

Borden, Eric; Schill, Wolf-Peter

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DIW Berlin
German Institute for Economic Research
Mohrenstr. 58
10117 Berlin

Tel. +49 (30) 897 89-0
Fax +49 (30) 897 89-200
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Policy efforts for the development of storage technologies in the U.S. and Germany

Eric Borden

Deutsches Institut für Wirtschaftsforschung (DIW Berlin), Alexander von Humboldt Foundation, Berlin¹

Wolf-Peter Schill

Deutsches Institut für Wirtschaftsforschung (DIW Berlin), Berlin²

Abstract: Recent developments in electricity markets such as the increased deployment of variable renewable generation have prompted renewed interest over the role of energy storage. While storage technologies can in principle provide various benefits for the functioning of an electrical grid, many energy storage technologies are in initial stages of development and demonstration. The role of public policy is thus vital for development and market integration of storage technology. We identify and discuss selected policy efforts by the United States of America and Germany with a focus on less-developed storage technologies. While research and demonstration of storage technologies has increased in both countries, we find that public funding is still small compared to overall energy-related expenditures. Both countries use technology-push and market-pull approaches. Whereas the U.S. focuses on technologies which are useful to improve system stability, like batteries, capacitors, and flywheels, Germany has a stronger focus on bulk seasonal storage that may aid the integration of variable renewables, for example power to gas. We conclude that increased data-sharing and cooperation between the two governments and research institutions will help enhance the efficacy of both countries' publicly funded storage research. U.S. research institutions that link basic research with commercialization of technology, as well as developments in U.S. regulation of ancillary markets, may provide useful models for Germany. The U.S., on the other hand, may look to Germany's institutions as inspiration for its loan guarantee program.

Keywords: Energy Storage, Technology-Push, Market-Pull, U.S., Germany

JEL: Q38, Q42, Q48

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1 Introduction

Recent developments in electricity markets have prompted renewed interest over the role of energy storage technology in electrical grids. Storage can provide various benefits for the functioning of an electrical grid, including improvement of system stability, help in meeting peak demand, the deferral or avoidance of adding or updating grid infrastructure, aiding the integration of large amounts of variable renewable energy, lowering the cost of average dispatch, and other functionalities that improve the stability and resiliency of the electrical grid (Eyer et al., 2010; Denholm et al., 2010).

The majority of energy storage technologies, other than pumped-hydro storage, are not widely used commercially or are in initial stages of demonstration. These technologies include compressed air energy storage, various types of batteries, kinetic energy storage, power to gas technologies, as well as district and decentralized heat storage which can be used either to take up temporary power generation surpluses or make combined heat and power generation more flexible. The adoption of these types of energy storage face numerous obstacles typically encountered by new and/or less-developed technology, including an incomplete valuation of storage benefits in power markets, the regulatory treatment of storage, and various risks and uncertainties for storage investors (Sioshansi et al., 2012). In addition, limited large-scale demonstration, insufficient technical progress, lack of standards and models, and weak stakeholder understanding is also mentioned in the literature (DOE, 2010).

Given this state, the role of public policy is vital for the development and market integration of energy storage technology. The intention of this paper is to identify and discuss selected policy efforts by the United States of America (U.S.) and Germany primarily for less-developed storage technologies, at a time when these efforts are particularly critical for their development. We concentrate on those policies and regulations most applicable to grid-level applications of storage technology, though efforts on storage in the automobile industry, for instance for batteries and fuel cells, are likely also applicable for grid-level storage implementation.

This paper identifies and discusses the major programs and regulatory frameworks that can be attributed to storage technology development and market applications, in an effort to understand the current policy landscape affecting the implementation of storage in the electrical grids of the U.S. and Germany.³ The two countries provide an interesting and useful comparison. The U.S. is a world leader in innovation and entrepreneurship. Germany's "Energiewende," or energy transformation, has spurred a rapid increase in renewable energy development throughout the country, and Germany is viewed as a world leader in development, implementation, and innovation in clean-tech.

³ U.S. and German efforts are investigated here independently – e.g. they are not selected based on equivalent or easily compared programs in the other country.

