installed demonstrations in a Washington Metro station and on a highway sign over the Capital Beltway.

63. Alex Wilson, "Sulfur Lighting No Longer on Track," *Environmental Building News* 14, no. 8 (August 2005), https://www.buildinggreen.com. Fusion licensed the patents to LG of Korea.

64. Author's conversations with various lighting industry individuals in 2000 and 2001.

Schumpeter’s creative response in the form of LEDs was gaining market share by 2003, upending research agendas in private and public sectors alike.

These two projects failed, one due to problems of invention, the other due to problems of diffusion. Other lighting policy moved forward in the 1990s as EPAct92 efficiency mandates and Green Lights’ voluntary agreements helped to move solid-state ballasts and CFLs into commercial and industrial markets. Private sector actors supported these efforts to aid in diffusing expensive new products. Small steps to regulate a few residential lamps generated modest energy savings without antagonizing too many people. Although energy policy dropped on the Clinton administration’s agenda, engagement continued between public and private sector actors. That aided both when a tragic policy window opened and renewed federal interest in energy policy.

2000s: unexpected events

On 11 September 2001, Islamic radicals commandeered four commercial airliners and used three to destroy the World Trade Center in New York City and severely damage the Pentagon. Like the onset of both world wars and the oil embargo, that horrific event opened a policy window that pushed the US out of routine political and economic paths, changed agendas, and resulted in reordered priorities.[65] In the aftermath, new priorities included enhancing the security of US energy infrastructures and addressing a slow but

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65. *National Electricity Policy: Federal Government Perspectives. Hearing Before the Subcommittee on Energy and Air Quality of the Committee on Energy and Commerce*, 107th Cong., (20 September 2001), 1, https://web-beta.archive.org. Chairman Barton's opening statement began, “As a result of last Tuesday, our Nation’s focus has fundamentally shifted.” That is one of many such statements.

steady rise in oil prices.[66] Despite better lamp and appliance efficiency, adoption of air conditioners, personal computers, and other electrical devices increased electricity demand. Grid capacity and reliability rivaled fuel supplies on policy makers' agendas.[67]

The Clinton Administration's interest in energy policy had centered on climate change, but they accepted the EPAct92 legislation they inherited as advancing those goals.[68] While some law makers objected to energy standards crafted by "overzealous bureaucrats" that would "sharply limit" consumer choice, most legislators viewed the standards as either successful or mildly annoying.[69] Larger problems, especially with the electrical infrastructure, occupied their attention. Utilities still depended heavily on fossil fuels linked to climate change. The failure of California's restructuring program in 2000 and the uneven status of similar efforts across the country added to their concerns. Less worried about climate change than boosting energy supplies, a new Bush Administration began seriously discussing new energy regulations in early 2001.

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66. Alexander E. Farrell, Hisham Zerriffi and Hadi Dowlatabadi, "Energy Infrastructure and Security," *Annual Review of Environment and Resources* 29 (2004): 421-469, http://www.annualreviews.org.proxy-bc.researchport.umd.edu. Energy Information Agency, "U.S. Landed Costs of OPEC Countries Crude Oil," https://www.eia.gov. This and other measures show a downward trend in oil prices right after 9/11, then a slow rise from Spring 2002 to 2008.

67. *Various Electricity Proposals Including, but not Limited to, S. 475, the Electric Transmission and Reliability Enhancement Act of 2003: Hearing before the Committee on Energy and Natural Resources.*, 108th Cong. (27 March 2003), http://frwebgate.access.gpo.gov. Nye, *Consuming Power*, 238-246.

68. 143 Cong. Rec. S11,019 (23 October 1997), https://www.congress.gov (Remarks of President Clinton on Global Climate Change Before the National Geographic Society). Clinton cited CFLs as one way to reduce CO_2 emissions.

69. 141 Cong. Rec. S12,024 (9 August 1995), https://www.congress.gov. (Remarks of Mitch McConnell on Amendment 2323). The amendment, a 1 year moratorium on standards, including fluorescent ballasts, generated mild debate (S12,032), and became part of an Interior Dept. appropriations bill vetoed by President Clinton. Amendment text: 141 Cong. Rec. S11,860 (8 August 1995); Interior appropriations bill: H.R.1977. Clinton's veto message, 141 Cong. Rec. H15,057 (18 December 1995), cites "slashes" in energy conservation programs as one factor. Congress did not override the veto. https://www.congress.gov.

As Kingdon pointed out, legislation frequently requires years of negotiations and adjustments that span several Congressional sessions. "The first major energy legislation of the 21st century," proved no exception.[70] Both House and Senate debated the Securing America's Future Energy Act of 2001, a bill that transitioned into the Energy Policy Act of 2002. That bill expired in conference committee, but an amendment for a Next Generation Lighting Initiative (NGLI) called on DOE to assemble an industry consortium to make grants and promote LED research and development.[71] NGLI returned in new Energy Policy Acts introduced during the next two Congressional sessions, as did energy standards for exit signs, traffic signals, and torchieres, but no bill completed the legislative process. In 2003, the US invaded Iraq, oil prices rose, and a blackout darkened the North East and parts of Canada.[72]

After two more years, Congress passed and George W. Bush signed the Energy Policy Act of 2005.[73] Most of EPAct05 dealt with energy supplies but slim Republican majorities in Congress meant that standards to improve lighting efficiency remained a necessary compromise. As with EPAct92 the new standards incrementally expanded

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70. Kingdon, *Agendas*, 116. 147 Cong. Rec. H5,008 (1 August 2001), https://www.congress.gov, for quote. (Text of H.R. 4, Securing America's Future Energy Act of 2001). *National Energy Policy: Conservation and Energy Efficiency. Hearing Before the Subcommittee on Energy and Air Quality of the Committee on Energy and Commerce*, 107th Cong., June 22, 2001, https://web-beta.archive.org. The people and positions in this hearing reappear in subsequent years.

71. 147 Cong. Rec. S7,516 (11 July 2001), https://www.congress.gov. (Remarks by Jeff Bingamanand text of S.1166, a bill to establish the Next Generation Lighting Initiative at the Department of Energy). This became section 912 in EPAct05.

72. Nye, *When The Lights Went Out*, 154-180. See also, *Blackout 2003: How Did It Happen and Why? Hearings Before the Committee on Energy and Commerce House of Representatives*, 108th Cong., (3-4 September 2003), http: //www.gpo.gov.

73. Energy Policy Act of 2005, Pub. L. 109-058, 119 Stat. 594 (2005), http://thomas.loc.gov. Hereafter EPAct05.

previous regulations. Comparing 1990 and 2002 lighting electricity consumption (figure 9.1 above and 9.2 below), the effect of adopting CFLs and solid-state ballasts had started lowering the percentage of energy used outside the residential sector. EPAct92 played a role in the energy savings. EPAct05 continued to promote efficient lighting products for commercial buildings and included tax deductions to encourage their use, but also included more rules that affected the residential market. Light kits for ceiling fans, for example, were required to include an Energy Star compliant lamp for each socket.[74] Though intended to promote CFLs, fan makers could instead "use [other Energy Star compliant] light sources."[75] That clause and new standards for traffic and pedestrian signals meant LEDs. EPAct05's inclusion of NGLI, "to develop advanced solid-state organic and inorganic lighting technologies based on white light emitting diodes" showed policy makers' awareness of technical advances and conceded uncertainty.[76] Supporting two distinctly different types of white light LEDs, "organic or inorganic," avoided suppressing competition by prematurely selecting either, an approach Stoneman and Diederen, who warned of the risk of too quickly introducing a new technology, would appreciate.[77]

LEDs seemed like a way around public discomfort with mercury in CFLs, especially as LED efficacy climbed steadily higher, but high purchase cost remained a problem. By 2005, CFLs were much less expensive than 20 years earlier and getting cheaper as large retailers such as Walmart began using and selling them instead of

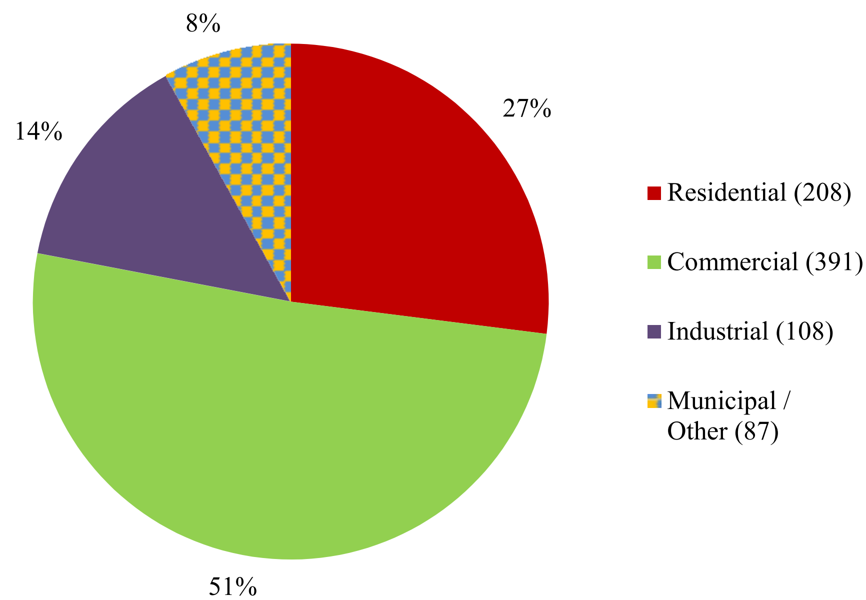
74. EPAct05, Sec. 135. For ceiling fan light kits see subsection ff, 119 Stat. 633.

75. EPAct05, 119 Stat 633, subsection ff, paragraph 2, B, ii.

76. EPAct05, 119 Stat 859. (42 USC 16192).

77. EPAct05, 119 Stat. 858 for LEDs and OLEDs. Stoneman and Diederen, "Technology Diffusion," 919.

Figure 9.2: US electricity consumed for lighting, by sector, 2001[78]



In 2001, the percentage of electricity used for residential lighting use had risen, reflecting continued use of incandescents as EPAct92 standards began to affect other lighting sectors. The figures cited combine the data for municipal and other electricity use. Residential energy use for lighting doubled since 1990 (figure 9.1) while the combined energy used to light other sectors remained about the same. Electricity consumption figures are in billion kilowatt-hours.

incandescents.[79] As with CFLs in the 1980s, LED makers needed to amortize production lines, recover research investments, and develop marketing programs. White light LEDs for general applications began entering the market at the high end of the cost curve. Rebate coupons that subsidized lamp purchases of CFLs at one price point and LEDs at another reflected the different stages of each lamp's price structure as late as 2012.[80]

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78. Navigant Consulting, with Xenergy, Inc. *U.S. Lighting Market Characterization, Volume I* (US Department of Energy, Office of Energy Efficiency and Renewable Energy, September 2002): x, 63, http://apps1.eere.energy.gov.

79. Chrun, et sl., "Corporate Environmentalism," 350. In 2005, Walmart stopped selling general purpose incandescent lamps in favor of CFLs.

80. Southern Maryland Electric Cooperative, "Grow Your Savings-One Bulb at a Time," coupon emailed to

Including more lighting standards provoked only modest debate in the various hearings leading to EPAct05. No lamp makers testified; as before they relied on NEMA, whose president, Malcolm O'Hagan offered the following in 2003 testimony:

> Market based incentives and solutions should be the primary vehicle to enhance energy efficiency and conservation. However, NEMA acknowledges that *on a case-by-case basis there is value in other interventions such as targeted incentives and standards*. We are pleased to see that the bill relies on standards which I just cited. Market based incentives include Energy Star, and we support making this a statutory program. NEMA also recommends that the legislation include energy conservation standards for medium-based compact fluorescent lamps, *which is not currently the case*.[81]

Their acquiescence indicates that NEMA's lighting members, especially GE, Philips, and Osram Sylvania, not only accepted but encouraged the standards. That O'Hagan then recommended adding standards for medium-based CFLs (adopted as Section 135) indicated the desire to continue pushing CFLs, and also to exclude lower quality lamps coming in from China.[82] NEMA would not have supported these regulations over the objections of their members but would have taken no position, as they did when Philips objected to mercury disposal rules that GE and Sylvania supported.[83]

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author 19 April 2012. By presenting the coupon to a participating retailer one could "save $1.50 on a single [CFL] or $3 on multipacks [and] save $10 on Energy Star qualified LEDs."

81. *Comprehensive National Energy Policy: Hearing before the Subcommittee on Energy and Air Quality of the Committee on Energy and Commerce*, 108th Cong., (5-13 March 2003), 150, https://webbeta.archive.org. Emphasis mine.

