Federal Energy Technology Deployment Policies Since the 101st United States Congress

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EXECUTIVE SUMMARY

On Monday, November 29th, 2010, the President's Council of Advisors on Science and Technology (PCAST) sent a report to President Obama called *Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy*. It highlighted areas of possible reorganization for the federal government concerning the nation's energy innovation system. Amongst its recommendations, it highly encourages Congress to allocate $16 billion per year for federal support for energy technology research, development, demonstration, and deployment. Of this amount, $4 billion per year is recommended to go specifically to large-scale demonstration and deployment projects (President's Council of Advisors on Science and Technology, 2010). This very recent report gives insights into the present day discussion in the United States about the nature of the energy technology innovation process and its inherent barriers.

This paper focuses on energy technology deployment (ETD), one subset of the energy innovation system discussed in the PCAST report. The results of this study are presented in three parts. First, six ETD barriers described in the literature are presented. These barriers are cost, network infrastructure, slow capital stock turnover, market development, information, and financing options. Second, a general categorization of example ETD policies was conducted for major energy-related federal statutory law since the 101st United States Congress (1989-1990). Seven major energy-related laws were analyzed. The results from this general categorization are given in the tables presented in this paper. Finally, a detailed explanation of specific ETD examples and their effects on deployment barriers is presented. The specific examples show both positive and negative effects resulting from actions to decrease ETD barriers implemented by federal statutory law.

In all, this paper describes the nature of the barriers to energy technology deployment, and a subset of implemented federal-level policy tools of the last 20 years seeking to decrease these barriers. The examples of policies presented in the categorization sections of this paper are just a few that have been set into law at the federal level. This snapshot shows what types of policies have been implemented, and specific results from just a subset of those policies. Understanding policies of the recent past can assist policymakers in designing future programs by learning what has worked, what has not, and what has yet to be done.

INTRODUCTION

To answer the complex, energy-related problems in today's world, energy technologies need to be more than just invented. They need to be supported, deployed, and commercialized. Ideally, open markets should work to provide all the necessary steps in the process for energy technologies to be invented, nurtured, grown, and accepted in common use. Do these actions occur for energy technologies, and if they do not, what are the barriers keeping these actions from occurring?

The PCAST report describes this innovation process as an energy technology ecosystem, consisting of four parts: invention, translation, adoption, and diffusion (See Figure 1). Invention describes the timeframe over which an idea is created and refined, containing both disclosure of the insight and the work to understand its nuances. Translation is the time when the ideas are refined through innovation into new or better products. The last two timeframes during which adoption and diffusion occur are the main focus for this paper's discussion. These are the periods when deployment of energy technologies is occurring. The PCAST report describes these stages as "the most critical for renewing our energy infrastructure, because of the need for new technology to displace incumbent technologies" (PCAST, 2010). The report also notes the highly interlocked relationship between the various stages, where work in any one stage affects work in the others.

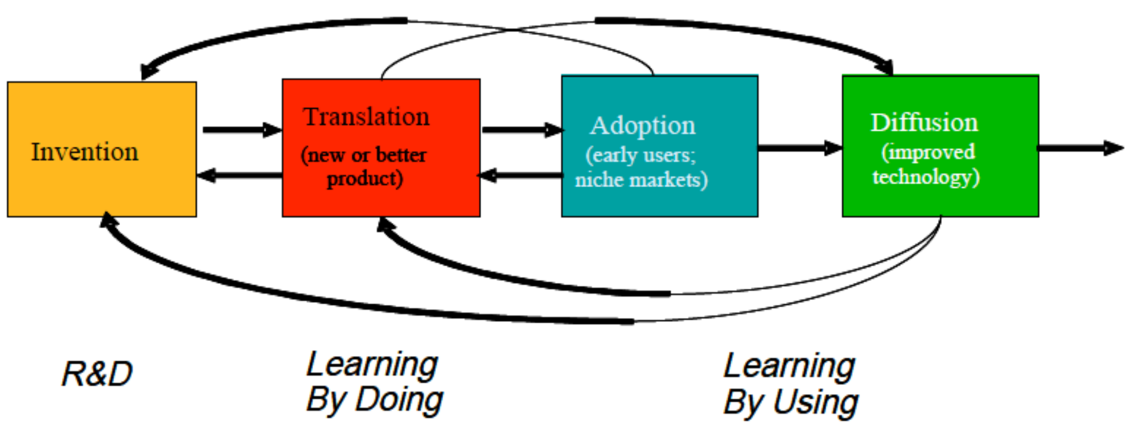

Figure 1. Energy technology ecosystem – the process of technological change (PCAST, 2010)

PCAST uses this visualization, and their understanding of the nature of this technological change process, to make a general point in the report: the federal government has done a great job supporting this process during the invention (R&D) stage, but it has *not* done very well in the later stages, and specifically, this has occurred for two reasons. First, as PCSAT describes, "the government historically performs much less well at translation, adoption, and diffusion, partly because the Federal actions that influence these components of the energy technology ecosystem are diffused so widely across government," and secondly, "energy sector decision making is ultimately in the hands of the private sector" (PCAST, 2010). Their conclusion is that the efforts of the federal government, while many, are spread thin over many aspects of governmental work. These efforts are not contained by an organizational structure which can correctly guide the later innovation system processes, seeking to influence private actors in the energy sector who are making the decisions. The report sheds light on the process, organization, and funding of the Department of Energy, and brings useful recommendations to the ongoing discussion, but it does not focus on a deeper understanding of specific policy tools and the reasons behind their use.

This paper will analyze federal energy technology deployment (ETD) policies. These specific policies are very unique for energy technologies due to physical requirements of the technologies and to organizational constraints of their markets. First, due to the capital-intensive, network-based organization of these systems, new technologies have a bias against them. The energy system is generally risk-adverse, change-adverse. With a utility for example, new technologies pose unanswered questions for systems charged with keeping necessities available and of decent quality to all people within a certain utility's jurisdiction. A great deal of capital and financial risk is needed to deploy energy technologies. Secondly, many energy technologies are used in regulated markets, where State-level Public Service Commissions must approve large projects, programs, and ventures. Third, customers are separated from decisions and information in today's energy system, because they use these systems for a service, and not as just a product in-and-of itself. For these reasons, energy technologies are difficult to deploy in markets. Social regulation, and in this paper's case, federal statutory law, can be used to bolster and advance energy technologies into their respective markets. Laws at many levels of government are used to assist these technologies as they mature from initial invention. This paper will focus only on federal energy-related laws and energy technology deployment titles and sections contained within them.