The remainder is structured as follows: First, we look at the role of public investment for technological innovation. Next, U.S. and German policies and programs are investigated. Finally, we compare major differences and similarities between the two countries' approaches, leading to important insights about the policies currently implemented.

1.1 Role of the Public Sector for Technological Development

The notion of public sector involvement in the development of new technologies has become mainstream in economic theory. The fundamental premise is that government and other non-profit institutions (such as universities) play a significant role in basic scientific research and the development of new technology in order to achieve socially optimal outcomes. Private firms in a market-oriented system will tend to under-invest in research and development of novel and less-developed technologies, relative to a social optimum. This phenomenon was discussed over half a century ago by Nelson (1959).

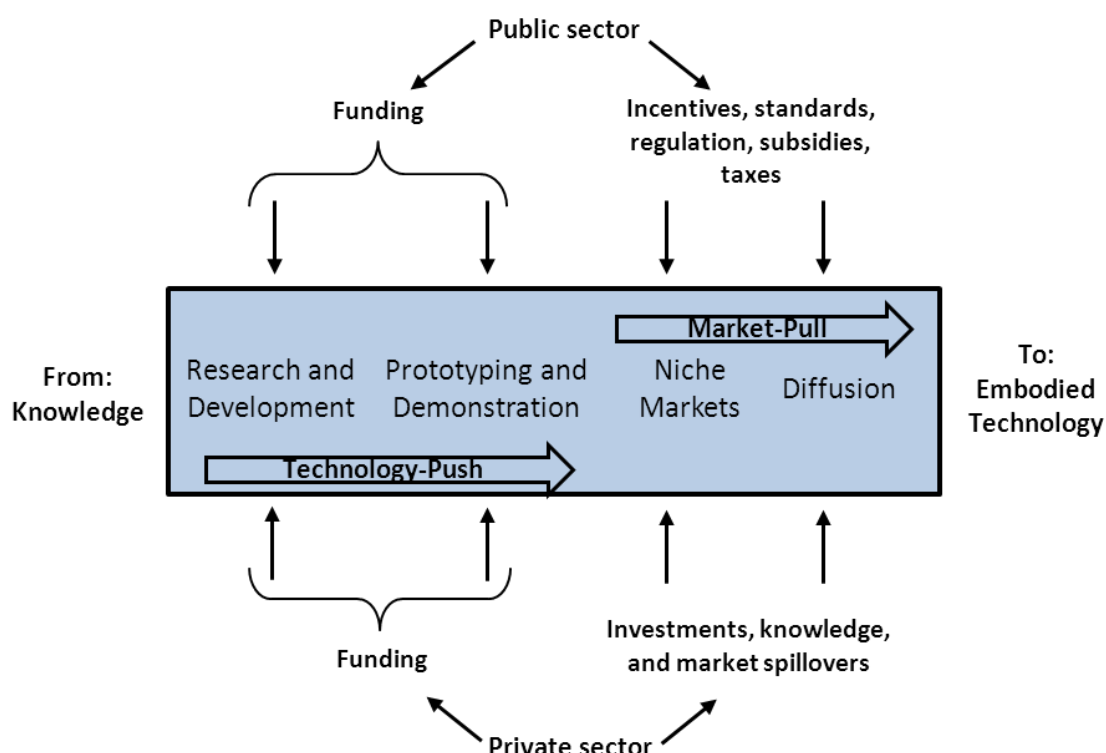
Similarly, Yokell (1979) points to the risk-aversion of investors for new technology, alternatively suggesting that a society's appetite for risk is higher because it is spread over a larger number of individuals in comparison with a private enterprise. For a new technology, under-investment may occur at several steps along the development chain, including the so-called "valley of death" which, for new technological innovations, occurs between proof-of concept and commercialization of a product (Weiss and Bonvillian, 2009). This is the area in which prototyping and demonstration becomes critically important before a technology plays a significant role in the market.

