1. Introduction

The [OPEC] Oil Embargo which began on October 19, 1973 sparked a fundamental reassessment of the nation’s vulnerability to imported energy and also forced a reassessment of the role that energy R&D could play in helping secure the nation against hostile acts like the Oil Embargo. (Dooley, 2008, p. 9)

THE IMPORTANCE OF ENERGY TECHNOLOGY

The oil crisis of the early 1970s led the United States (and the world) to realize that cheap oil was not an ‘inalienable right’ and that the existing transportation system (from well head to wheel) was not sustainable. The decade also saw the Three Mile Island incident and witnessed the emergence of the environmental movement. By the end of the 1970s there was a consensus that new and more efficient technologies were needed to ensure economic growth, to reduce the United States’s dependence on foreign energy sources, and to protect the environment.

Following the embargo, the US government aggressively began pursuing enhanced/alternative energy options. The DOE, activated on October 1, 1977, assumed the responsibilities of the Federal Energy Administration, the Energy Research and Development Administration, the Federal Power Commission and parts and programs of several other agencies, with the mission to ‘[e]nsure America’s security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions.’ (Energy.gov, 2011)

Over the past 30 years, a wide range of energy technology research programs have been pursued, under the frequently stated goal of the United States achieving energy independence within a specified number of years. To name a few, research programs have included technology development in areas of nuclear, solar, hydrogen, and biofuels. Over the decades, all of these initiatives have shown promise and to varying degrees been promoted as a potential (or at least partial) solution to energy issues with breakthrough on the horizon.

However, today we face much the same energy issues that were present in the 1970s. The United States’s energy consumption distribution by energy source has changed only modestly (see Table 1.1). Whereas overall
Public investments in energy technology

Table 1.1 Comparison of US energy consumption by energy source

<table>
<thead>
<tr>
<th>Energy source</th>
<th>1970a (% share of total)</th>
<th>1980a (% share of total)</th>
<th>2009a (% share of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>13.0</td>
<td>16.3</td>
<td>20.9</td>
</tr>
<tr>
<td>Oil</td>
<td>31.2</td>
<td>36.2</td>
<td>37.3</td>
</tr>
<tr>
<td>Natural gas</td>
<td>23.0</td>
<td>21.4</td>
<td>24.7</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.3</td>
<td>2.9</td>
<td>8.8</td>
</tr>
<tr>
<td>Hydro</td>
<td>2.8</td>
<td>3.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.0</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Wind</td>
<td>0.0</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Solar</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Biomass</td>
<td>1.5</td>
<td>2.6</td>
<td>4.1</td>
</tr>
<tr>
<td>Energy intensity per output b (GDP) (BTU/$)</td>
<td>15889</td>
<td>13379</td>
<td>7343</td>
</tr>
<tr>
<td>Energy intensity per capita c (Million BTU/Capita)</td>
<td>330.9</td>
<td>343.1</td>
<td>307.9</td>
</tr>
</tbody>
</table>


...energy intensity has decreased (as measured as a share of gross domestic product [GDP]), little improvement has been made on energy consumption per capita. And the dependence on fossil fuel has persisted over time even in the face of increasing direct costs, and more recently, increasing concerns over the indirect costs associated with climate change and military interventions to ensure foreign supply.

It has become increasingly clear that in the near to midterm there is not likely to be a breakthrough innovation that on its own will solve the world’s energy problems. For example, biofuels have many attractive attributes in that they are renewable and have the potential of low greenhouse gas (GHG) emissions. However, with the current technologies, production of 15 billion gallons of corn ethanol, which replaces only 12 per cent of imported oil, requires landmass of about the size of Iowa (Hertel et al., 2010).

In addition, problems in the intersection of energy production and food production are likely to increase over time as developing countries work to raise the standard of living of their growing populations.

Improvements are going to be needed across a broad range of energy technologies to meet the energy challenges of the 21st century. Research cannot just focus on a few high-profile, high-impact (but maybe low probability) energy initiatives. A true portfolio of energy technology research...
is needed and should also include low-tech solutions and incremental improvements to existing technologies. For example, improved insulation in commercial, residential, and institutional buildings has the potential to reduce US energy consumption by 15 per cent. As discussed throughout this book, combustion engines are likely to be the primary transportation power source for many years to come, and even small improvements in efficiency can lead to significant reductions in gasoline and diesel consumption.

There is a role for government investment in research throughout a technology’s life cycle, and to its credit, the DOE has historically pursued a portfolio approach to energy technology development. However, much of the R&D public policy discussion has previously focused only on early-stage R&D, moving new technologies from laboratories to commercialization or developing radically new energy infrastructures. The case studies herein demonstrate that significant social returns can be achieved by removing barriers to enhancing and implementing existing technologies that are at different levels of maturity.

We present three case studies that focus on different technologies at different stages of maturity:

- primarily applied R&D (solar)
- market implementation (geothermal)
- efficiency improvements of a mature technology (combustion engine).

Each of these technological advancements has been developed in the private sector with technical and financial support from the DOE. As a starting point for the methodological development and case studies that follow, we begin with an overview of legislation related to developing energy technology.

LEGISLATIVE BACKGROUND

At the time of the Organization of the Petroleum Exporting Countries (OPEC) oil embargo, the US infrastructure related to energy was the Atomic Energy Commission (AEC). In response to the OPEC oil embargo, President Nixon launched Project Independence on November 7, 1973; the goal of the project was to achieve energy independence by 1980.