82. *Comprehensive National Energy Policy* for O'Hagan's testimony about needing standards because of "cheap" products. L. J. Sandahl, T. L. Gilbride, M. R. Ledbetter, H. E. Steward and C. Calwell, *Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market* (Report for US Department of Energy, Office of Energy Efficiency and Renewable Energy, June 2006), https://energy.gov. See page 3.6 for report of 2001 EU sanctions on China for dumping low-cost CFLs that "caused numerous suppliers from Asia to shift their marketing efforts to North America, greatly increasing the available supply of CFLs, especially low-cost products, and driving additional price competition."

83. John Chilcott, "New Rules Proposed for Mercury Lamp Disposal," *Lighting Design & Applications* 27,

As noted above, comprehensive legislation like EPAct05 can often take years and several sessions of Congress to enact but there are exceptions. Democrats gained control of Congress in 2006 and immediately began revising EPAct05 to strengthen parts they favored and weaken or repeal parts they opposed. During negotiations in 2007 both sides sought to advance their agendas while avoiding a veto from a lame-duck president who recognized that a revised energy bill was likely and accepted compromises. In December, Congress passed and Bush signed the Energy Independence and Security Act of 2007.[84] EISA's most important lighting provisions set efficiency standards for general purpose incandescent lamps with the expectation that LEDs and CFLs would replace them.

Medium-based lamps in 40, 60, 75, and 100 watt ratings were required to meet minimum efficacy standards phased in between 2012 and 2014.[85] Maximum wattage ratings for smaller bases were set and adapters prohibited.[86] EISA exempted almost two dozen special products like rough-service and appliance lamps but set "backstop" standards to be enacted if people began substituting those to circumvent the law. The Secretary of Energy was directed to begin reviewing the standards by 2020 with changes to take effect by 2022. The delayed implementation gave suppliers time to sell existing inventory and CFL prices time to fall, while allowing time to pass in anticipation of a

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no. 12 (December 1997): 20.

84. EISA07.

85. EISA07, 121 S 1577 gives implementation dates as 1 January 2012 for 100 W lamps, 1 January 2013 for 75 W lamps, and 1 January 2014 for 40 and 60 W lamps.

86. EISA07, Sec. 321, 121 Stat. 1573. While intermediate-based lamps are relatively uncommon, many homes have candelabra-based lamps in decorative fixtures. 121 Stat. 1578. For base adapter prohibition, 121 Stat. 1586.

political backlash. Advocates repeatedly stressed that EISA standards could be met by incandescent halogen lamps, CFLs, and LEDs, but the law effectively banned ordinary incandescent lamps common in most homes and many people would be upset.

Almost thirty years after component standards began boosting lighting efficiency in other sectors, policy makers felt ready to take major action in the residential sector, the largest market for general purpose incandescent lamps.[87] As reflected in figure 9.3, eliminating those lamps represented a large opportunity to reduce lighting energy in the US.[88] Unlike other users however, most residential users cared little about efficient lamps. Lighting consumed such a small portion of residential energy budgets that the prospect of paying high prices for new, unfamiliar lamps to gain a minor reduction on electric bills caused an uproar about government overreach. Some in Congress, citing personal freedom, objected to eliminating consumers' ability to choose Edison's "beloved" invention, and introduced bills to repeal the standards, but few members signed as cosponsors.[89] Other opponents objected to the mercury in CFLs, while proponents noted the greater amount of mercury released by burning coal to operate incandescent lamps.[90]

In Senate hearings Howard Brandston testified in support of repeal, irritated mostly

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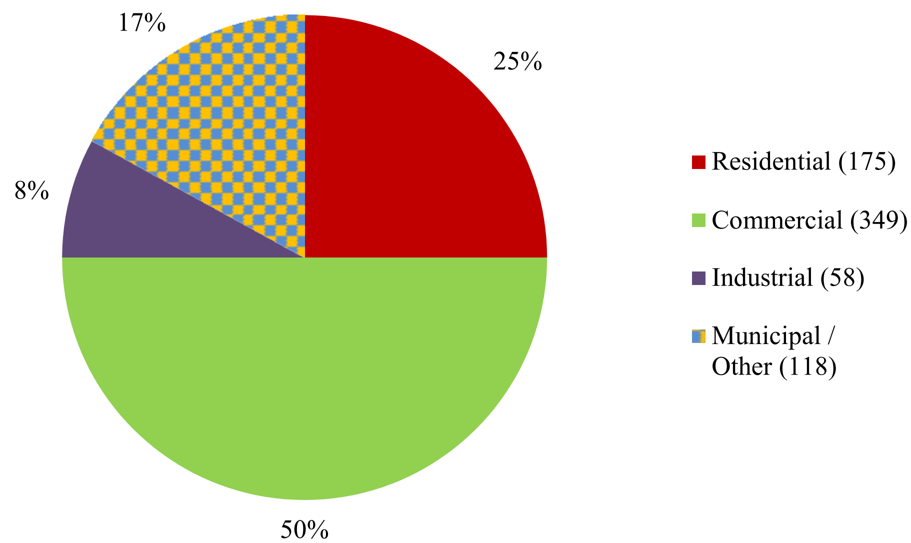
87. Ashe et al., *2010 U.S. Lighting Market Characterization,* 64.

88. Eugene Hong, Louise A. Conroy, and Michael J. Scholand, *U.S. Lighting Market Characterization, Volume II: Energy Efficient Lighting Technology Options* (US Department of Energy, Building Technologies Program, 30 September 2005), 1-3, http://www1.eere.energy.gov.

89. Better Use of Light Bulbs Act, S. 395 and H.R.2417, 112th Cong. (2011), https://www.congress.gov. Thomas Edison BULB Act, H.R.3818, 113th Cong. (2014), https://www.congress.gov; for two examples of repeal attempts.

90. The Senate *Energy Efficiency Standards* hearing (March 2011) includes a discussion of the mercury issue. Evan Mills and Mary Ann Piette, "Advanced Energy-Efficient Lighting Systems: Progress and Potential," *Energy* 18, no. 2 (1993): 75-97.

Figure 9.3: US electricity consumed for lighting, by sector, 2010[91]



By 2010, the percentage of electricity used for residential lighting began to fall, reflecting adoption of CFLs. Efficient lamps and energy saving designs continued to reduce lighting energy use in other sectors also. The figures cited combine the data for municipal and other electricity use as "outdoor." Electricity consumption figures are in billion kilowatt-hours.

by interference in his design options, but he also recognized the role of producer self-interest in the standards.[92] "This de facto ban is a marvelous bit of marketing for those companies—they had a product that wasn't selling as well as anticipated—now the government is banning the favored product."[93] He correctly saw that lamp makers were using the legislation to replace older lamps with new expensive ones. EISA continued twenty years of incrementally enacting lighting component standards developed by public and private sector actors, each with their own goals in mind. Most in the industry strongly

91. Ashe et al., *2010 U.S. Lighting Market Characterization*, xii.

92. *Energy Efficiency Standards,* (March 10, 2011).

93. *Energy Efficiency Standards,* (March 10, 2011), 67.

opposed repealing EISA standards for economic reasons, including "avoiding a patchwork of state standards," "addressing market failures and barriers," and to prevent "[stranding] millions of dollars of investments."[94] In hearings, other witnesses supported the standards as reducing pollution and curtailing electricity load growth, thus placing social benefits above individual convenience. Barack Obama's Administration shared that view and the EISA standards took effect on schedule.[95]

The delayed implementation also allowed for more LED refinements. Between Nakamura's 1993 breakthrough and passage of EISA, LED efficacy had gone from about 20 lpW to about 80 lpW.[96] As seen in table 9.2, that rate of increase was unmatched by improvements in any other light source. Although prices could approach $60 for one lamp, technical advances combined with adoption in other markets for such uses as street lights promised near-term price reductions.[97] EISA encouraged that work by offering prizes for a mass-producible, 60 W incandescent lamp replacement that met standards attainable only by LEDs, and committed GSA to buying the winner for federal facilities.[98]

Certainly LEDs had problems and people needed time to adjust to the new lamps.

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94. *Energy Efficiency Standards,* (March 10, 2011), 28 for state standards and market failures; 47 for stranded investment concern.

95. The House reportedly voted to delay implementation on 16 December 2011. I can find no record of a vote in the Congressional Register. Diane Cardwell, "Despite Delay, the 100-Watt Bulb Is on Its Way Out," *New York Times* (17 December 2011): B1, http://search.proquest.com.

96. M. George Crawford, Nick Holonyak, Jr., and Frederick A. Kish, Jr., "In Pursuit of the Ultimate Lamp," *Scientific American* 284, no. 2 (February 2001): 64. LED efficacy can vary depending on the materials used and the wavelength of light, around 2001 it ranged from about 7 lpW to about 50.

97. Julie Scelfo, "Any Other Bright Ideas?" *New York Times* (10 January 2008): F1, http://search.proquest .com. An LED lamp is shown with a price of $59.

98. EISA07, 121 Stat. 1702-1703. The "Bright Tomorrow Lighting Prizes" could award up to $10 million.

Table 9.2: Lamp efficacy comparison (lpW), 1990-2015[99]

Date	Regular inc.	Tungsten halogen	Mercury vapor*	Metal halide	Linear flu.	CFL	LPS	HPS	LED
1990	15.38	27.14	43.75	80	87.5	46.6	183	112.5	20
1995	15.38	28.57	45.5	80	88	54.6	198.47	112.5	50
2000	15.38	33	45.5	100	100	58.86	198.47	125	90
2005	15.38	33		100	100	80	198.47	125	92
2010	15.38	33		100	100	80	198.47	125	105
2015		33		100	100	80	198.47	125	113

During the 1900s and 2000s, efficacies for most lamp types plateaued. LED efficacies rose far faster however. Unable to meet minimum energy standards, regular incandescent and mercury vapor lamps were removed from the market during this time. The examples in this table are representative, selected to show efficacy improvements. An attempt was made to keep parameters such as wattage equivalent within each type, but changes in makers' product offerings and inconsistent data between manufacturers make comparisons approximate.

Some municipalities in the south-west discovered their new LEDs traffic signals failed prematurely in high ambient temperatures. Special designs were needed for use with the dimming controls common in many homes and offices; ordinary LEDs could catch fire when used with dimmers. People complained about high brightness. Not all adjustments were technical, though. In 2010, GE closed their last US factory for general purpose incandescent lamps, the heavily-automated "shining" Winchester, Virginia, plant they had upgraded with great fanfare in 1990.[100] Two hundred workers lost their jobs as GE turned to selling CFLs and LEDs, many of which came from other countries.[101] However, in 2015 near Raleigh-Durham, North Carolina, Cree began expanding their ultra-clean, LED fab.

99. Source: product catalogs, NMAH EC-LRF. Values cited are representative examples.

100. Peter Whoriskey, "How innovation killed the lights," *Washington Post*, 8 September 2010, http://www.washingtonpost.com.

101. Peter Whoriskey, "Light bulb factory closes; End of era for U.S. means more jobs overseas," *Washington Post*, 8 September 2010, http://www.washingtonpost.com.

Employment exceeded 7000 workers to meet increased demand for a product that faced declining competition from other lamps.[102]

With more investment, LED efficacies continued to rise, costs declined, and adoption in all market sectors exploded in the 2010s. Long life ratings, modular designs, and high output meant that LEDs could be adapted for applications from surgical lamps to sports arenas. In 2014, Philips designed a commercially practical lamp that gave 93.4lpW to claim EISA's award (the "L Prize"), and began supplying a version of that lamp to mass retailers the following year.[103] Commercial products with efficacies of over 100 lpW became common by 2015 and laboratory experiments exceeded 300 lpW.[104] Users could swap fluorescent lamps for tubes containing LEDs to avoid replacing luminaires.[105] New applications added to demand, as non-traditional lighting companies designed products that included illumination as an accessory. App designers developed ways for smartphones to communicate with lighting systems through the LEDs. Retail chains installed LEDs with WiFi capabilities so they could track shoppers inside their stores via smartphones.[106] Some users found that internet-enabled smart lamps gave criminals a path into home computer

102. Greg Merritt, conversation with author, 5 April 2016.

103. Office of Public Affairs, US Department of Energy, "Department of Energy Announces Philips North America as Winner of L Prize Competition," Press Release with Attachments (3 August 2011), in NMAH EC-LRF.

104. Peter Kelly-Detwiler, "LEDs Will Get Even More Efficient: Cree Passes 300 Lumens Per Watt," *Forbes* (27 March 2014), https://www.forbes.com.

105. Willard L. Warren, "Ingenious Upgrade," *Lighting Design & Applications* 47, no. 4 (April 2017): 24. See also http://www.cee1.org.

106. Paul Buckley, "LEDs tap indoor location technology for social shopping," *EETimes.com* (30 May 2014), http://www.electronics-eetimes.com.

systems.[107] High efficacy and the ease with which LEDs could be digitally controlled promised significant energy savings and further convergence.