The analysis for this paper has four broad parts to it. First, a timeframe was chosen for analysis. The beginning of this analysis was chosen to be the 101st Congress, or about 20 years ago. The 111th Congress will finish in December 2010. Each new Congress is two years in length. Twenty years was chosen because it is a timeframe that is manageable from an analysis point of view while also containing major energy provisions that have reshaped many portions of the United States energy system. Second, a general statutory law search was conducted to find the major pieces of specific, energy-related legislation during this time period. With a list then set, the third step was setup to identify specific titles and sections of the chosen legislation relating to known, major ETD barriers. Fourth, specific examples addressing the energy technology deployment barriers were discussed, bringing to bear the results of certain policies. Finally, additional research and analysis areas were addressed to give a more complete view of understanding energy technology deployment policies.

From a realistic point of view, understanding the types of policies implemented in the past shows future policymakers the type of tools that can be passed into law at the federal level. It is critical to know what policies are implementable. Additionally, the areas addressed by these past policies should be understood. Further actions may be necessary in those areas, or different policies may need to be created for those or other areas, depending on outcomes. Therefore, positive and negative outcomes of policies should be analyzed and discussed.

Energy technology deployment is very important to understand because emerging technologies, essential to energy system advancement, can fail to enter markets if not supported correctly. Policies to conduct this deployment work must be developed and understood for market entry to occur. Further, understanding these deployment policies and what barriers they are dealing with will assist policymakers in managing balanced levels of funding for all stages of technology research, development, demonstration, and deployment – known as RDD&D or RD^3 (Sagar & Gallagher, 2004). This balancing act shows the inherent policy prioritization that happens whenever funding is discussed in legislatures.

Understanding the barriers to energy technology deployment is essential to policy creation. The next section elaborates on these barriers, giving them in detail.

ENERGY TECHNOLOGY DEPLOYMENT BARRIERS

Existing offices in the federal government are tasked with assisting in private and public technology deployment issues. Having roots in the energy crises of the 1970's and christened with its current name in 2001, the Energy Department's Office of Energy Efficiency and Renewable Energy (EERE) devotes two main programs to the cause of energy technology deployment. These two programs are the Federal Energy Management Program and the Commercialization & Deployment Program. These programs have within them sets of initiatives to buffer what is termed the "Valley of Death" as shown in Figure 2 (Department of Energy, Energy Efficiency and Renewable Energy). This terminology is a catch-all for the situations arising after invention and research occur, having to do with the dynamic intersection of science and engineering with finance and business. In Figure 2, the "Valley of Death" occurs during the introductory and early growth periods of the technology and business.

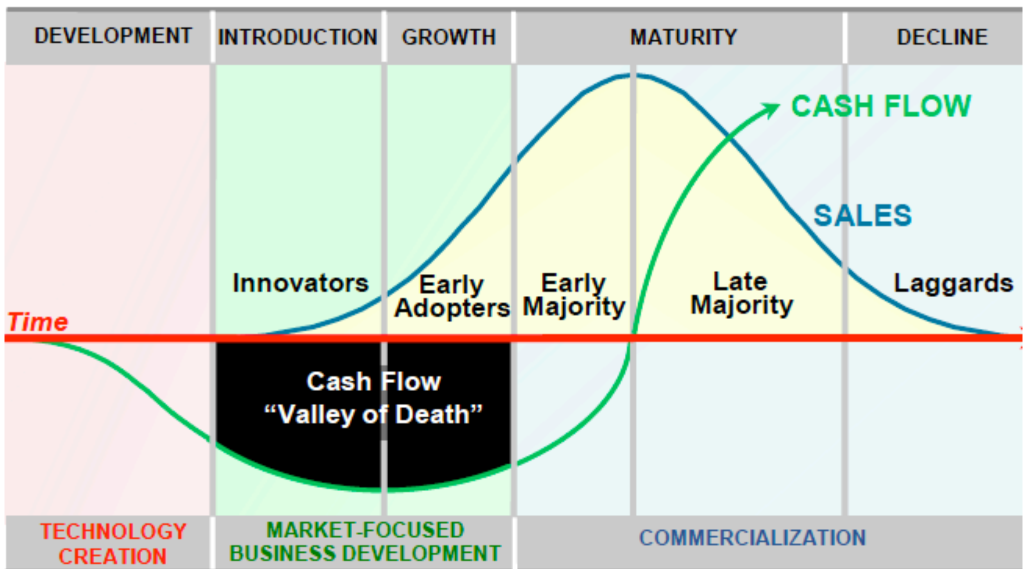

Figure 2. Technology timeline from R&D to decline – Deployment policies buffer issues arising in the area termed the "Valley of Death" (Department of Energy, Energy Efficiency and Renewable Energy)

EERE initiatives include supporting entrepreneurs within public laboratories, showcasing technologies to private interests, and supporting technologies through specific funding mechanisms amongst others (Department of Energy, Energy Efficiency and Renewable Energy). These initiatives are administrative in nature, ideally working off previous mistakes and successes. The initiatives are usually public or public-private ventures meant not to give a layer of bureaucracy to some supposedly inherent market quality (i.e. a quality that supposedly must "thin the pack" leaving only the strongest deployable technologies to survive), but to provide bridges for ideas and inventions who's merits already have been proven through previous research and development (R&D) accomplishments (DOE, EERE). The investment of R&D is made more valuable through the use of deployment policies, making sure that these R&D investments do not wither in this "Valley of Death," but can survive to the marketplace where companies compete for customers and not for future technological advances or pathways.

These administrative departments and programs get their authority from statutory law. Even though these departments and programs exist, this paper will focus on a general analysis of federal statutory law with respect to barriers involved in the energy technology ecosystem process. Statutory law is the origin of the authority for these programs related to ETD. A specific analysis will also be conducted to detail policy examples relating to general ETD barriers.

Energy technology deployment into markets is difficult. Energy technologies hold a unique place in the economic fabric of modern society. In the most general sense, these technologies have as a basic goal to manage necessities, electricity or fuel, in a more efficient way. Additionally, the markets, where many of these technologies are ultimately used, traditionally are regulated marketplaces at both the state and federal level. These two notions of necessity and regulated markets help to form the framework for understanding why energy technology deployment is so difficult, but these two notions do not form a complete set of answers as to why deployment difficulties for energy-related innovations exist. Foundational barriers must be understood as to why market deployment falters. In other words, what are the many components that form the "Valley of Death"? The literature on the subject defines six main areas that form the barriers to energy technology deployment. These barriers are cost, network infrastructure, slow capital stock turnover, market organization, information, and financing options (Gallagher, Holdren, & Sagar, 2006). Each of these barriers is now discussed.