On December 4, 1973, President Nixon created the Federal Energy Office in the Executive Office of the White House to allocate then scarce petroleum supplies to refiners and consumers (Fehner and Holl, 1994).
More generally, in his State of the Union address on January 30, 1974, President Nixon stated: ‘Let it be our national goal: At the end of this decade, in the year 1980, the United States will not be dependent on any other country for the energy we need to provide our jobs, to heat our homes, and to keep our transportation moving.’ (American Presidency Project, 2011.)

On October 11, 1974, President Ford reestablished the Nixon emphasis on energy independence by signing the Energy Reorganization Act of 1974, Public Law 93-438. This Act built on the Federal Nonnuclear Energy Research and Development Act of 1974, which stated: ‘The Congress declares the purpose of this Act to be to establish and vigorously conduct a comprehensive, national program of basic and applied research and development, including but not limited to demonstrations of practical applications, of all potentially beneficial energy sources and utilization technologies.’ (Office of the Under Secretary for Defense, 2011.)

The Energy Reorganization Act established the Nuclear Regulatory Commission to carry out the responsibilities of the abolished AEC. The Act also created the Energy Research and Development Administration (ERDA) to, among other things, encourage and conduct: ‘research and development in energy conservation, which shall be directed toward the goals of reducing total energy consumption to the maximum extent practicable, and toward maximum possible improvement in the efficiency of energy use [. . .] and research and development in clean and renewable energy sources.’ (US Nuclear Regulatory Commission, 2002.)

Then, on August 4, 1977, President Carter signed the Department of Energy Organization Act of 1977, Public Law 95-91, transferring the mission of ERDA to the newly formed DOE. As stated in the Act, Congress finds that:

- The United States faces an increasing shortage of nonrenewable energy resources.
- This energy shortage and our increasing dependence on foreign energy supplies presents a serious threat to the national security of the United States and to the health, safety, and welfare of its citizens.
- A strong national energy program is needed to meet the present and future energy needs of the nation consistent with overall national economic, environmental, and social goals.
- Responsibility for energy policy, regulation, research, development, and demonstration is fragmented in many departments and agencies and thus does not allow for the comprehensive, centralized focus necessary for effective coordination of energy supply and conservation programs.
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- Formulation and implementation of a national energy program requires the integration of major federal energy functions into a single department in the executive branch. (US Department of the Interior, 2011.)

By this Act, Congress declared that establishing such a department in the Executive Branch was in the public interest and would promote the general welfare by ensuring coordinated and effective administration of federal energy policy and programs. The DOE would, according to the Act:

Carry out the planning, coordination, support, and management of a balanced and comprehensive energy research and development program, including—(A) assessing the requirements for energy research and development; (B) developing priorities necessary to meet those requirements; (C) undertaking programs for the optimal development of the various forms of energy production and conservation; and (D) disseminating information resulting from such programs.

The Office of Conservation and Solar Energy was created after the passage of the National Energy Conservation Policy Act of 1978, Public Law 95-619.

The office of EERE was formed within the DOE in 2001 when the Office of Conservation and Solar Energy was renamed and reorganized. The general goals of EERE are to advance a wide range of clean energy technologies, with the mission of strengthening the economy, protecting the environment, and reducing dependence on foreign oil. EERE’s programs rely heavily on partnerships with the private sector, state and local government, DOE national laboratories, and universities.

EERE is organized around ten energy programs: Biomass Program; Building Technologies Program; Federal Energy Management Program; Geothermal Technologies Program (GTP, discussed in Chapter 6); Fuel Cell Technologies Program; Industrial Technologies Program; Solar Energy Technologies Program (discussed in Chapter 5); Vehicle Technologies Program (discussed in Chapter 7); Wind and Hydropower Technologies Program; and the Weatherization and Intergovernmental Program.

OVERVIEW OF THE BOOK

The remainder of the book is outlined as follows. In Chapter 2, the economic arguments for governmental investments in R&D and new technology are summarized. Therein is discussed the barriers to new technology
that bring about market failure related to private investment in improved energy efficiency. The chapter emphasizes that these barriers exist throughout the technology life cycle. Associated with this involvement is a responsibility of accountability, as discussed in Chapter 3. Chapters 2 and 3 are brief, and although their subject matters are related, they are presented separately to emphasize the importance of the topics.

A counterfactual evaluation methodology is used to quantify the net social benefits of public investments in energy technology in the three case studies presented in Chapters 5, 6, and 7. Chapter 3 provides an overview and critique of this counterfactual evaluation methodology and related evaluation metrics.

Chapter 4 introduces the three retrospective case studies that follow. This chapter summarizes the technology background relevant to the case studies with an emphasis on applied R&D (investments in solar power), market technology (geothermal technology), and efficiency improvements in mature technology (combustion engines).

Chapter 5 presents an economic analysis of the net social benefits accruing from the investments of the DOE’s Solar Energy Technologies Program in photovoltaic energy systems, specifically from photovoltaic module technologies that are encapsulated sets of solid-state solar cells that convert solar energy into electricity.

Chapter 6 presents the findings from an economic analysis of technology supported by the DOE’s Geothermal Technologies Program. The study compares historical economic activity with the GTP’s investments with what would have likely happened in the absence of these public investments.

Chapter 7 focuses on the Vehicle Technologies Program’s investments in laser and optical diagnostics and combustion modeling for heavy-duty diesel engines. It describes how US diesel engine manufacturers have used the technology that came about from these public investments, and it offers quantitative measures of the resulting net social benefits.

Chapter 8 concludes the book with a brief statement of the policy implications to be drawn from the findings in the three case studies presented.