As LEDs prices dropped, consumers also adapted. In May 2017, the Walmart in La Plata, Maryland, displayed a 32-foot run of residential and consumer lamps that included a few fluorescents, halogens, and specialty incandescent lamps, all EISA compliant. Well over half of the products offered were LEDs. A four-pack of 60 W-equivalent lamps sold for $1.97 and a four-pack of dimmable lamps for $3.97. CFLs were conspicuous by their absence. The Home Depot in Centerville, Virginia, displayed a 60-foot run of residential and commercial lamps including about a dozen CFLs, clearly being discontinued. The store stocked EISA compliant incandescents, linear fluorescents, and discharge lamps but again over half the lamps offered were LEDs. A four-pack of 60 W-equivalent lamps sold for $6.98.[108] Diffusion of LEDs into all lighting market sectors proceeded at a steady pace. Incremental changes in federal lighting policy to save energy and reduce pollution helped advance a technological revolution.

Later period, second phase: the end of an era

The political, economic, and technical contexts in which US lighting policy has been crafted all changed during this last period of study. George H. W. Bush signed EPAct92 in front of an oil derrick, signaling his support for increasing energy supplies. In a 1997 speech, Bill Clinton touted CFLs as a way to reduce carbon emissions, reflecting his

107. Paul Buckley, "Security vulnerability of smart bulbs is revealed," *EETimes.com* (7 July 2014), http://www.electronics-eetimes.com.

108. Site visits, Walmart, 15 May 2017; Home Depot, 27 May 2017.

environmental priorities. George W. Bush signed EPAct05 at Sandia National Laboratory. While committed to increasing energy supplies, Bush needed to deal with complex problems in the electric power infrastructure. Barack Obama visited Cree in 2011 and discussed how LEDs and other efficient devices could create jobs.[109] For all their differing political views, they shared a trust that technology could help solve the nation's energy problems.[110] However, as Amory and Hunter Lovins wrote in 1991, taking a holistic approach to lighting design would require more than "just new technology but *also new thinking*, and new ways to deliver integrated packages of modem hardware *plus managerial and cultural changes*."[111] Those cultural changes became apparent as a new generation of illuminating engineers and lighting designers entered practice, less wedded to the more-light-is-better-light paradigm of earlier generations.[112] Cultural change reinforced the other contextual changes to make the mid-2010s a different environment for lighting policy than 1990.

The relationship between public and private sector aided both in pursuing their respective goals. Legislation from 1988 through 2007 set lighting standards guided by interactions within the actor networks. As per the first research question, the invention and diffusion of high efficacy lamps during that period gave policy makers realistic and

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109. Barack Obama, "Remarks at Cree, Inc., in Durham," *Public Papers of the Presidents of the United States: Barack Obama, 2011* (Washington, DC: GPO, 13 June 2011), 1:659-662, https://www.gpo.gov.

110. Rep. Joe Barton (R-TX) correctly observed that during the Clinton years, "we've had an environmental policy that drove energy policy." Joseph Kahn, "Energy Efficiency Programs Set for Bush Budget Cuts," *New York Times* (5 April 2001): A15, http://search.proquest.com.

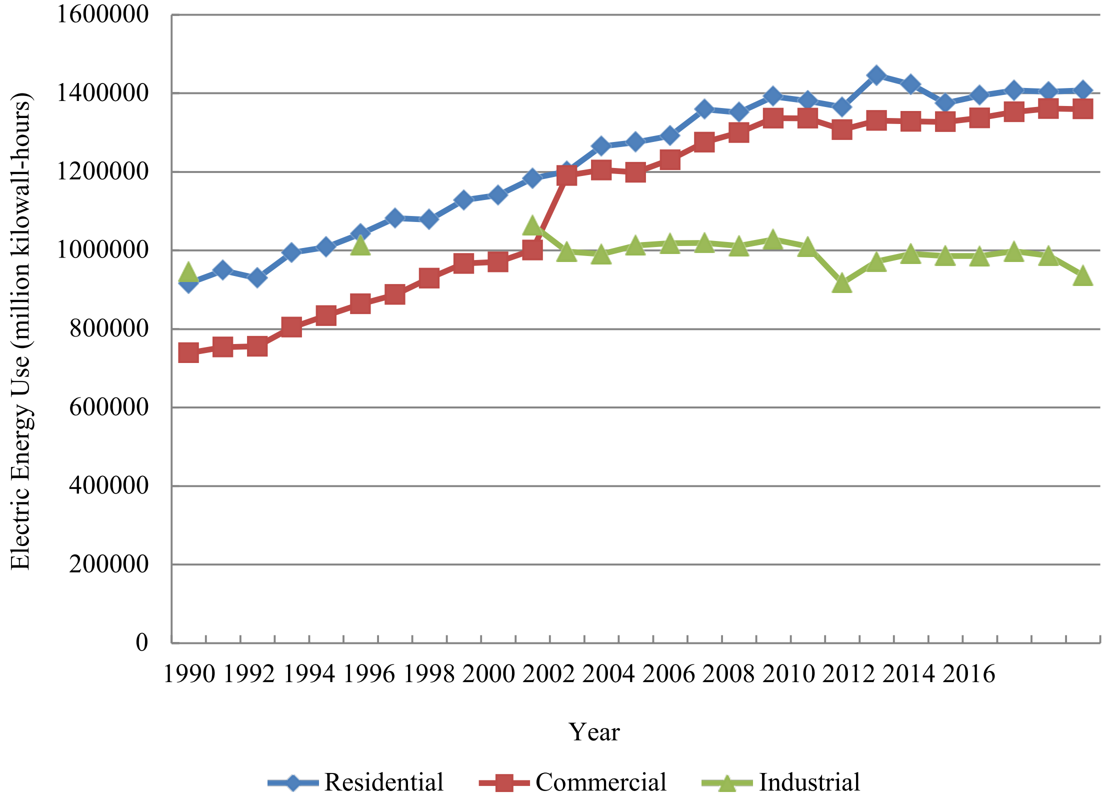
111. Amory B. Lovins and L. Hunter Lovins, "Least-Cost Climate Stabilization," *Annual Review of Energy and the Environment* 16 (1991): 444, http://www.annualreviews.org.proxy-bc.researchport.umd.edu. Emphasis mine.

112. Clear and Berman, "Economics," 77-86. Conway, "Lighting Makeovers," 20-25.

increasingly affordable alternatives when developing those policies. And as per the third research question, the private sector used those policies to promote the new products and clear the market of older inventory. Active engagement helped avoid problems seen in policies of the 1910s and 1940s. In this later period, competition and a desire to avoid the appearance of collusion enhanced the role of groups like NEMA and IES. The former could represent producers' views while the latter served as a cultural link between professionals in government and industry. A wider range of network actors allowed the emphasis on efficiency to come forward. The paradigm shift in lighting, discussed in chapter eight, was accepted by many new network actors so that pressure to maintain lighting energy levels could be overcome. The desire to cut energy used for lighting drove policy goals and ultimately contributed to a leveling of electrical demand growth, as seen in figure 9.4.

Considering the second research question—policy makers used lighting to advance energy goals in this era and deliberately pursued an incremental approach that first affected change in low-profile yet important areas, while building partnerships in the lighting industry. They later extended early success and took advantage of political opportunities to enact more controversial interventions when potential opponents wanted compromise. Although one must avoid the fallacy of counterfactual history, there seems little doubt that federal policy pushed the introduction of high efficiency lighting much sooner than would otherwise have occurred. The speed and extent of that acceleration might be debated, but successive federal lighting policies helped bring the nation to the threshold of a major advance in energy efficiency that previously seemed impossible. That is, the retirement of

Figure 9.4: Electric energy use in the United States, by sector, 1990-2016[113]



Electrical energy use trended upward throughout the 1990s but plateaued in the 2000s. The effect of the 2008 recession is apparent. Note: The Industrial sector data in the Annual Energy Review is given only in 5-year increments from 1970 through 2000, annual data resumes at that point.

incandescent lamps for general purpose lighting nearly 140 years after Thomas Edison's demonstration on the snow-covered grounds of his Menlo Park laboratory. That achievement raises important questions for future policy makers, such as what happens when the last of the low-hanging fruit has been harvested?

113. Source: Gavin Wright, "Electrical energy–sales and use: 1902–2000," Table Db229-231 in *Historical Statistics of the* United States. EIA, "Electricity End Use," (January 2016), 123.

Chapter Ten: Conclusions and Consequences

Energy efficiency standards that encouraged adoption of light emitting diodes (LEDs) in place of incandescent lamps fed revolutionary changes in the world of electric lighting. Energy conscious policy makers saw decades of work bear fruit when the share of electric power spent lighting the US fell from about 15% of the total generated to about 7% between 2010 and 2017, as seen in figure 10.1.[1] While lighting remains symbolically useful to policy makers for now, success in pushing markets toward efficient products lessens the impact of lighting initiatives in advancing energy and environmental objectives. The adoption of lamps with extremely high efficacy coupled to devices that must not be deactivated means that policy makers will need to rethink their how they use lighting to advance energy conservation goals. Adopting a holistic, systems approach would be one reasonable approach that would seem to offer room for continued improvements. Encouraging more use of automated lighting controls would be another. Regardless, ongoing fundamental changes in the technology and business of lighting make this an ideal time to look back at the intersections of federal policies and industry developments to learn how we arrived at this point. Understanding what changed, what remained constant, and the contexts within which past decision makers worked can help future policy makers avoid mistakes such as employing false analogies, and improve the probability of success for new alternatives.

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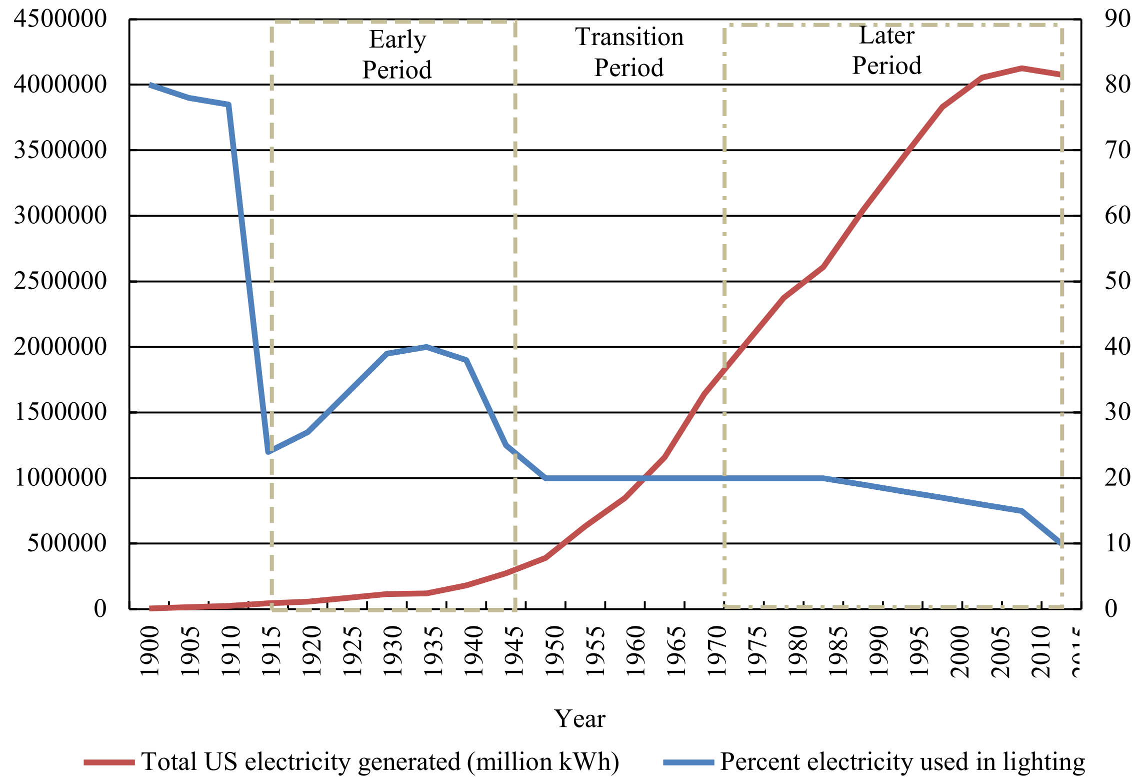
1. EIA, "How much electricity is used for lighting in the United States?" (15 February 2012), https://www.eia.gov, for 15 percent figure; EIA, "How much electricity is used for lighting in the United States?" (9 February 2018), https://www.eia.gov, for 7 percent figure.