COST

Cost is a very important factor in energy technology deployment. There are two primary reasons for this importance. First, the cost of older technologies does not usually include the environmental costs associated with pollution. These are rarely included in market costs, and hence are called externalities. For new energy technologies, decreasing environmental costs will have no effect against technologies that do not include those costs at all (Gallagher et al., 2006, and Sagar & Gallagher, 2004). Secondly, initial prices for new energy technologies can be much larger than incumbent technologies, inducing a "sticker-shock" to consumers. Although these two barriers exist, the literature presents pathways to decrease them (Gallagher et al., 2006).

A number of policy tools can be used to internalize externalities and reduce early adoption prices. First, market-based instruments, like pollution allowance trading or pollution taxes, can be used to add environmental costs into the cost structure of existing technologies. This action gives an incentive for new energy technologies to reduce or eliminate these environmental costs through the production of cleaner energy. For example, common carbon dioxide charges generally include setting a dollar amount per ton of CO_2. Second, regulation can be used in a similar way to impose fines and limits on pollution. Third, subsidies can be used to decrease sticker prices through grants or credits, or existing subsidies can be removed to increase costs for old technologies. Finally, the government can use its large purchasing power to procure technologies in their early phase thus giving the energy technology producer a more constant market for sales, allowing costs to therefore fall through increased sales (Gallagher et al., 2006).

Network Infrastructure

Many energy technologies use network transmission, distribution, and maintenance systems to support the general use of a certain type of technology. Examples of existing infrastructure networks include roads, natural gas pipelines, liquid fuel stations, and electricity distribution systems. These networks are vast, representing decades of investment. New energy technologies may use very different network infrastructure if brought into common use. For example, both hydrogen and electric vehicles would need new refueling or charging stations if they were to be used widely. Government intervention is needed to provide subsidies or incentives to build these new infrastructure networks if a certain technology pathway is pursued (Sagar & Gallagher, 2004, and Gallagher et al., 2006). Old technology infrastructure is a barrier to new technology infrastructure.

As networks were developed over the past decades to support existing technologies, inertia was also building against deploying other forms of infrastructure networks. In other words, the existing network infrastructure is ‘locked-in’ (Sagar & Gallagher, 2004). Because certain energy technologies are ‘locked-in’ – they are the default technology – other technologies with certain benefits, but requiring different network systems, are at a large disadvantage. Governmental action is almost always necessary to bring down this network infrastructure barrier for future network-heavy technologies. This action would not be possible in only voluntary market transactions due to the size and risk that these networks would impose on possible private investors.

Slow Capital Stock Turnover

Non-network energy technologies also have long lifetimes. Power plants are regularly used 40-50 years before decommissioning. Vehicles are used for more than a decade. Home appliances stay in use for years on end. For energy technologies like the ones just mentioned, slow capital stock turnover exists. This slow pace of turnover impedes new energy technologies from commercialization, hindering partial or full deployment. Governmental actions can be used to decrease these barriers by quickening the pace of capital stock turnover, allowing other technologies to be drawn into more common use. For example, performance standards, bans, and technology phase-in or -out are all possible policy tools available to policymakers. These policies force the conditions in the market to be more favorable to newer technologies that have benefits like more efficient energy use or lower pollution generation (Gallagher et al., 2006).

Market Development and Organization

The inherent qualities, rules, and setup of a market also affect the deployment of new energy technologies. In the literature, this area is called market development and organization. New technologies pose risks, and markets, specifically investors, may not be willing or able to carry those risks for commercializing new technologies. To develop these markets, governments can use certain policy tools to decrease risks and share costs before effective market commercialization can take place. Some policy tools include targeting niche markets, transforming existing markets through rule or standard changes, and developing public-private partnerships (Gallagher et al., 2006). These efforts are taken on by government to decrease the likelihood that useful technologies fail to reach full deployment or commercialization in a given market after public or public-private R&D investments have been made.

Information

Large organizations, businesses, or other entities have the resources to hire energy analysts to perform audits or give recommendations for energy technology related updates. For these groups, information is not a problem, because it can be purchased. But other groups like small businesses or individual consumers most likely do not have the resources to find or understand this information. On its own, the market has shown that the information usually won't be voluntarily given to consumers. Because information is very necessary for consumers to make appropriate decisions, government programs can be setup to ensure the necessary conditions for getting this information into the market. For example, labeling and public education programs have found common use (Gallagher, 2006, Sagar, 2004) to address this problem of a lack of information. These programs organize and present information about energy use or efficiency achievements to consumers who would not otherwise be able to gather this information on their own. Governments can decrease information barriers to allow consumers to weigh the details of existing technologies in comparison to new technologies.

FINANCING OPTIONS

Due the capital-intensity of energy technology, acquiring the appropriate financial resources is a very important part of the deployment process. If new energy technology projects cannot obtain the correct financing, many projects will just never be built, hindering deployment. This financing options barrier has roots that are both economic and risk based. Due to financing limitations available in open markets, governmental actions can be taken to decrease these barriers, allowing better deployment possibilities. For example, policy tools include backing projects with publicly financed loan guarantees, issuing specific energy-related bonds, and creating development banks (Gallagher, 2006). These options can create financial conditions tailored to the problems that energy technologies face. With these new conditions, financial barrier to deployment can be reduced.

These six barriers form a framework for describing the issues facing energy technology deployment. By understanding these barriers more fully, policymakers can form tools to appropriately deploy technologies into marketplaces more efficiently and effectively. For this paper, federal statutory policies regarding energy technology deployment were studied and categorized against this list of barriers. In doing this categorization, implemented statutory law can be placed under the microscope to better understand the reasoning behind certain policies, and to see if current law addresses all barriers in a comprehensive way. This methodology can unveil weaknesses and strengths in legislation, showing where continued work must be done.

GENERAL ENERGY TECHNOLOGY DEPLOYMENT POLICY ANALYSIS

Since the 101st United States Congress, there have been seven major energy-related federal statutory laws. These laws are detailed in Table 1. Besides federal laws in 1990 and 1992, the other five Acts have been signed into law after 2005. This separation shows the recent focus of energy policy specifically tied to events that have affected the energy system of the United States, and shows that major legislation (here, relating to energy) can come in waves.

The focus of this paper is to analyze energy technology deployment by asking two questions: 1) what barriers to deployment exist, and 2) what policies have been implemented to address these barriers? The analysis used these seven Federal statutory laws (Table 1), and found examples in the laws relating to the six ETD barriers. Search terms were used to find examples. These examples were then recorded and are shown next to their associated ETD barrier they desire to decrease or generally affect. Common names for the federal statutory laws are also given, highlighting the regular practice of abbreviating the long names of these Acts.