Figure 10.1: Electricity used for lighting as percent of total generated, 1880-2015[2]



As the amount of electricity used for lighting declined in percentage, the interests of lamp makers and utilities diverged. Rapid adoption of electricity for other uses accounts for 1900-15 decline in percentage of electricity used for lighting. A rebound from 1915-40 came with the push to raise light levels using tungsten lamps. The 1940-55 decline reflects adoption of fluorescent lamps and rural electrification. After stabilizing from 1955 to 1985, use dropped with adoption of high efficiency linear fluorescents and CFLs, hastened after 2010 by LEDs.

The preceding chapters examined federal policies related to electric lighting and interactions between public and private sector actors beginning in the technology's earliest

2. Sources: Atkinson, et al., *Analysis*; Campbell, "Facts about lighting;" EIA , "How much electricity;" Jacob Martin Gould, *Output and Productivity in the Electric and Gas Utilities: 1899-1942* (New York: National Bureau of Economic Research, Inc., 1946); Nadine Lihach, "Evolution in Lighting," *EPRI Journal* 9 (June 1984): 6-13; Gavin Wright, "Electrical energy - sales and use: 1902-2000," Table Db228-233 in *Historical Statistics of the United States, Earliest Times to the Present*, Millennial Edition, edited by Susan B. Carter, Scott S. Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, (New York: Cambridge University Press, 2006). Data points are approximations due to variation in record keeping but the trends are accurate. The Bureau of the Census began tracking lighting in 1902 but contemporary sources agree that almost all dynamo-generated electricity was devoted to lighting before that time.

years. The goals were to understand the decisions people made, how those decisions affected the course of events, and to determine if lessons exist for future policy makers. To pursue those goals I chose three interconnected research questions that looked at the historical record from the perspectives of technology, policy, and economics. In the sections below I review those research questions, recount the major themes as they appeared during each historical period, present findings, and offer lessons learned and insights that emerged from this research.

The research revealed a distinct periodization wherein differing political and economic contexts directly affected policy formation and outcomes. The different rates of change in US electricity used for lighting seen in figure 10.1 are just one example of that periodization. More profound examples for policy makers also emerged from the research. After an introductory period when even the inventors worked to comprehend the technical and commercial intricacies of the new systems, two noticeably dissimilar periods of federal engagement with lighting ensued: an early period from about 1917-1945, and a later period from about 1973-2016. During both periods some policies succeeded while others failed.

Although the two periods differ in detail from Marc Eisner's regulatory regimes (described in chapter 2), each displays his idea of shared "principles [that] condition relationships," in this case, relationships among various participants in actor networks built around lighting.[3] A transitional period (1945-1973) separated the two main periods during which key political and economic frameworks changed. Throughout all periods some core societal principles remained evident. As detailed below, those principles along with specific events shaped the contexts for policy formation, and contributed to policy success

3. Eisner, "Discovering Patterns," 157.

or failure. A revolution in lighting (LEDs) that began in the 1960s and accelerated after 1993 ended the later period of lighting policy in the mid-2010s. That marks the onset of a new transition period during which contextual frameworks will probably change again.

As noted in chapter one, throughout the 1880-2016 timeframe, two differing types of federal policies affected lighting producers, conveyors, and consumers. The first type included antitrust laws, patents, government purchases, and other broadly applicable policies that affected most industries and technologies. Important decisions such as the consent decrees signed by GE and others in 1911 and 1953, and the Supreme Court decision in 1926 contributed to the context within which policy makers worked, regardless of the strengths of those individual cases.[4] The second type of policies included those specifically directed at electric lighting, such as prohibitions on exterior lighting and enactment of minimum energy-efficiency standards. That second type did not always target lighting exclusively; mandatory efficiency standards also affected automobiles and electric motors, for example. The lighting specific policies were more selective than the broadly applicable policies, however, designed to achieve precise goals such as reducing fuel consumption, rather than promoting general goals such as containing the economic power of corporations. Because the details of the broadly applicable policies have been well-explored elsewhere, either within the context of lighting history or as case studies that examine the respective larger policies, I concentrated on the lighting specific policies that have not previously been examined in a holistic manner.[5]

4. *US v. GE*, in equity, no. 8120; *US v. GE*, 115 F. Supp. 835; and *US v. GE*, 272 U.S. 476.

5. Bright, *Electric Lamp Industry*; Reich, "Lighting the Path;" Bijker, "Majesty of Daylight," for coverage of broad policies like patents and antitrust.

A mix of methodologies from policy and political science, economics, and the history of technology provided the intellectual framework for my research and analysis, as detailed in chapter three. The most important concepts were path dependence, social constructivism, John Kingdon's "garbage can" model of policy making, and various models of networked relationships (such as described by Latour, Heclo, and Rogers). Some concepts appear in slightly different forms in each discipline's literature, though they show significant overlap. Path dependence, for example, was discussed by Rosenberg (an economist), Pierson (a political scientist), and Hughes (a historian), though the latter used the term "technological momentum." Despite the nuances, all of these authors discussed the role of sequencing (the order of events counts), positive feedback (later decisions reinforce those made earlier), and an increasing difficulty in shifting paths as time passes. Examples of how specific methodological concepts were applied appear in the discussions of the research questions below. All of these concepts helped to explain decisions and actions of the various policy participants regardless of the period in which they lived.

The role of efficacy in electric lighting policy

The first research question asked how changes in lamp efficacy affected the development of electric lighting policy. Efficacy, lighting professionals' term for energy efficiency, is the light output of a given lamp (measured in lumens) divided by the lamp's energy input (in watts). I found that policy makers repeatedly incorporated improved efficacy lamps into their plans before the technology was sufficiently developed and before significant market demand for new products existed. The policies were typically intended to quickly reduce the amount of energy used for lighting, so technical problems and market resistance that slowed adoption of the new devices hindered success. To promote new lamps at an early stage of development, such as fluorescent lamps in the late-1930s, policy makers needed to engage with the process of technological diffusion. As discussed in chapter three, Rogers, Rosenberg, and others describe technological diffusion as a complex process, especially in a mature market where users may see little benefit of a new product over the old. Gradual policy implementation allowed extra time for technologies and markets to develop and helped promote policy success, as shown with advanced fluorescent lamps in the 1980s and 1990s (chapter eight). However, that gradual pace made efficacy improvements less appropriate for use in policies intended to achieve results quickly, such as banning carbon lamps during WWI.

Policy makers found the process of diffusion complicated by the fact that different network actors valued the two sides of efficacy (light output / energy input) differently. While policy makers typically wanted to reduce the amount of input energy used for lighting, other groups, such as electrical utilities, pushed to increase light output while holding input energy constant; a view at odds with policy intent. As Schneider and Ingram argued (chapter 2), definitions matter and are reflected in policies.[6] To save energy by using high efficacy lamps, policy advocates had to enforce their definition of efficacy (reducing input energy while holding light output constant); something they only accomplished in the later twentieth century by enacting minimum efficacy standards.

As part of that effort, they needed to make their technical definition of lamp

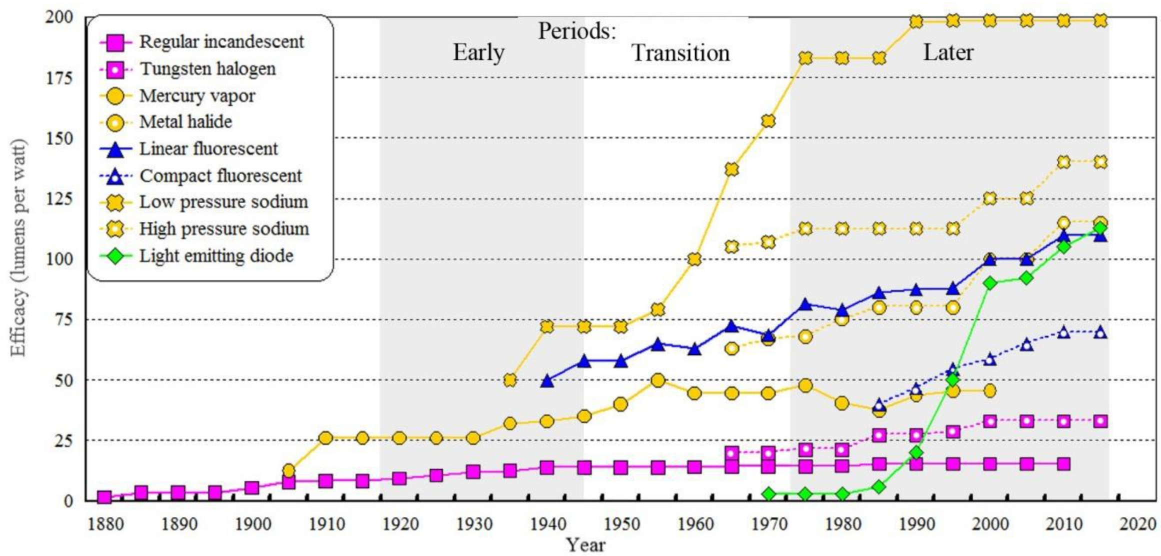
6. Schneider and Ingram, "Social Construction of Target Populations."

efficacy the primary factor within larger, socially constructed definitions of lighting efficiency and quality that had existed since the early twentieth century (see chapter 5). Groups opposed to reduced electricity use or to a particular technology (like CFLs) espoused definitions of efficiency in which efficacy was simply one factor coequal to others, like cleaning dirt from luminaires, and rarely involved lowering input energy. Thus opponents could dilute calls for high efficacy lamps by proposing alternatives to improve lighting efficiency by other means consistent with their preferred definitions. Making and using definitions in this manner is consistent with social-constructivist methodologies, and I found that approach critical in interpreting the many industry articles that promoted alternate ways of viewing lighting efficiency.[7]

As the US grew dependent on electricity during the twentieth century, lighting continually consumed a substantial share of that power (as seen in figure 10.1 above), and policy makers realized that advances in lamp efficacy could save energy. Five significant advances in lamp efficacy have affected federal policy: the shift from carbon to tungsten filaments (1910s, chapter five), introduction of fluorescents (1930s-40s, chapter six), improved linear fluorescents and introduction of compact fluorescents (1980s-90s, chapter eight), and light emitting diodes (2000s-10s, chapter nine). Policy makers adopted each new technology to cope with increased demand for energy with varying degrees of success (as reviewed in the next section). An overview of efficacy advances seen in figure 10.2 reflects the periodization evident in technological development, such as the burst of innovation (tungsten halogen, metal halide, HPS) at GE after the 1953 consent decree.

7. Harrison and Colville, "How to Reduce Your Light Wastage," as cited in chapter 9, for example.

Figure 10.2: Lamp efficacy changes, 1880-2015[8]



Policy makers' options in the later period were expanded by the introduction of new lamps after 1960, and policy interventions helped drive the rise in efficacy seen after 1975. Data points represent approximate highest efficacy for commercially available lamps in the given product line from time of introduction. The four major technology types are grouped by color.

During WWI, the US Fuel Administration encouraged lamp makers' ongoing transition from carbon filament to tungsten filament lamps so they could redirect coal to other purposes. The War Production Board encouraged industry to adopt fluorescent lamps during WWII to maximize use of both energy and strategic resources like tungsten. The Department of Energy (DOE) promoted a new type of fluorescent lamp in the aftermath of the oil embargoes of the 1970s. In the 1990s, both DOE and the Environmental Protection Agency (EPA) promoted compact fluorescent lamps; the former to relieve stress on the nation's electric grids, the latter to reduce emissions from coal fired power plants. Both organizations shifted their efforts to light emitting diodes during the mid-2000s as that

8. Sources: manufacturers' product catalogs, NMAH EC-LRF. Data is approximate due to changes in product offerings over time, and changes in test and measuring procedures, but the trends are accurate.

technology matured and environmental concerns about CFLs grew. These federal programs typically aided technical and market research as well as the diffusion of devices that emerged from private sector work. In only one case (the 1970s electronic ballast initiative) did a federal program directly drive a technical advance in lamp efficacy.

The way efficacy influenced lighting policy is exemplified by the market differentiation that occurred as buyers in the different sectors (residential, commercial, industrial, and municipal) turned to different lamps. As seen in table 10.1, market divergence occurred as different user groups adopted different lamps as best fit their needs.

Table 10.1: Lamp technology by market sector, 1880s-2010s

Decade	Residential Market	Commercial Market	Industrial Market	Municipal Market
1880s	G; I	G; I	G; A	G; A
1890s	G; I	I; G	A; I	G; A
1900s	I; G	I	A; I; D	A
1910s	I	I	I; D	A
1920s	I	I	I; D	A; I
1930s	I	I	I; D	I; D
1940s	I	I; LF	D; LF; I	I; D
1950s	I	LF; I	LF; D	D; LF
1960s	I	LF	LF; D	D
1970s	I	LF	LF; D	D
1980s	I	LF	D; LF	D
1990s	I	LF; D; CFL	D; LF	D
2000s	I; CFL	D; LF; CFL	D; LF	D; LED
2010s	I; CFL; LED	D; LF; LED	D; LF; LED	D; LED

Legend:
A – Arc
CFL – Compact Fluorescent Lamp
D – Discharge
G - Gas
I – Incandescent
LED – Light Emitting Diode
LF – Linear Fluorescent

Incandescent lamps competed against gas and electric arc lamps when first introduced in 1880 but by the 1930s had displaced most other sources in all market sectors. Markets diverged as discharge and linear fluorescent lamps better met differing users' needs. After 2000, markets re-converged as producers made light emitting diodes for differing needs.

With a few special exceptions, from the 1880s until the 1930s electric lighting became synonymous with the incandescent lamps that dominated applications in each market sector. That situation began to change in the 1930s when manufacturers introduced new lamps (fluorescent and mercury vapor) with higher efficacy and longer life than incandescents. Although the new lamps were more complex and expensive, commercial and industrial buyers could justify the tradeoffs and began adopting them, while residential users, for whom lighting constituted a smaller share of electric bills, continued primarily with incandescents.

By the 1960s market differentiation grew pronounced as products in each sector demonstrated path dependencies that reflected accrued financial and research investment, designs for specific applications like street lighting, and specialized technical refinements (see chapter seven). Starting in the mid-1970s, federal policy makers took advantage of that differentiation by developing specific policies aimed at the types of lamps used most widely in each sector. For example, commercial users faced a series of mandatory energy standards for fluorescent lamp and ballast systems in the late 1980s that left residential users largely untouched (chapter eight). This incremental policy approach successfully shifted the large commercial lighting sector to higher efficacy lamps while avoiding the politically sensitive residential market since they used far fewer fluorescent lamps. The ongoing adoption of LEDs by all market sectors marks a reversal of that differentiation and the return to a situation in which one technology dominates electric lighting.

Standards of efficacy and efficiency, whether theoretical or embodied in new products, were always contested and required negotiation to ensure acceptance since they conveyed commercial advantage. This might seem obvious, but the surprised reaction of Eric Noble and his colleagues to being "reamed" over proposals to adopt lighting efficiency standards suggests otherwise (chapter nine).[9] The negotiations, as described in Actor Network Theory, occurred at many points between many actants. Negotiations often took place between producers and residential consumers as with the shifts from carbon to metal filament incandescents in the 1910s, and then to compact fluorescents in the 1990s. Sometimes negotiations occurred between particular interest groups as when scientists and utility managers fought over the basis for rating lamps (described in chapter five), or when the interests of lamp makers and electrical utilities slowly diverged as lighting lost priority as an electrical load (seen in figure 10.1).

Regardless of the location of negotiations, differences revolved around definitions of problems based on conflicting values such as the desire to reduce fuel use versus the desire to sell electricity. Larger definitions of efficiency continue to be contested today, especially as new energy standards are considered. The debate now revolves around whether policy makers should continue to focus on individual components like lamps or take a systems level approach that holistically considers all the energy-using devices in a building.[10] By no means new, this debate has taken on a fresh perspective since LEDs may soon be as efficacious as technically and economically practical, and all sectors are adopting that device. To seek better efficiency in lighting for whatever reason may require that efficiency be redefined yet again; it will certainly require rethinking past practices.

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9. Ruling, "Lighting Legislation."

10. Mills and Piette, "Advanced Energy-Efficient Lighting Systems."

Federal policy and electric lighting

The second research question asked how and why federal policies targeted electric lighting through time. Throughout the past 100 years, policy makers repeatedly pursued initiatives that included blackouts and promotion of high efficacy lamps to conserve energy, enhance national security, and promote social goals like rural electrification. Often they used lighting for symbolic reasons such as emphasizing the existence of a national crisis. Though their policies affected a critical technology and usually touched both industry and consumers, they never expected lighting to be the sole answer to their problems. Using lighting to conserve energy, for example, was always one part of larger efforts to improve efficiency in US energy use. Continued use of lighting specific policies make it important to understand the reasons for past interventions, the means attempted, and the context within which those policies operated, in order to improve policy design and the chances for future success. That importance is magnified given the technological revolution now underway as the lighting industry adopts very high efficacy light emitting diodes for most applications.

As noted above, two distinct chronological periods of policy engagement became evident (1917-1945, 1973-2016), separated by a time of transition (1945-1973) during which significant changes in political and economic contexts occurred. The most important changes included a settlement decree in the long running antitrust suit against General Electric, dissolution of the international Phoebus cartel, and political support for government interventions to address problems like pollution. Those contextual changes accounted for a striking shift from the occasional, short-term lighting policies enacted during the earlier period (1917-45) to a sustained policy engagement during the later period (1973-2016). Policies in the earlier period responded to problems perceived as temporary, like a coal shortage during war. These were typically broadly-targeted interventions that affected all lighting users, were enacted quickly with minor input from affected stakeholders, and failed to achieve policy makers' goals. The policies of the later period usually responded to problems perceived as persistent, such as capacity constraints in the electric power grid. These were typically more tightly focused interventions that affected specific user groups, were enacted incrementally with significant input from stakeholders, and proved more successful in achieving goals.

Table 10.2 shows the most important policies that affected lighting along with the problems they were enacted to address, within this periodization. Adopting the Historical Institutionalists' view of contexts as shaping, enabling, and constraining policy makers' work (discussed in chapter three), I found the contextual changes of the 1950s and 1960s crucial in understanding the shift in policies between the early and later periods.[11] Recognizing one context that did not change proved equally important when considering policy success or failure, specifically, the consistently held values and beliefs within the US polity. These beliefs remain evident today and include a strong aversion to centralized authority, deference to commercial prerogatives, and a high regard for individual autonomy.[12] Policy makers during the past century always contended with these persistent beliefs regardless of altered economic and political contexts, unique events, and the

11. Orren and Skowronek, *Search*, 113.

12. Karl, *Uneasy State*.

Table 10.2: Significant federal policies that affected electric lighting, 1917-2007

Event	Policy problem	Policy response affecting lighting	Enacted	Ended
Early Pd.				
WWI	Coal shortage	Blackouts; Advertising & exterior lighting ban	1917	1918-20
		Ban carbon incandescent lamps	n/a	n/a
Depression	Rural areas not electrified	Promote lighting as a prime use of electricity	1935	~1958
WWII	Military attacks	Blackouts	1941	1943
		Dimouts		1945
	Shortage of fuel and strategic materials	Promote fluorescent lamps	1939	1945
		Advertising & exterior lighting ban	1941	
		Ration materials; promote energy conservation	1941	
Transition				
Postwar boom; Cold War	GE market control	Obtain consent degree in antitrust action	1953	In force
	Phoebus cartel	Promote market competition	1945	In force
	Pollution	Enact pollution controls: APCA; CAA; CWA	1955-72	Amended
Later Pd.				
Oil embargo	Oil shortage	Advertising & exterior lighting ban	1973	1974
		EELB project: fund R&D for residential lamp	1974	Projects & program ongoing. Laws in force or amended.
		SSEB project: fund R&D for electronic ballasts	1974	
Environmental activism	Toxic substances in environment	TSCA76: ban polychlorinated biphenyls	1976	
		CAA90: cut mercury releases into environment	1990	
		Green Lights program: promote efficient lamps	1991	
Mideast wars; Deregulation; 9/11	Electrical power grid stressed; climate change	NAECA88: efficacy standards for ballasts	1988	
		EPAct92: efficacy standards for fluorescents	1992	
		EPAct05: promote LEDs & special luminaires	2005	
		EISA07: efficacy standards for residential lamps	2007	

Events in the early period drove lighting specific policies that ended when the event passed. During the transition period, contexts shifted such that later period policies remained in force and reinforced each other.

influence of specific people. In both early and later periods, policies that called for curtailed lighting use (like blackouts) drew criticism and resistance from many people. As we saw in chapter six, even in the midst of war, military authorities complained of businesses that refused to extinguish or even dim their lights, while other citizens grimly warned authorities “don’t try to push us.”[13] Policies that succeeded typically either encouraged lighting use (rural electrification, chapter six) or sought to shift users from one technology to another without curtailing use (LEDs, chapter nine).

The iconography of light is less important here than recognizing its long existence, resonance with individuals, and continuing presence in American political discourse.[14] As David Nye wrote, the loss of light (blackouts) indicated a significant problem and departure from normality that could awake primal fears.[15] At the onset of both World Wars and during the 1973 oil embargo federal authorities rushed to extinguish lights so as to emphasize the onset of a national crisis. While many questioned whether blackouts resulted in energy savings, few denied that they grabbed people’s attention and allowed political leaders a theatrical prop in which to advance agendas. Because politicians’ definition of wasteful lighting always included advertising (illuminated billboards, for example), calls for blackouts also grabbed the attention of lamp makers and commercial lighting users, ensuring their active attention to lighting policy debates.

From the 1910s through the 1940s the US faced three national crises—World War I, the Great Depression, and World War II—during which policy makers enacted lighting regulations that touched everyone. Throughout this early period (as discussed in chapters five and six), Progressive philosophy fueled an agenda that featured an active government

13. Morgan, “Don’t Try to Push Us Around.”

14. Finn, “The Incandescent Electric Light,” 247-263 is one example of studies of the symbolism of light.

15. Nye, *When the Lights Went Out*.

role in national affairs. That included a belief that government based on professional expertise and centralized planning could address social problems such as lack of electricity in rural America, as well as balance the economic influence of large corporations like General Electric.[16] While many Americans agreed, empowering the Progressive agenda, persistent distrust of central government authority served as a significant contextual constraint on policy makers' plans. Broad lighting restrictions like lightless nights, even when voluntary, largely failed when consumers and the unified lighting industry resisted government directives. Mandatory measures fell short when local authorities proved loath to enforce restrictions in the face of local resistance. The successes came with narrowly targeted policies that promised economic gain, as when manufacturers culled product lines in WWI and used rationed materials to fill orders for defense related goods like blackout lamps in WWII. Depression-era programs that specifically promoted lighting to rural Americans also succeeded, largely due to the deliberate pace of policy makers' efforts and their outreach to the target population. Many otherwise skeptical people decided to participate in the rural electrification program in order to replace labor intensive oil lamps, and to partake in the social advancement electric lighting represented.

In the immediate aftermath of WWII, lighting-specific policies returned for a time to the limited scope and scale of the pre-WWI era. However, as discussed in chapter seven, the postwar era was a time of transition in which the national economic and political contexts changed, and a widespread sense of national strength and international stature enabled a more active federal role in policy making. Military victory along with the

16. O. L. Graham, Jr., *The Great Campaigns: Reform and War in America / 1900-1928* (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1971), 22-39.

perceived success of New Deal programs led to increased expectations of government among many in the polity, especially regarding nationwide challenges (Cold War, energy shortages) that seemed amenable to scientific and engineering solutions. A feared return to Depression did not occur and Americans in the postwar decades propelled a booming economy that fueled a general sense of national optimism. That economy and US society writ large became increasingly dependent on electrical power, a point driven home by a major blackout in 1965.