Table 1. Major energy-related federal statutory law since the 101st Congress

Congress	Year	Federal Statutory Law Name	Abbreviation or Common Name
101st	1990	Clean Air Act Amendments	CAAA
102nd	1992	Energy Policy Act	EPAct1992
109th	2005	Energy Policy Act	EPAct2005
110th	2007	Energy Independence and Security Act	EISA2007
110th	2008	The Emergency Economic Stabilization Act of 2008 – Division B: The Energy Improvement and Extension Act	EIEA
110th	2008	Food, Conservation, and Energy Act	The 2008 Farm Bill
111th	2009	American Recovery and Reinvestment Act	ARRA

This examination of these seven Acts starts with the general categorization of ETD policies in the 1990 Clean Air Act Amendments (CAAA). Examples of ETD policies are given in Table 2, and categorized by their related ETD barrier. The CAAA was intended to address acid rain, urban air pollution, specifically smog, and toxic air emissions, which the original Clean Air Act was unable to do at a satisfactory level (EPA Summary of CAAA). The CAAA instituted new programs for cleaning the air, including a pollution allowance program for SO_2, which was a policy innovation at the time of enactment. Additionally, the law focused on the use of bans, clean fuel programs, monitoring, public inventory evaluation and setup, and tax incentives for renewable energy. All of the provisions sought to work toward the goal of removing certain particles and pollution out of the air (101st United States Congress, 1990). The reason behind this regulation was environmental in nature. Acid rain had become a problem in the United States and the Congress wished to address this issue through new social regulation. New technologies were also deployed as a result of the legislation due to requirements to pollute less, but still provide sufficient amounts of electricity to power the nation.

Table 2. The 1990 Clean Air Act Amendments example section names and numbers related to energy technology deployment barriers (101st Congress, 1990)

ETD Barrier	Section Name	Section Number
Cost	Acid Deposition Control – SO_2 Allowances	401
Network Infrastructure	*NO MAJOR PROVISIONS*	-
Slow Capital Stock Turnover	Prohibition on Production of Engines Requiring Leaded Gasoline	211
Market Development and Organization	Clean Alternative Fuels Program	206
Information	Enhanced Monitoring and Inventories	102
Financing Options	Solar and Renewable Energy Incentives	1001

The Energy Policy Act of 1992 sought to restructure the electric power system to allow for more market-like organizational arrangements. First, it created the necessary rules and mechanisms for competitive wholesale electricity generation markets to form. This change stood in contrast to the traditional electricity generation structure. Second, national transmission lines were opened up to wholesale suppliers. These two large changes directly affected natural gas use, which was intended to (and did) rise due in part to the passing of this Act and the CAAA (EPAct Summary). Additionally, the EPAct1992 contained many sections related to technology, and the ones related to ETD policy are detailed in Table 3. The EPAct1992 began the first federal renewable energy production incentive to reduce the cost of deploying renewable energy technologies. Other example sections in the law included vehicle infrastructure development, building energy efficiency standards, privatization of government-owned uranium enrichment facilities, labeling and energy efficient mortgages (102nd United States Congress, 1992).

Table 3. The Energy Policy Act of 1992 example section names and numbers related to energy technology deployment barriers (102nd Congress, 1992)

ETD Barrier	Section Name	Section Number
Cost	Renewable Energy Production Incentive	1212
Network Infrastructure	Electric Motor Vehicle Infrastructure and Support Systems Development Program	Title 6, Subtitle B
Slow Capital Stock Turnover	Building Energy Efficiency Standards	101
Market Development and Organization	Establishment of the United States Enrichment Corporation	901
Information	Labeling Requirements for Alternative Fuels	406
Financing Options	Energy Efficient Mortgages	105-106

The Energy Policy Act of 2005 (EPAct2005) included many provisions about energy security, environmental quality, and economic growth (CRS, Summary of EPA2005). The Act was the first energy bill signed into law after many indirect and direct energy-related issues had been faced by the nation. These events included the growth of electricity markets due to deregulation in many states (and the problems which correspondingly arose), the rise and fall of Enron, rolling blackouts in California, the Northeast blackout, September 11th, and the wars in Iraq and Afghanistan. These events affected how this legislation was formed. The policies contained in the EPAct2005 mainly related to the restructuring of electricity market rules, renewable fuel standards, and tax incentives for energy efficiency and domestic energy production (CRS, Summary of EPA2005). The EPAct2005 include many ETD-related policies. These policies, and their section information, are categorized with respect to the general ETD barrier in table 4. Of note, the EPAct2005 created a production tax credit for advanced nuclear power facilities. This action sought to incentivize the construction of new nuclear plants. The EPAct2005 also created the first renewable fuel standard (RFS) in the nation, which desired to deploy corn ethanol into the gasoline system (109th United States Congress, 2005). The desired effect of the RFS was to decrease dependence on foreign oil, thus addressing national security concerns.

Table 4. The Energy Policy Act of 2005 example section names and numbers related to energy technology deployment barriers (109th Congress, 2005)		
ETD Barrier	**Section Name**	**Section Number**
Cost	Credit for Production from Advanced Nuclear Power Facilities	1306
Network Infrastructure	Advanced Power System Technology Initiative Program	1224
Slow Capital Stock Turnover	Renewable Content of Gasoline	1501
Market Development and Organization	Technology Infrastructure Program	1002
Information	Energy Efficiency Public Information Initiative	134
Financing Options	Electric Transmission Property Treated As 15-Year Property	1308

Unlike the EPAct2005, the Energy Independence and Security Act of 2007 (EISA2007) focused primarily on energy efficiency and renewable energy. The EISA2007 contained increases to CAFE standards, increases to the renewable fuel standards (set by EPA2005), and appliance and lighting standards (CRS, Summary of EISA2007). The focus on gasoline supply and use was due in part to the effects Hurricanes Katrina and Rita, which affected these supplies.

Table 5. The Energy Independence and Security Act of 2007 example section names and numbers related to energy technology deployment barriers (110th Congress, 2007)		
ETD Barrier	**Section Name**	**Section Number**
Cost	Federal Matching Funds for Smart Grid Investment Costs	1306
Network Infrastructure	Renewable Fuel Infrastructure Grants	244
Slow Capital Stock Turnover	Efficient Light Bulbs	321
Market Development and Organization	Smart Grid Interoperability Framework	1305
Information	Periodic Review of Accuracy of Fuel Economy Labeling Procedures	110
Financing Options	Advanced Battery Loan Guarantee Program	135

EISA2007 ETD policies were categorized from this Act and are shown in Table 5. The EISA2007 was to the first major federal law to contain significant provisions and funding for Smart Grid technology deployment. Funding was given in the form of matching fund, which could be granted to applicants wishing to share costs with the government. Additionally, Congress mandated the creation of the Smart Grid Interoperability Framework. This framework sought to setup a structure of standards for all market players for follow when creating and deploying Smart Grid technologies (110th United States Congress, 2007).