For the lighting industry, the postwar era brought fundamental changes: the end of GE's rigid control of the domestic lighting market, dissolution of the Phoebus cartel's control of the international lamp trade, and civilian application of wartime research. I interpret these economic and technical context changes in terms of path dependence as described by both Pierson and Rosenberg.[17] GE's ability to reinforce earlier decisions was critically impaired, and the economic momentum of long-standing practices and relationships began to fade. Although full realization of domestic and international competition in lighting took decades, the end of controlled markets at home and abroad removed powerful impediments to change. The industry's technological path began to shift when a burst of innovation, driven by expectations of real competition, resulted in four new types of lamps: tungsten halogen, metal halide, high pressure sodium, and LEDs. Of only niche value at first, those lamps' introduction in the 1960s provided important field and market experience that made them potent options for policy makers seeking alternatives to

17. Pierson, *Politics in Time*; Rosenberg, *Exploring*; both discussed in chapter three.

meet energy challenges later in the twentieth century.[18]

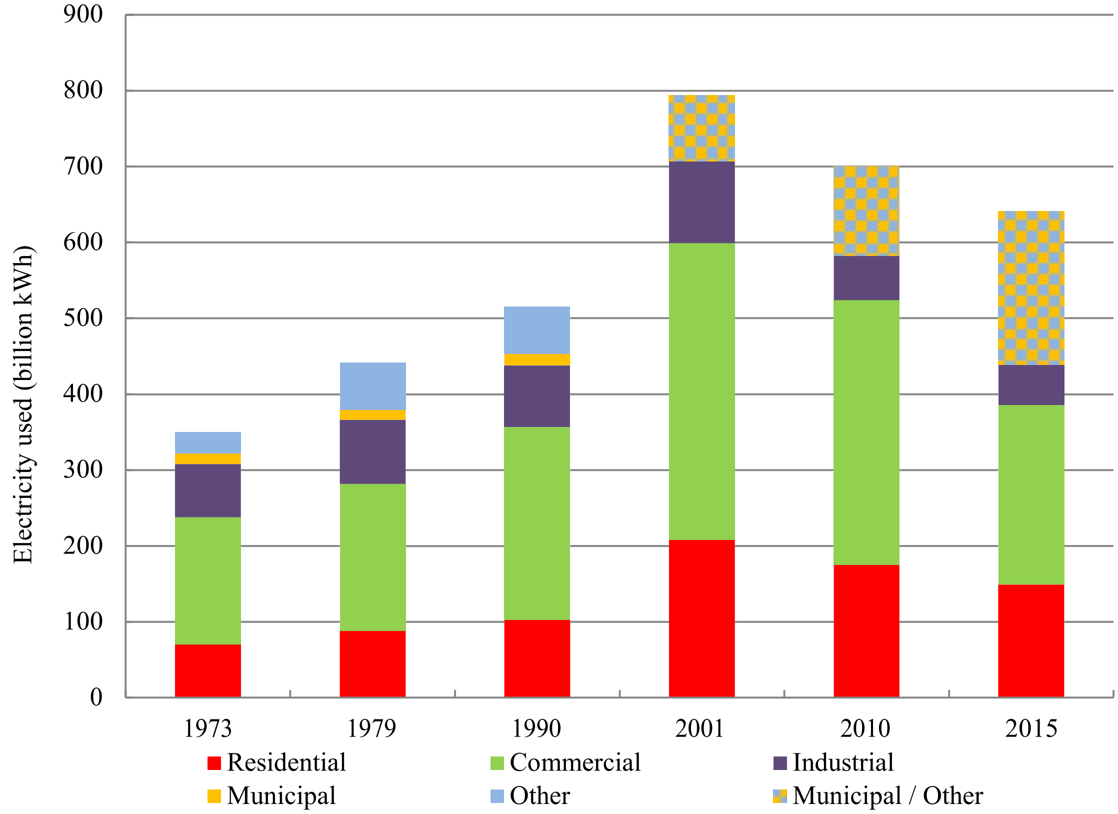
From the 1970s through the mid-2010s, policy makers faced a variety of problems that affected the US energy infrastructure and particularly threatened the technical and economic stability of the electrical system. As discussed in chapters eight and nine, these problems included growing demand for energy, technological stasis in the electric power infrastructure, environmental degradation, and economic miscues by government planners anxious to restrain energy prices for consumers. To help address these problems policy makers pursued a series of lighting-specific policies in a way that differed significantly from the temporary policies of the early twentieth century. Unlike then, the fundamental problems in this later period never went away, so federal policy actors embarked on a sustained engagement with the lighting industry to reduce the share of electricity used for lighting. Initial success with a program to develop solid-state fluorescent ballasts led to enactment of a series of lighting efficiency standards starting in 1988 that gradually shifted markets by setting minimum efficacy ratings for lamps. As seen in figure 10.3, declines in the different sectors' lighting energy began to emerge in the 2000. While recognizing that correlation does not equal causation, it is reasonable to expect that a portion of the decline can be attributed to successful implementation of the lighting energy standards.

Their ability to advance policies over three decades stemmed from a commitment to incremental change, an approach Charles Lindblom would not find surprising.[19] Simultaneously, the redefinition of pollution from the status of a condition (to be tolerated

18. Kennedy, *Freedom*, 852-858, for postwar national changes.

19. Lindblom, "Science," 143.

Figure 10.3: Electricity used for lighting in the US, 1973-2015[20]



Energy savings from efficiency standards are reflected in the reduced amount of electricity used for lighting in the 2000s. Declines are seen in the residential and commercial sectors. Apparent growth in the combined municipal (mostly street lighting) and other categories may be an artifact of the data or may reflect increased LED use in outdoor illumination.

as unavoidable) to that of a problem (and subject to treatment) brought new policy actors and a new set of goals to federal lighting policy.[21] The mix of energy and environmental goals serendipitously allowed policy promoters to tailor arguments in a waythat sustained

20. Sources: Campbell, "Facts about lighting." S. Berman, R. Clear, J, Klems, F. Rubinstein, S. Selkowitz, and R. Verderber, "Energy Efficient Lighting Program, Annual Report 1979," Lawrence Berkeley Laboratory LBL-11768, December 1979, US Department of Energy, 1. Atkinson et al., *Analysis*. Navigant Consulting, *U.S. Lighting Market Characterization, Volume I*, x; Ashe et al., *2010 U.S. Lighting Market Characterization*, xii; Nicole Buccitelli et al., *2015 U.S. Lighting Market Characterization* (US Department of Energy, Office of Energy Efficiency and Renewable Energy, December 2017): 3.

21. Kingdon, *Agendas*, 110-112; Tarr, *Ultimate Sink*, 205.

federal lighting interventions through the tenure of presidential administrations holding divergent values and policy preferences. Though the level of support fluctuated in response to political negotiations, the engagement remained continuous and gave researchers time to refine technology while markets adjusted, resulting in major advances toward achieving both energy and environmental goals.

Another important difference in the later period was policy makers' recognition that lighting markets were segmented rather than a unified whole, a fact that allowed them to design nuanced interventions that affected groups of consumers in piecemeal fashion. Commercial organizations used up to half of their electricity for lighting, far more than residential consumers. Dealing with commercial lighting and other specialized equipment first, demonstrated that the policy interventions using new technology could succeed and diluted political resistance. Policy actors' interactions with professional organizations and private sector experts in the later period was key in that approach, and aligned well with Heclo's ideas about issue networks (see chapter three). Cooperation gave affected interest groups reason to participate, took advantage of their specialized knowledge, and encouraged their positive intercession with their own commercial and political networks. This last proved especially important for lighting policy as it gave policy makers leverage with private sector actors who sought to turn public policy to their advantage, a situation that occurred throughout both early and later periods.

Private sector utilization of lighting policy

The third research question asked how private sector actors involved with electric lighting adapted public policy to further their own goals. The key finding is that manufacturers repeatedly used federal policy initiatives to facilitate introduction of expensive new lamps in the face of resistance from conveyors and consumers satisfied with existing low cost devices. The details varied and the actions occurred during different periods, but lamp makers so used policy initiatives in at least five cases: the shift from carbon to tungsten filaments (1910s, chapter five), the introduction of fluorescents (1930s-40s, chapter six), improved linear fluorescents and compact fluorescents (1980s-90s, chapter eight), and light emitting diodes (2000s-10s, chapter nine). Each invention entailed high initial costs due to the need for new production equipment, use of expensive materials, and significant research investment. In each instance a low cost, mature technology existed in established markets, but for various reasons most producers felt compelled to proceed with commercialization rather than suppress the new invention. In at least two cases however, specific private sector actors worked to suppress particular versions on a new invention in favor of their preferred alternatives (cold-cathode fluorescents, chapter six; solid state ballasts, chapter eight). As seen in table 10.3, the policy periodization remains evident in relations between both sets of players, especially once the industry ceased to speak with one (GE's) voice.

George Stigler noted one reason for industry to seek regulation as a desire to control product "substitutes and complements." Though he referred to competition between industries, in this instance his observation applies to competing products within the lighting industry.[22] GE and others either sought out (in WWI, WWII) or took advantage of policy opportunities (EISA07) to advance substitute products. I found no

22. Stigler, "Theory of Economic Regulation," 6.

Table 10.3: Lighting companies' uses of lighting-specific policies, 1917-2007

<table>
<tr><th>Event</th><th>Private sector problem(s)</th><th>Federal policy</th><th>Private sector goal(s)</th></tr>
<tr><td>Early period</td><td></td><td></td><td></td></tr>
<tr><td>WWI</td><td>Many efficient lamps caused confusion; consumers and utilities resisted new lamps</td><td>Ban carbon incandescent lamps</td><td>Facilitate tungsten lamp; clear market of old lamps, especially GEM lamp</td></tr>
<tr><td>Depression</td><td>Rural lighting market under-developed</td><td>Promote lighting as a prime use of electricity</td><td>Develop rural market and sell product</td></tr>
<tr><td rowspan="2">WWII</td><td rowspan="2">Utilities resist new lamps; little residential demand; competing technologies</td><td>Promote hot cathode fluorescent lamps</td><td rowspan="2">Establish market for fluorescent lamps; suppress alternate design</td></tr>
<tr><td>Ration materials; promote energy conservation</td></tr>
<tr><td>Transition</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Postwar boom; Cold War</td><td rowspan="2">*Loss of clear market leader; dissention about light levels</td><td>Obtain consent degree in antitrust action</td><td rowspan="2">Compete in new lighting market structure</td></tr>
<tr><td>Promote free trade</td></tr>
<tr><td>Later period</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Oil embargos</td><td rowspan="2">*Government push for new lamps; established companies protect old technology</td><td>EELB project: fund R&D for residential lamp</td><td rowspan="2">New actors: overcome entry barriers; established actors: control new technology</td></tr>
<tr><td>SSEB project: fund R&D for electronic ballasts</td></tr>
<tr><td rowspan="3">Environmental activism</td><td rowspan="2">*Critical substances found to be toxic</td><td>TSCA76: ban polychlorinated biphenyls</td><td rowspan="2">Reduce use or replace toxic substances</td></tr>
<tr><td>CAA90: cut mercury releases into environment</td></tr>
<tr><td rowspan="3">Commercial & industrial consumers resist new lamps; conveyors have stocks of old product</td><td>Green Lights program: promote efficient lamps</td><td rowspan="3">Facilitate adoption of advanced fluorescents; clear market of old lamps</td></tr>
<tr><td rowspan="4">Mideast wars; Deregulation; 9/11</td><td>NAECA88: efficacy standards for ballasts</td></tr>
<tr><td>EPAct92: efficacy standards for fluorescent, special incandescent lamps</td></tr>
<tr><td rowspan="2">Residential consumers resist new lamps; conveyors have stocks of old product</td><td>EPAct05: promote LEDs, specialty luminaires</td><td rowspan="2">Promote CFLs & LEDs, clear market of incandescent lamps</td></tr>
<tr><td>EISA07: efficacy standards for residential lamps</td></tr>
</table>

*Policy activity preceded private sector problem.
In the early period the problems facing the lighting industry preceded the problems policy makers wanted to address, giving industry actors an opportunity to use policy. After the transition, policy makers' activities tended to precede lighting industry problems, and private sector interests fragment. Policy actors gained leverage with the lighting industry.

evidence that they pursued this tactic with awareness of past episodes, although their reactions to other policies like wartime blackouts and bans on outdoor advertising were clearly influenced by memories of past events. Many WWII-era references characterize such WWI-era policies as failures before suggesting industry preferred alternatives. Rather than an example of regulatory capture however, this finding indicates lamp makers took opportunistic advantage of an open policy window, as Kingdon might predict. Policy makers pursued their goals with legitimate public benefits in mind, reducing electricity demand in lighting for example, that private actors cared little about or actively resisted. Their goals aligned, federal policy makers sought to advance energy efficient technology and lamp makers sought to push new product into resistant markets. By acting in the name of patriotism, producers deflected criticism from affiliated stakeholders like electric utilities and withstood negative public reaction.

That private sector actors would seek to influence public policy was expected. Their use of policy in times of crisis to aid with technology diffusion caught my attention however. More curious still was how public sector actors influenced the private sector through a combination of profit motive, positive public relations, and desire to influence regulations perceived as inevitable, EPA's Green Lights being one example. Literature on regulatory capture seems to generally focus on influence that moves from regulated to regulator, yet in the 1980s and 1990s (chapters eight and nine), public-private influence flowed in both directions.[23] By recognizing that the private sector has used policy windows to overcome market obstacles, policy makers who pursue alternatives incorporating new technology gain a means to enlist support for their policies.

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23. Ernesto Dal Bó, "Regulatory Capture: A Review," *Oxford Review of Economic Policy* 22, no. 2 (Summer 2006): 203-225, http://www.jstor.org. L. J. Sandahl et al., *Compact Fluorescent Lighting in America: Lessons Learned*, for two-way influence.

In the early twentieth century (chapters five and six), GE came to control about 97 percent of the US lighting market through the strategic use of patents, restrictive licensing agreements, retail price fixing, and cooperation with an international cartel.[24] Though content to sell existing lamps, GE and its partners during that period twice felt compelled to push new products rather than cede market share as old patents expired, new technology became available, and some actors worked to evade license agreements. In both World Wars the lighting industry positioned these commercially problematic new products, tungsten filament incandescent and fluorescent lamps, respectively, as appropriate alternatives to meet government policy goals of resource and energy conservation.

Government support gave the companies patriotic cover to push the new lamps despite opposition from utilities fearful of reduced revenue and from users accustomed to low priced lamps. WWI ended before regulations to terminate production of the particularly troublesome GEM carbon lamp took effect, but continued coal shortages allowed makers to proceed with the phase-out. In the years following both wars energy issues receded as a policy priority but by that time lamp makers no longer needed the policy boost; lighting's path had shifted far enough to make going back to the older technology unrealistic. Both cases, tungsten and fluorescent lamps, demonstrated path dependencies (the influence of positive feedback, for example) but also show that paths are not deterministic. Sales of carbon lamps never returned to prewar levels and in 1951 fluorescent lamps generated more light in the US than incandescents.[25]

In the wake of the 1973 oil embargo policy makers again turned to the lighting

24. Reich, "Lighting the Path," for 97 percent figure.

25. Bright, *Electric Lamp Industry*, 489-490; Inman, "Fluorescent Lamps," *GE Review*, July 1954.

industry, which created more opportunities to push expensive new products onto the market (chapter eight). That did not happen as quickly as before since the industry spoke less with a single voice (GE's) in this later period, and not everyone believed that energy and environmental challenges were long term problems. During the 1980s, a DOE program supported firms outside the traditional lighting industry, like Stevens-Luminoptics, that demonstrated the practicality of solid-state ballasts. Several lamp makers introduced compact fluorescent lamps for home and commercial use with a boost from another DOE program. Some in the lighting industry resisted the introduction of new ballasts and residential lamps until it became obvious that government interest in energy and environmental problems was not temporary and that competitors could profitably make and sell products. At that point many industry actors (unconsciously) adopted the strategy of their predecessors.

Over the course of thirty years they helped to enact federal regulations that phased-out obsolete products such as older fluorescent lamps (chapter 9), pushed out new products during their initial, most expensive stage, and let public sector actors absorb public ire. By participating in the policy process, producers and conveyors gained the time they needed to shift production lines to new devices and clear inventories of old stock. Simultaneously, industry and regulators cooperated in dealing with the environmental problems of PCB and mercury by crafting policies that included market based approaches such as private recycling companies. EPA's Green Lights program took a cooperative, voluntary approach that eschewed mandatory participation and gave lamp makers another avenue to achieve their commercial goals.

The two sets of policies intermeshed in a surprising way in the later period as energy policies pursued by Republican administrations alternated with environmental policies supported by Democrats. In both cases regulators and industry actors tailored their approaches to muster sustained political support for incremental action, an ability gained in part due to the relative stability of the public and private sector actors involved. Unlike earlier, wherein substantial participant turnover occurred between episodes of policy intervention, many of the same people participated in the sustained engagement of the later period, as seen in the witness lists of Congressional hearings in the 1980s and 1990s. The continuity of people in executive agencies, legislative committees, and special interest and industry groups, became essential in the flexible, incremental approach by promoting a form of shared institutional memory within the actor networks.

The establishment of large, national corporations in the nineteenth century brought them into play as policy actors; controlling them provided an important justification for the expansion of the US administrative state that began in the 1890s.[26] David Ciepley persuasively argued that corporations are neither private individuals nor public entities but occupy an area between the two, sharing aspects of both.[27] Able to harness the capabilities and resources of many, they are far more powerful than single individuals and yet operate privately within legal and physical frameworks set and enforced by local, state, and federal authorities. Relationships between the federal government and lighting companies (particularly GE, founded in 1892) have run the gamut from highly adversarial to closely

26. Chandler, *The Visible Hand*; Campbell, *Growth of American Government*.

27. David Ciepley, "Between Public and Private."

cooperative depending on the nature of events, the flow of the political stream, and the motives each perceived in the other.

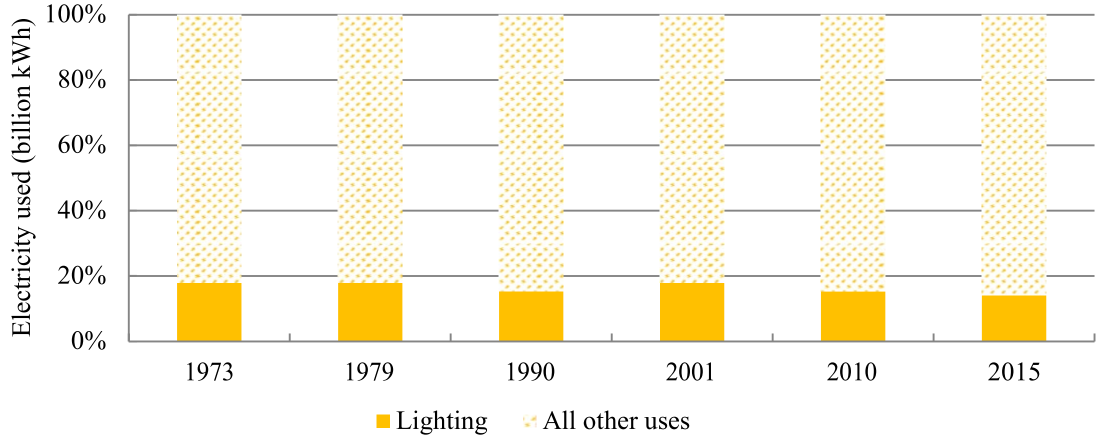
Despite the different eras and often contentious relationships, industry actors adopted similar tactics in the early and later periods to help establish new lighting products. Over time, both sets of network participants adapted to each other while individuals came and went, social and economic environments changed, and internal cultures evolved. As Neustadt and May would argue, by "placing" organizations and people in their particular historical contexts, we can understand how this federal-industrial relationship changed over time and how the vital interests of each overlapped or clashed. Both public and private sector actors demonstrated an ability to work cooperatively to achieve their goals; disparate through those goals may have been at times. This finding offers both sets of actors a model for mutually beneficial cooperation.

Significance of findings for lighting policy

Lighting today is travelling a much different path from that anticipated by anyone only twenty years ago, largely due to technical breakthroughs that produced a light source of unprecedented flexibility and efficacy: LEDs, as discussed in chapter nine.[28] As seen in figure 10.4, lighting's share of total US electrical use is dropping; further adoption of LEDs promises to drive that figure lower. That fact holds significant consequences for federal policies that seek to use lighting to achieve goals because the technical and economic foundations of the lighting industry have permanently changed. In early 2014, IES Policy

28. Don Peifer, "Five Things I Thought I'd Never See," *LD&A e-Report: Hot Topics* (June 2017), https://www.ies.org.

Figure 10.4: Lighting as percentage of total US electricity consumption, 1973-2015[29]



This chart shows the reduced role of lighting in US electricity use since 2001. Adoption of high efficiency LEDs in all market sectors may be expected to continue this trend.

Director Robert Horner dismissed the idea that Congress might repeal lamp efficiency standards contained in EISA07 to save ordinary incandescent lamps.[30] The cost of shifting paths back to an earlier era had become too high.

Federal policy played little role in the invention and development of LEDs, but played a substantial role in the diffusion of that technology through a long term effort that promoted energy efficient lamps. By working slowly, in incremental steps that recognized market sector differences and accommodated the needs of producers and conveyors, federal policy nudged markets away from one path and toward another. By the mid-2010s, the market differentiation that previously helped policy makers started to fade as each

29. Sources: Campbell, "Facts about lighting." S. Berman, et al., "Energy Efficient Lighting Program," 1. Atkinson, et al., *Analysis*. Navigant Consulting, *U.S. Lighting Market Characterization, Volume I*, x; Ashe et al., *2010 U.S. Lighting Market Characterization*, xii; Buccitelli et al., *2015 U.S. Lighting Market Characterization*, 3. Total energy figures from EIA, "Electricity End Use," (January 2016), 123.

30. Robert Horner, "Lighting Legislation: The Good, the Bad, and the Ugly," (lecture, IES Washington DC Section, 25 February 2015). Recognition of this reality may be one reason for the lack of cosponsors signing onto standards repeal bills like the BULB Act.

lighting sector turned to LEDs, a confluence not seen since the 1930s when incandescents dominated all lighting applications. Long time private sector actors also changed. GE, Philips, and Osram showed little interest in updating and reopening incandescent production lines. In fact, all three had purchased LED companies and began to consider exiting the lighting business entirely.[31]

Granted, there are limits to focusing on technology to advance policy goals. Laws of nature may prove intractable as seen with the silicon carbide filament research in the 1990s. Unexpected changes in other technologies may render practical devices quickly obsolete, as with the sulfur lamp. Policy support for one device may not match market realities, as when the electrodeless Litek lamp failed in the face of competition from compact fluorescents that used traditional electrodes. Technology reliance also invites equity problems if some consumers can afford a new device and others cannot. Despite these limits, policy makers decided that using technology served to advance their goals better than other options at their disposal. Mandating restrictions on use of light met with significant non-compliance during both World Wars, for example. Tax policy, through credits or assessments, would be complex to devise and difficult to implement. Component level technology regulation, by contrast, limited the number of producers from whom compliance was needed and allowed policies to be crafted for different market sectors.

That approach allowed policy makers to make technological path dependencies

31. “Philips takes control of LED maker Lumileds,” *LEDs Magazine.com* (15 August 2005), http://www.ledsmagazine.com; Tim Whitaker, “Philips to buy Color Kinetics in $791 million deal,” *LEDs Magazine.com* (27 August 2007), http://www.ledsmagazine.com. Maury Wright, “Osram sells LEDvance SSL business to Chinese trio,” *LEDs Magazine.com* (27 July 2016), http://www.ledsmagazine.com. Katie Fehrenbacher, “A better way to cool LEDs gets attention from GE,” *Gigaom.com* (19 July 2011), http://gigaom.com; Katie Fehrenbacher, “GE to buy LED tech maker Lightech,” *Gigaom.com* (25 July 2011), https://gigaom.com.

work for them. As discussed in chapter three, the concept of path dependence builds on ideas of sequencing and positive feedback. Those ideas emerged clearly not only in lighting technology and markets but in policy developments as well, especially in the later policy period. Policy makers and lamp makers alike leveraged investments in education, research and production of one technology to support introduction of the next. Engineers combined rare-earth phosphors and practical solid-state ballasts to make significantly improved fluorescent lamps in the 1980s. Though expensive, commercial and industrial consumers recognized the cost savings and adopted the new lamps that also helped them deal with PCB and mercury problems in older fluorescent systems. Energy standards enacted in 1988 and 1992 accelerated that diffusion by clearing the market of older systems.

The critical phosphor and electronics research fed development of compact fluorescent lamps that could then be adopted to replace incandescent lamps. EPA's 1991 Green Lights program promoted CFLs while federal legislation in 2005 promoted energy standards for exit signs and other specialty devices. Those activities boosted CFL sales that were already rising due to electric utility rebate programs. Work on miniaturized electronics for CFLs, along with the years spent educating consumers about inefficient incandescent lamps, paved the way for LEDs. EPAct05 and EISA07 legislation supported—though did not mandate—LED adoption by enacting minimum efficacy standards that ordinary incandescent lamps could not meet, again clearing the market of older technology. In each successive case, rising sales led to decreased production costs through economies of scale. Lower costs increased product acceptance and brought profits that encouraged the gradual shift in paths. A key aspect of path dependence theory is the high cost and difficulty of shifting paths, especially long travelled paths such as electric lighting with decades of investment, technical development, and social acceptance. Yet, as Pierson, Rosenberg, and others pointed out and this study shows, difficult does not mean impossible. With the most recent path shift, electric lighting has entered a new period.[32]

When considering this path shift and the potential uses of history for policy makers, Neustadt and May's advice about avoiding false analogies comes to mind. In the past, for example, when manufacturers introduced a lamp with higher efficacy, lighting use tended to increase via industry pursuit of higher light levels and development of new applications. If the adoption of LEDs leads to more lighting use a rebound effect would reasonably concern those interested in energy policies.[33] Indeed, during the last decade LEDs have turned up in almost every type of device imaginable including products that never before included lamps, such as greeting cards. Products that formerly contained a single indicator lamp now include a LED—usually more than one. New devices from flash drives to Bluetooth receivers seem incomplete without a cluster of flashing LEDs. Meanwhile, many people have complained about LED brightness. Although brightness and lumen output differ in a technical sense, these very efficient lamps do produce a lot of lumens. So a rebound effect with LEDs is certainly plausible but may be difficult to measure. Many devices that incorporate LEDs operate on batteries so their cumulative effect may be

32. Pierson, *Politics in Time*; Rosenberg, *Exploring*.

33. Richard B. Howarth, Brent M. Haddad, and Bruce Paton, "The Economics of Energy Efficiency: Insights from Voluntary Participation Programs," *Energy Policy* 28 (2000): 477-486. The authors argue the rebound effect is insignificant since "large aggregate improvements in energy efficiency are accompanied by cost savings that are too small to substantially affect individual demand for energy services."

subtle, indirect, and unlike that of previous lamps that operated on 120 volts. Power plant loads devoted to lighting may drop while energy used making and disposing of batteries and LEDs may rise.[34] In this instance at least, designing a policy based on past analogy would be misleading due to the changed circumstances and technical details.