During the financial crises of 2008, a bill called the Emergency Economic Stabilization Act (EESA) of 2008 was passed. It is frequently called the "bank bailout" in popular political debate. Included in the EESA, there was an important energy-related bill in Division B of the law called the Energy Improvement and Extension Act (EIEA). The EIEA mainly focused on the allocation of tax credits for energy efficiency and renewable energy. The tax credit focus of the law was primarily driven by the financial nature of the overall package of legislation passed at the time (EIEA Summary). The energy technology related sections of the EIEA were categorized into Table 6 in order to show examples of implemented law relating to ETD barriers. Due to the financial nature of the law, it did not contain any major provision which addressed the ETD barriers of market development, or information. It did contain provisions for tax credits for alternative vehicles, continued financial support for new Smart Grid installations, modified tax credits to encourage new energy efficient appliances to replace old capital stock, and finally updated and expanded the use of Clean Renewable Energy Bonds (110th United States Congress, 2008).

Table 6. The Energy Improvement and Extension Act of 2008 example section names and numbers related to energy technology deployment barriers (110th Congress, 2008)

ETD Barrier	Section Name	Section Number
Cost	Credit for New Qualified Plug-in Electric Drive Motor Vehicles	205
Network Infrastructure	Accelerated Recovery Period for Depreciation of Smart Meters and Smart Grid Systems	306
Slow Capital Stock Turnover	Modifications of Energy Efficient Appliance Credit for Appliances Produced After 2007	305
Market Development and Organization	*NO MAJOR PROVISIONS*	-
Information	*NO MAJOR PROVISIONS*	-
Financing Options	New Clean Renewable Energy Bonds	107

The Food, Conservation, and Energy Act of 2008, also known as the 2008 Farm Bill, contained energy sections specifically related to biofuels, both corn-based and cellulosic. These sections created or continued many provisions from the 2002 Farm Bill, EPAct2005, and EISA2007. The goal of these provisions was to enhance both energy independence (by decreasing imported oil), and rural development (by increasing support for corn-based ethanol). The 2008 Farm Bill's energy section was well-rounded in its support for continued action on biofuel deployment (CRS, Summary of 2008FB). Sections relating the ETD are categorized in Table 7, showing the specific efforts to decrease these barriers. For example, section 9001 was a detailed part of the 2008 Farm Bill, which had provisions that affected many of the ETD barriers described in the literature (110th Congress, 2008). The notation ' " ' in front of the section number means that the section is changing a previous piece of legislation.

Table 7. The Food, Conservation, and Energy Act of 2008 example section names and numbers related to energy technology deployment barriers (110th Congress, 2008)

ETD Barrier	Section Name	Section Number
Cost	Energy ("Biorefinery Assistance)	9001 ("9003)
Network Infrastructure	Biofuels Infrastructure Study	9002
Slow Capital Stock Turnover	Energy ("Repowering Assistance)	9001 ("9004)
Market Development and Organization	Energy ("Bioenergy Program for Advanced Biofuels)	9001 ("9005)
Information	Energy ("Biodiesel Fuel Education Program)	9001 ("9006)
Financing Options	Energy ("Rural Energy for America Program)	9001 ("9007)

The American Recovery and Reinvestment Act of 2009 (ARRA) was signed into law at a very economically tumultuous point for the United States. The economic condition of the country was the main driver for the passage of the ARRA, also known as the "stimulus package" in current popular political debate. The energy sections of the ARRA, and their corresponding fiscal allocations, are a reflection of the desired investment into the economy of the law in order to increase demand in various marketplaces. The ARRA's energy sections generally related to energy efficiency, transportation, renewable energy, and energy system modernization (CRS, Energy Sections summary of ARRA). Many of the energy sections related to deployment of technologies. Examples of policies directly addressing ETD barriers are given in Table 8, showing the breadth of the ARRA's provisions. For example, credit was extended to the purchase of energy property to help decrease cost, title IV allocated $4.5 billion to electricity grid modernization, and the Weatherization Assistance Program was funded $5 billion in order to continue changing over the older weather striping and insulation capital stock.

Table 8. The American Recovery and Reinvestment Act of 2009 example section names and numbers related to energy technology deployment barriers (111th Congress, 2009)

ETD Barrier	Section Name	Section Number
Cost	Extension and Modification of Credit for Nonbusiness Energy Property	1121
Network Infrastructure	Energy and Water Development – Department of Energy – Electricity Delivery and Energy Reliability	Title IV
Slow Capital Stock Turnover	Weatherization Assistance Program Amendments and Funding	Title IV, 407
Market Development and Organization	Energy and Water Development – Department of Energy – Energy Efficiency and Renewable Energy; 'Additional State Energy Grants'	Title IV, 410
Information	Availability of Data	405 E
Financing Options	Renewable Energy and Electric Power Transmission Loan Guarantee Program	406

The point of the exercise above was to give examples of specific policies from federal statutory law, signed into law, which directly address the generalized ETD barriers described in the literature. This overview gives some insight into the types of implemented policies addressing these barriers. To further illustrate the use of statutory law to address ETD barriers, the next section will detail the issues regarding specific policies from the sample set of ones categorized above under the 'Section Name' headings of Tables 2-8.

SPECIFIC FEDERAL LEVEL POLICY TOOLS

Although a general policy analysis, through categorization, shows varying efforts in addressing ETD barriers, an analysis of specific policy tools would give more understanding to how implemented policies actually affect these barriers. Each barrier area – cost, network infrastructure, slow capital stock turnover, market development, information, and financing options – is detailed below with an example from one of the seven Acts (Table 2-8) analyzed in this paper. Analyzing these policies in detail will show how they are implemented, and if they can be considered an effective policy for decreasing ETD barriers.

COST EXAMPLE: ACID DEPOSITION CONTROL, SECTION 401, CAAA

The cost barrier is very important to overcome. One policy tool used to address this barrier is a market-based mechanism using pollution permits in a cap and trade system. In the United States, the only federal program using cap and trade was created in the CAAA for controlling SO_2 emissions, and therefore the problem of acid rain. A cap and trade mechanism is considered a useful alternative to command and control practices due to cap and trade's use of pollution markets to decrease compliance costs within the system being controlled.

The point of this pollution program is to set a cost on SO_2 to deter the act of polluting. When this cost is added in, the economics change for pollution control technology (akin to energy technologies) deployment, at least in theory. Using these technologies is now incentivized because there is a new cost, the cost of pollution, which these technologies can now seek to minimize. In the literature, it has been shown that the SO_2 pollution permit system was able to induce demand-pull in the electric power sector for lower polluting technologies, and to decrease regulatory compliance costs with respect to traditional methods (Bohi & Burtraw, 1997 and Taylor, Rubin, & Hounshell, 2005). But, with respect to increasing technological progress and technology deployment, SO_2 pollution permit system's results were mixed.

First, the creation of this SO_2 pollution market has been shown to be an effective way to induce demand-pull for pollution control technology, and therefore push the number of inventions up as patent data shows (Taylor et al., 2005). The demand for new inventions comes from the desire to create lower cost technologies for reducing the same amount of SO_2. Further, by increasing the use of pollution control technology, operating costs for these technologies are reduced through experience (Taylor et al., 2005). Finally, the SO_2 cap and trade system was found to have increased technological progress, of which deployment is a step in the process, by 1-2% form the baseline (Kumar & Managi, 2010). But, with respect to direct technology deployment, specifically the installation of Flue Gas Desulfurization (FGD) systems, the effect was minimal, and the "expected large demand for retrofit units did not materialize" after the CAAA became law. As Figure 3 shows, the U.S. did not see a large rise in FGD systems, unlike both Germany and other European countries in the mid-1980's and mid-1990's respectively. FGD installations did not increase due to the availability of low-sulfur coal. This coal was used, instead of FGD technology deployment, to comply with SO_2 cap and trade limitations (Taylor et al, 2005).

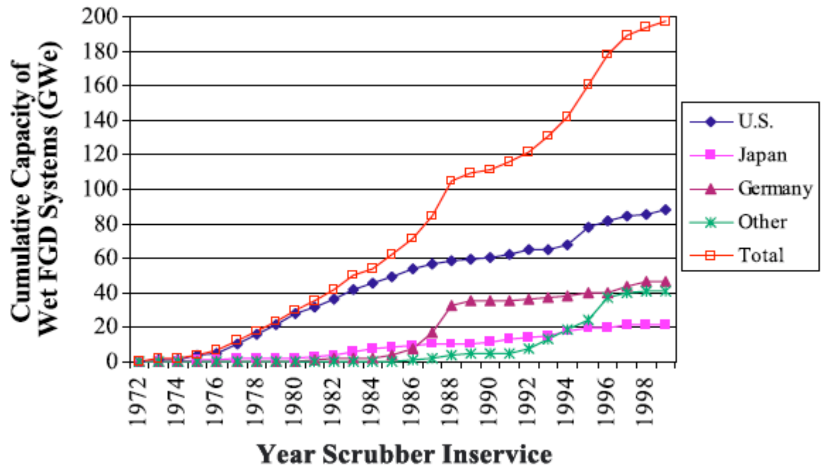

Figure 3. Installation of Wet FGD Systems between 1972 and 1999 (Taylor et al., 2005)

The outcomes reported above show that the SO_2 pollution market could be used as a mechanism for reducing costs for decreasing compliance costs, and inducing some technological change, but was less effective at deploying specific pollution control technologies. These changes are incentivized under this system by including pollution costs, thus creating demand-pull, driving down operating costs, and inducing technological progress. As a pollution control mechanism, the creation of this SO_2 pollution market through the CAAA was found to be a success in achieving its goals at lower cost than traditional regulatory approaches (Bohi et al., 1997). It has been shown that these types of markets, like the one CAAA created, can induce technology change, but not necessarily setup the correct conditions for new technology deployment.

NETWORK INFRASTRUCTURE EXAMPLE: ELECTRICITY DELIVERY AND ENERGY RELIABILITY, TITLE IV, ARRA

Existing network infrastructure is also a barrier to energy technology deployment. When previous network infrastructure was built, it is 'locked-in,' being available for only certain consumer side technologies. The Electricity Delivery and Energy Reliability Title IV in the ARRA gives a specific policy tool to bring down this network infrastructure barrier. In this title section of the ARRA, direct government investment is used to build network infrastructure. Specifically, the amount of $4.5 billion in public money is allocated for grid modernization. The intent of the Title is to spur use of new technologies (largely under the umbrella of Smart Grid technologies) in the electricity grid (111th Congress, 2009).

In the Office of Electricity Delivery and Energy Reliability's Recovery Program Plan, it describes the federal infrastructure investments as an "overhaul of the electrical grid to utilize Smart Grid technology [which] will have significant effects on increasing energy efficiency [and]…allow for clean, renewable sources of energy to be supplied to consumers across the electrical grid in a reliable manner" (Office of Electricity Delivery and Energy Reliability, 2009). These public funds were used in a competitive grant matching program, where up to 50% of the proposed project funds would paid with a public grant (Office of Electricity Delivery and Energy Reliability, 2010). These direct public funds (subsides) are investing in new network infrastructure technologies, which can then be used to spur other efficiency and renewable energy investments relying on these same network technologies. The investment to change out old network infrastructure for new types is costly. Private companies are adverse to putting up the money needed to install new network infrastructure. One answer, as shown here, is to use direct public subsidies to spur these changes. In effect, this action spreads the risk of investment to both public and private sector actors. Subsidies are another policy tool to decrease ETD barriers, and in this case, these subsides decrease network infrastructure barriers.

SLOW CAPITAL STOCK TURNOVER EXAMPLE: EFFICIENT LIGHT BULBS, SECTION 321, EISA2007

The incandescent bulb has found widespread use since its invention in spite being very inefficient. Although other, more efficient lighting technologies have been developed since the incandescent bulb's inception, their use has not overtaken the place in society of the incandescent bulb. Figure 4 shows lighting efficiency (lumens per watt) over time for a different kinds of lighting technologies. The incandescent lamp, historically, is the least efficient, but still finds use after more than 100 years (Narukawa, Ichikawa, Sanga, Sano, & Mukai, 2010). Regulation from the EISA2007 sought to change this stagnation in technological turnover.