Widespread adoption of very high efficacy LEDs for most if not all illumination tasks raises additional policy questions, not all of which center on lighting. In 2015, GE executive Gerald Duffy described New York City's new municipal lighting system in which each new street light contains a cluster of LEDs.[35] Aside from providing light each LED serves as an independently addressable communications portal, a so-called LiFi system.[36] The street lights communicate with a central computer that receives data from parking meters around the city, along with inquiries from vehicle navigation systems and pedestrians' smart phones. The LiFi network enables the system to guide drivers to open parking spaces thereby saving time and energy. The street lights can precisely locate a 911 emergency call, allowing the system to quickly direct responders to the scene. Duffy noted that future revisions to this system could reduce accidents by autonomously monitoring vehicle and foot traffic to warn cars, cyclists, and pedestrians of imminent collisions, or coordinate self-driving vehicles to smooth traffic flows.[37]

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34. Paul Buckley, "Recycling LEDs: How to tackle a growing challenge?" *EE Times Europe* (02 November 2015), http://www.ledlighting-eetimes.com.

35. UN General Assembly Resolution 68/221, "International Year of Light and Light-based Technologies, 2015," 20 December 2013, www.light2015.org.

36. LiFi or Li-Fi is industryshorthand for "light fidelity," a method of using light to communicate and is wordplay on WiFi or "wireless fidelity" for similar internet access systems using radio frequencies.

37. Gerald Duffy, "Solid State Lighting: Transforming Our World," International Year of Light symposium *Light for a Better World: A Celebration of U.S. Innovation* 12 September 2015, http://sparkstreetdigital.com.

These systems, now being installed in several major cities, convey obvious public benefits but the surveillance capability of this technology provides a sobering counter-balance. Policy makers concerned about privacy may need to consider how lighting affects their alternatives.[38] Convergence of lighting and telecommunications complicates energy policy because such hybrid devices must remain active, especially if emergency responders depend on them. Regulators may be unwilling or unable to order deactivation of these devices due to the non-lighting functions.[39] The high efficacy of LEDs means that deactivating only the lamps would result in insignificant energy savings in any case. The emerging Internet of Things (IoT), including so-called smart lights, compounds the problem by bringing an issue into private homes that previously affected only public spaces; the very residential market most wary of federal mandates. This recalls one of Achembaum's uses of history, "the need to keep perennial value conflicts and enduring social tensions in mind," so policy actors should tread carefully in that area.[40] For now, decisions regarding LiFi systems mostly involve state and local governments, though federal actors could play a role if the District of Columbia seeks to purchase the system.

Even the nature of lighting research has changed in a way that makes federal efforts less significant. At a 2014 lighting conference, one speaker asserted with confidence that LED efficacy would soon push theoretical limits; a level so high that further improvements in energy efficiency would not be worth the research investment

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38. "Spokane to Test AI for Streetlights," *LDA Newswire* (17 May 2017). Paul Buckley, "Connected LED opens path to 'intelligent cities'," *EE Times Europe* (20 April 2015), http://www.electronics-eetimes.com.

39. Junko Yoshida, "Convince me why washer must talk to grill," *EE Times Europe* (July 15, 2014), http://www.electronics-eetimes.com.

40. Achenbaum, "Making:" 45.

needed to achieve them.[41] That same year, a senior member of the profession reported that seeking higher efficacy had ceased to be the major concern of many researchers, replaced by a focus by “human-centric factors.”[42] Lighting researchers worry less about how to generate light or optimize a source for a given application, and more about ways to use all that cheap, efficient light and its effect on people. Market acceptance of LEDs may ultimately render obsolete much lighting research supported by federal dollars in the latter twentieth century, despite the success of that research in the short term. However, seen in economic terms, short term successes should not be dismissed merely because they are temporary. The energy saved as a result of that research during those decades represented capital freed for investment in other areas, as much as $15 billion from the electronic ballast programs alone.[43] As with other investments, federal lighting research required patience and paid off in unexpected ways.

The policy and economic decisions that affected lighting, whether made by public or private sector actors, came within the context of specific moments in time, usually in response to crisis events when policy windows opened. The time scale of the given event mattered a great deal in that short term crises (wars and economic depression) in the early period failed to provide the sustained political and policy focus that longer term problems

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41. Donald Hirsh, “LEDs for Lighting Professionals,” (presentation, IES Baltimore Lighting Technology Conference, 17 September 2014).

42. Conversation with Mark Rea, Director, Lighting Research Institute, Rensselaer University, March 2014.

43. National Research Council, *Energy Research at DOE: Was it Worth It?* (Washington, DC: National Academy Press, 2001), 106. NSF presumed a 5 year advance in the introduction of electronic ballasts and their figure represents the “net cumulative energy cost savings” due to earlier introduction. Since the introduction of no technology is inevitable, I find their presumption of a 5 years advance optimistic, the true cost savings may in fact be much higher.

(energy supplies, environmental degradation) affected in the later period. Despite the seeming suddenness of changes over the past ten years, the shift in lighting's path really occurred incrementally over five decades starting in the 1960s, only recently reaching the point where completing the shift appeared more desirable than not. The cumulative effect of these incremental changes appears when examining the overall history of lighting policy, with each change understood within its historical moment. This slow shift spread out economic and political costs as technology changed, policy actors came and went, and national circumstances evolved; an evolution I found consistent with the APD school's view of policies as dynamic creations within social contexts (chapter three).[44] Understanding how the path shifted toward energy efficient lighting, the interplay of individuals and organizations in accomplishing that shift, and the mechanisms by which the policies succeeded now begs the question: what next?

Lighting policy today and options for future study

In November 2016, the US political pendulum swung in a direction that shocked most policy makers and political elites when political outsider Donald J. Trump won the White House. Near term affects for policies related to electric lighting would seem slight, since as Orren and Skowronek might argue, too much has changed making a "return to a prior state of affairs unlikely."[45] Private research funding has focused on LEDs, and both domestic and international markets are adjusting to the new product. Bob Horner was

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44. Zelizer, "Stephen Skowronek's Building a New American State," 425. (See Chap. 3, n4, above.)

45. Orren and Skowronek, *Search*, 77.

correct—the path shift has already occurred and it is highly unlikely that any but a niche company would expend capital on incandescent lamps, or any technology aside from LEDs. We are far enough along the new path that the costs to shift back would be prohibitive; for LED companies like Cree and Soraa, there is no going back. In the public sector, cuts to EPA and DOE would have only a limited effect on lighting research given advanced academic facilities at places like Rensselaer and UC Santa Barbara.

John Kingdon explained that presidents set agendas but that others develop and implement policies.[46] During his first year in office, Trump pursued other priorities and did not push to rescinding existing lighting policies. Given that industry has committed to moving on, a push to rescind would be symbolic; politically attractive for that reason perhaps but with little practical result. Future lighting policies will face more resistance if negotiators perceive no political advantage to compromise, such as existed with EPAct92 and EPAct05 (chapter nine), and as turnover in personnel disrupts the actor networks. The private sector may find less reason to cooperate with federal actors if no looming legislation concerns them or they see little economic benefit. No new, highly efficient lighting invention seems imminent that would require federal assistance for industry to introduce. Efficacy is moving toward a point where policy makers may lose the ability to cut energy consumption much further by means of lighting regulations. The political and problem streams have shifted into new channels, as Kingdon might say, calling for new approaches to lighting policy.

Building on the findings of this dissertation, future research might profitably

46. Kingdon, *Agendas*, 23.

examine policies that promoted efficiency as seen in other energy using technologies, especially those that demonstrated user group differentiation. As seen above in figure 10.3, heating and cooling consume large amounts of the nation's electrical output. Residential fans and commercial grade units rely on electric motors yet differ in design and construction, exhibiting measurable differences in energy efficiency. Improvements in efficient motor technology may have faced difficulties in market diffusion similar to efficient lamps; some regulations in EPAct05 to promote more efficient electric motors do seem to have been tailored to particular market sectors.[47] Fans that ventilate buildings and laptop computers are very different in size but both must work with automated controls, demonstrating issues of convergence with other technologies that may have hampered policy interventions. The overlapping historical timelines mean that national contexts would hold constant, while many of the same manufacturers and professional organizations have been involved so that actor networks also overlap. Other examples abound within electrical technologies. Historical studies of non-electric technologies developed during the same periods, gasoline powered motor vehicles for example, could provide useful policy comparisons to determine if electrical technologies have been especially unique and which policy theories may apply.

Moving forward, policy actors clearly require an understanding of past lighting policies and the contexts—technical, political, economic—in which those policies were developed. What has changed or not, what problems policy actors tried to address, the constraints within which they worked, and a sense of the path that lighting has travelled. In

47. EPAct05, 119 Stat 636.

September 1882, Edison began lighting a quarter square mile of lower Manhattan and boasted to a reporter, "I have accomplished all that I promised."[48] As his incandescent lamps fade from the scene many policy makers may share a similar sense of triumph, but the energy and environmental problems that drove recent lighting policies are not so easily resolved. Future policies may involve lighting but will need to do so in novel ways given the changes that have occurred, especially changes created by the emergence of new individuals, companies, and interest groups. Accounting for change over time is essential in understanding human affairs even as some things, such as the need for light, remain constant. We may indeed be unable to step into the same historical river twice but the river exists nonetheless with currents, eddies, and shoals that persist for varying periods of time. Those features present "a wonderful book" to those who "master the language of this water," as Mark Twain said of his beloved Mississippi, a book with no page "that you could leave unread without loss." About ten years after Edison's invention, Twain, a former river pilot, retraced his youthful voyages "in these new days of infinite change." He recorded one especially striking change that presaged both the promise and problems that remain with us to this day: "you flash out your electric light, [and] transform night into day in the twinkling of an eye."[49]

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48. "Edison's Light Turned On," *New York Sun*, 5 September 1882, 1, http://chroniclingamerica.loc.gov. Cited in Israel and Friedel, *Biography*, 222.

49. Mark Twain, *Life on the Mississippi* (Mineola, NY: Dover Publications, Inc., 2000; originally published 1883), 44, 130.

Note on Sources

This dissertation draws on primary and secondary sources consulted between 1995 and 2018. They are a mix of hard copies (originals, photocopies, or printouts), digital files (ab initio or scans), and items first accessed in hard copy but now available online.

Archival and library collections

Documents cited at the Smithsonian Institution's National Museum of American History (NMAH) exist in three locations: the Archives Center, the NMAH branch of the Smithsonian Libraries, and the Electricity Collections. In the Archives Center I consulted: N. W. Ayer Advertising Agency Records (AC#59), Warshaw Collection of Business Americana (AC#60), William J. Hammer Collection (AC#69), General Electric Nela Park Collection (AC#789), Louisan E. Mamer Rural Electrification Administration Papers (AC#862), and Reddy Kilowatt Records (AC#913). The NMAH Library holds business and technical journals as well as an extensive special collection of trade literature. The Electricity Collections holds additional trade literature as well as subject, biographic, and photo research files on lighting (cited as NMAH EC-LRF) dating from the late 1890s.

Records at the National Archives and Records Administration (NARA) include: the US Fuel Administration, the Rural Electrification Administration, and the War Production Board. Files accessed at the US Patent and Trademark Office in Crystal City have been moved to NARA's College Park, MD, location. The Library of Congress holds the Congressional Record and transcripts of committee hearings. The Government Printing

Office website contains text of bills, amendments, and hearings. Files viewed in the Department of Energy's Lighting Program Office in the late 1990s have been sent to NARA, placed in the NMAH Electricity Collections, or disposed of. The library of the Edison Electric Institute holds the records of the Better Light Better Sight Bureau. I consulted hardcopy and digital editions of the Thomas A. Edison Papers, located at Rutgers University. In the late 1990s, I viewed archival files at General Electric Lighting at Nela Park (Cleveland), and Sylvania publications at their Danvers, MA, headquarters.

Object collections

The NMAH Electricity Collections (cited as NMAH EC) includes about 3000 objects covering electric lighting from the 1850s through the present. The holdings of the former Mt. Vernon Museum of Incandescent Lighting are now at the Baltimore Museum of Industry as the Hugh F. Hicks Lighting Collection.

Digital resources

Several publications exist in digital format only and some traditional hard copy publications were augmented by digital content separate from the print editions. The Internet Archive was an invaluable resource for older items, such as Congressional hearings and White House documents. I obtained access to subscription based materials such as ProQuest through the Smithsonian Libraries and through the Albert O. Kuhn Library at UMBC. Many reports, journals, and other publications are available through Google Books and the Hathi Trust.

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