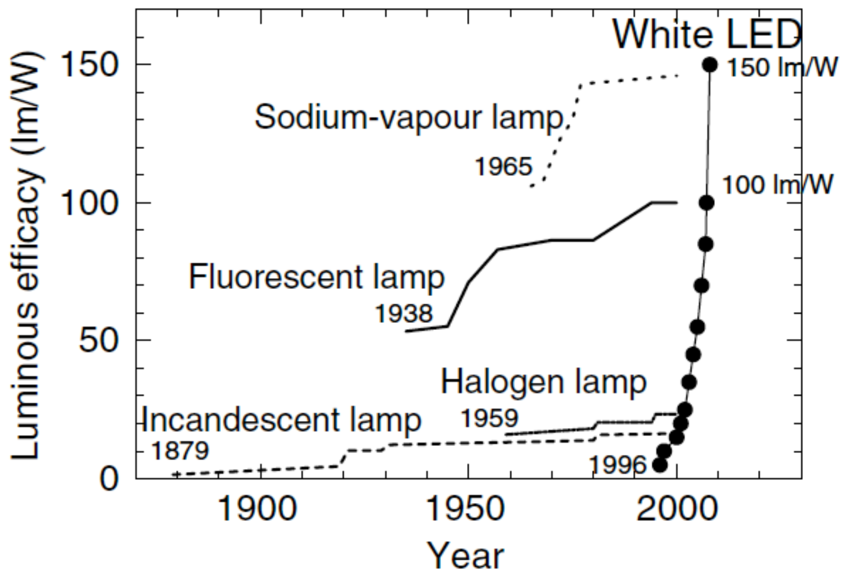

Figure 4. Luminous efficiency over time for five different lighting technologies (Narukawa et al., 2010)

The regulatory instrument used to induce this capital stock turnover was standard setting. The law used a two-tier system. As defined in Tier I, new light bulbs in 2012-2014 must be 25%-30% greater than a "typical" light bulb (See Figure 5). Tier II requirements will be set by the U.S. Department of Energy for implementation by 2020. There were no incandescent light bulb bans in the legislation (Congressional Research Service, 2008).

The result of the law is to move a slow changing technology sector, lighting, into one that must completely change the efficiency of retail offering to consumers by a certain date. This policy tool (standard setting) decreased the barrier to entry for other energy technologies by setting standards, which modified the nature of the market, by a certain date, to only allow products of certain efficiency qualities.

Electricity Use in Today's Bulbs (Watts)	Light Output Range (Lumens[a])	Future Performance Standard (Watts)	Effective Date
100	1,490-2,600	72	January 1, 2012
75	1,050-1,489	53	January 1, 2013
60	750-1,049	43	January 1, 2014
40	310-749	29	January 1, 2014

a. A lumen is a measure of the amount of light that reaches an area of interest.

Figure 5. Tier I light bulb efficiency standards set in the EISA2007 (Congressional Research Service, 2008).

MARKET DEVELOPMENT AND ORGANIZATION EXAMPLE: ESTABLISHMENT OF THE UNITED STATES ENRICHMENT CORPORATION, SECTION 901, EPACT1992

Not all statutory actions result in the reduction of ETD barriers. The establishment of the United States Enrichment Corporation (USEC) is one of those examples. Uranium enrichment operations for commercial nuclear power plants was founded in the 1950's, and was as a completely public entity under the purview of the Department of Energy. After the Cold War ended, privatization pressures surfaced as national security concerns decreased. USEC was created by the EPAct1992 as a government corporation in preparation for later privatization through an initial public offering in 1998 (Guttman, 2001). This action transformed the enrichment services market in the U.S., going form a publicly owned service to a privatized, investor owned monopoly market in just over five years. USEC held about 90 percent of the U.S. market, and about 40 percent of the world market for enrichment services in the late 1990's (Orzag, 1996). As the Government Accounting Office made clear in testimony to Congress in 1995, the reason for privatization was clear – government uranium enrichment facilities should be run in a more business-like manner (GAO, 1995). With respect to ETD barriers, would privatization decrease market development and organization ETD barriers to allow energy technologies to move more quickly into common use?

The USEC claimed, in 1998, that it would be able to continue deployment of new enrichment facilities even after privatization. The new enrichment technology it wished to deploy was called Atomic Vapor Laser Isotope Separation (AVLIS). And as Orzag interestingly notes, "because of statutory restrictions that were undoubtedly the result of employment-driven political pressures, a public-sector USEC [was] prohibited from fully developing the AVLIS technology." Theoretically, a move out of the public-sector would help USEC to further develop and deploy this technology. USEC had placed a great deal of research and development funds (mostly public) into advancing this technology to deployment scale, envisioning a replacement of its existing (at the time) gaseous diffusion and gas centrifuge enrichment technologies. But as Guttman notes, "In April 1999, USEC announced that it would abandon the technology (called AVLIS) on which it had staked its future, and on which hundreds of millions of taxpayer dollars had been invested" (Guttman, 2001). The reason behind the decision to abandon the new energy technology was purely financial. After privatizing, finances at USEC deteriorated, due in part to public laws passed after privatization that required continuation of operations that were in the national interest, but not profitable. For example, USEC was required by Congress to continue operation of both gaseous diffusion plants until 2004, it was also required to protect the public interest in uranium mining, enrichment, and conversion services, and finally, it was made Executive Agent in talks between U.S. and Russia for the handling of enriched uranium from Russian warheads (Guttman, 2001 & Orzag, 1996). It did not take long for USEC to default on many aspects of these public obligations for to private, profit-maximizing reasons.

The example of the establishment of the USEC gives a counter example to good public policy concerned with the knocking down of ETD barriers instead of raising them. Although the creation of the USEC was completed to access internal efficiency gains derived from becoming a new corporation, the allocative efficiency of resources both internally and externally affecting the uranium enrichment market (including national security, and ETD concerns) decreased (Orzag, 1996). As a result, a privatized USEC was unable to deploy its AVLIS technology, instead resulting in larger ETD barriers and stifling other uranium enrichment technologies from emerging.

INFORMATION EXAMPLE: ENERGY EFFICIENCY PUBLIC INFORMATION INITIATIVE, SECTION 134, EPACT2005

Information is very important for markets to work effectively. Consumers desire to have information to make appropriate decisions when deciding between various options during a transaction. The need for information is also present during transactions involved with energy technologies. Sometimes information is very expensive or logistically impossible to obtain. In these situations, actions by the government can correct for the lack of information. Two popular methods related to information availability are labeling and public outreach programs (Gallagher, 2006). In the EPAct2005, an information program using the public outreach method was created, which was called the Energy Efficiency Public Information Initiative.

The Initiative's programs were unveiled to the public on June 22, 2006, and contained many parts for both individual consumers and businesses. Under the umbrella of the initiative, a campaign was designed that was called the "Easy Ways to Save Campaign." For consumers, it included website called the "Energy $avers" Guide (www.energysavers.gov), public radio announcements, and the "Energy Hog" Program. For businesses, the Campaign included sending Energy Saving Teams to the top 200 energy-intensive factories in America, and offering partnerships with the DOE (Department of Energy, 2005). These programs were meant to act as a "get the word out" program for letting the public know that ways to be more energy conscience were provided as a free service by their government. These programs serve as information outlets for decreasing barriers to energy technology deployment. If more of the public knows about the benefits of certain energy technologies (because of this free government service), the public will be more informed about purchasing these technologies, thus deploying them more fully into the marketplace.

FINANCING OPTIONS EXAMPLE: NEW CLEAN RENEWABLE ENERGY BONDS, SECTION 107, EIEA

Private companies can build renewable energy projects, and the renewable energy produced by these new installations is eligible for a production tax credit, which can lower their overall taxes. But, for tax-exempt institutions like those in the public-sector, this financing option is not available, and it therefore a barrier to ETD in this sector of the economy. Clean Renewable Energy Bonds (CREBs) were created just for this purpose. These CREBs were created in the EPAct2005 legislation, and their next iteration, *new* CREBs, came about through the EIEA. The difference between them is one of the dollar amounts appropriated and small changes in CREB rules (Congressional Research Service, 2009). A CREB is "a type of tax credit bond, [where] the investor receives a tax credit from the U.S. Department of the Treasury rather than an interest payment from the issuer" (National Renewable Energy Laboratory, 2009). Investors are then incentivized to enter into this type of financing of public-sector projects they would not otherwise take part in as financier. This financing option provides for the reduction of this ETD barrier for non-taxable, public-sector entities.

Even though this may be the case, the CREB program does have its drawbacks. The U.S. National Renewable Energy Laboratory found that administrative costs like overly tight deadlines for issuing, reimbursing, and spending bond amounts hinder their use. Additionally, these high transaction costs were found to increase financing costs directly (National Renewable Energy Laboratory, 2009). These administrative and transaction costs work against the goal of decreasing the financing barrier for ETD. Further action through statutory law may possibly desire to address these costs in order to continually decrease the costs for using CREBs as an available ETD financing option.

Finally, one last barrier area related to the policy creation process by extension should be mentioned. It is termed regulatory "lock-out." Lock-out of new energy technologies occurs when laws are in place that continue to assist existing, incumbent technologies (Sagar & Gallagher, 2006). These policies do not relate to ineffective policies seeking to decrease ETD barriers, but those statutory laws that already exist and assist the incumbent, status-quo technologies.

Sagar and Gallagher give California's zero-emissions-vehicle (ZEV) policy of 1990 as an example. This policy effectively limited the choice of ZEVs to only electric cars, which were the only ones that offered this zero-emissions feature. Hybrids were locked-out by this policy. The effect was that American vehicle manufactures focused on only electric vehicles to meet the policy. When the policy was amended years later to allow hybrids, Japanese car markets had a greater advantage because they had implemented hybrid technology, but American manufactures had not, focusing solely on electric cars to meet the policy, were at a disadvantage, and lost great market share as a result (Sagar & Gallagher, 2006). Another way to decrease barriers to ETD is to remove these old policies focusing and assisting incumbent technologies, thus making way for newer energy technologies to enter the market.

Analyzing specific policies, as above, gives greater depth for understanding how these policies were implemented. These six example policies were chosen in order to explain some nuances of the ETD barriers explained in the literature. In giving an analysis on specific policies, the variation in effectiveness for the different implemented policies was shown. Not all of the policies worked perfectly, and some did not work as expected, but understanding the victories and failures of past policies is essential to future policymakers. This paper has given a small sample of the kind of analysis that could be used to expand the understanding of ETD barriers and policies.

ETD Barriers and the PCAST Report to the President

The PCAST report to the President of the United States highlighted areas where the Department of Energy could improve, focusing on the energy technology innovation process from invention to diffusion. Many recommendations were made in the report, and one of these recommendations stands out with respect to this paper: increase large-scale demonstration and deployment spending for energy technology to $4 billion per year (PCAST, 2010) – roughly a three-fold increase. This allocation should seek to be informed by the barriers discussed in this paper.

Additionally, the PCAST report also calls for research funds to be used to study questions still present in the energy technology innovation ecosystem. One of those questions is "what are the barriers to adoption?" (PCAST, 2010). This question is very pertinent for this paper as well as future, more specific research into why energy technology barriers exist, and what specific policies can be used to bring down these barriers. This paper has only presented a review of information presented in the literature and a general analysis of the ETD policies that can be found in federal statutory law of the last 20 years. More rigorous research could include larger timelines, greater categorization, creation of metrics for ETD effectiveness, and more specific study of how past ETD policies inform future policy debates.

SUMMARY AND CONCLUSIONS

Energy technology deployment policy is essential to understand from a policymaker's point of view. Especially today, as many look to the energy technology R&D field for answers to the problems which exist in and stem from our current energy system. R&D cannot stand alone, as both the PCAST report and the EERE literature has described. Deployment policies are necessary to make the investment in R&D more worth the funding effort. It seems desirable for technologies brought through the R&D stream to make it into markets. Deployment policies are needed to accomplish this task, and this deployment effort is directly needed because of the existence of common barriers. In the literature, these barriers are allocated into six areas: cost, network infrastructure, slow capital stock turnover, market development, information, and financing options. Implemented federal statutory law was then used to find examples of ETD policies related to decreasing barriers.

Throughout the last 20 years, since the 101st United States Congress, many examples of ETD policies were found for each of the barriers. Although not all of the laws were well rounded in their policy regarding deployment, many pertinent policies existed. No specific federal statutory law has just dealt with deployment policies, but these policies are included amongst many other priorities as would be expected from an allocation process like lawmaking.

In analyzing specific policies, mixed ETD policy effectiveness results were found. For example, the sulfur dioxide cap and trade system was not as effective for deploying pollution technologies, but was effective as a pollution reduction system at lower cost than traditional means. The specific ETD barrier policy examples were analyzed to give a more in depth snapshot of the types of policies that have been implemented. A complete analysis of these policies may show more precisely the effectiveness of implemented policies.

Further research could be conducted to give a very complete insight into ETD policies. For example, the number of statutory laws included could be much larger if a longer timeframe was used for the analysis. A coding system could also be used to more analytically describe the implemented policies. Finally, more formal metrics could be defined to rank the policies by effectiveness or ability to deploy technologies. Further areas of study in the innovation process include 'learning by doing' and 'learning by using.' These concepts help to frame the qualities of actions going on in the innovation system, and coupled with a more formal, larger analysis, may lead to better policies for encouraging new technologies to be deployed into their respective marketplaces.

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