Further, not only will the private market under-invest in new technology and research, but economic and political benefits continue to accrue to established technologies and industries past the point where they are financially necessary or socially optimal. Proponents of established technologies fight changes in the status-quo that threaten their established position (Weiss and Bonvillian, 2009). Thus, while a level playing field may be an optimal way to induce technology-neutral innovation, this ideal becomes difficult to achieve in practice.

Government's role in technology development may take on many different forms. In the investigation presented here, identified policy is categorized as either "technology-push" or "market-pull." Technology-push programs refer largely to Research and Development (R&D) and prototyping and demonstration (P&D), while market-pull support refers to integration of the technology into the market, including market incentives and regulatory treatment.⁴ Figure 1, which is based on Solomon et al. (2007), depicts the public and private levers to catalyze technological innovation in the context of the technology-push and market-pull framework used here.

⁴ Groba and Breitschopf (2013) review technology-push and market-pull policies for renewable energy technology development.

Figure 1: Innovation through Technology-Push and Market-Pull



In the literature as well as the wider public discussion, the two approaches (technology-push / market-pull) are often pitted against each other to advance or promote one or the other as leading to a higher degree of technological innovation. Schmookler (1966) is often cited as one of the original advocates of the market/demand side for innovation, stemming from his quantitative analysis of patents, used as a proxy for innovation. His conclusions were later questioned, for instance by Scherer (1982). Di Stefano et al. (2012) provide a useful summary of the evolving debate, as well as an in-depth literature review on innovation research over the last several decades. Recently, micro and macro-economic modeling and statistical analysis has been used as a tool to explore the issue –considered particularly important for addressing climate change and supporting innovation in clean energy technology. For instance, Acemoglu et al. (2012) utilize a quantitative model to measure potential impacts on clean energy development stemming from the two approaches (specifically, the regulatory framework of a carbon tax versus R&D subsidies). Grubb (2004) also expounds on this discussion in the clean energy sector, reaching the conclusion that the binary framework of choosing between the two alternatives is overly simplistic – technology development is highly complex and both approaches tend to promote innovation.

This paper does not enter the debate between technology-push and market-pull found throughout the literature. We do not seek here to determine an “optimal” policy allocation for storage technology development. Rather, we seek to identify major existing public policy that provides support to storage technology, utilizing the categories as an organizational framework to understand the type and scope of programs the U.S. and Germany are currently undertaking. A natural follow-on to our analysis may be to analyze the efficacy, or

amount of innovation stemming from the various programs, though it may be too early for some programs to make any definitive conclusion.

Thus, policy efforts and programs discussed in this paper are categorized broadly as technology-push or market-pull, and then more specifically as research and development (R&D), prototyping and demonstration (P&D), investment incentives, low-interest loans, and regulatory framework. This categorization facilitates identification of the types of policies currently supporting energy storage, as well as a tool to compare and contrast policy efforts in the U.S. and Germany.

In the following, we provide quantitative numbers wherever possible. Determining the exact budget spent on storage-related research and development, however, is challenging for many reasons. For example, many advanced storage technologies are in the state of basic research. Related research activities often deal with general aspects of multiple processes and materials, so directly linking their funds to storage is not possible. Moreover, there are many research projects that investigate energy storage in the context of other technologies like conventional or renewable power generation. In these cases, it is often not clear which part of the project budget is attributable to storage.

2 The United States

2.1 Technology-push Programs in the U.S.

2.1.1 Activities of the Department of Energy

The U.S. Department of Energy (DOE) and its Office of Electric Delivery and Energy Reliability encourage the development of energy storage technologies through its Energy Storage Systems Program (ESSP). The program conducts basic research and system analysis, and provides monetary and knowledge-based support for demonstration and deployment of multiple energy storage technologies. Traditionally the storage program has received less than \$6 million a year in funds (Boyes, 2007) but in fiscal year (FY) 2012 and 2013 the program received \$20 million and \$15 million, respectively (DOE, 2012b). The program has set multiple near-term objectives with regard to research and development, including reducing the cost of storage by 30%, raising device reliability, and cost targets for multiple battery compositions. Longer-term objectives involve the phasing out of less-promising technologies, the development of new technologies, and further cost reduction goals (DOE, 2011).

The DOE has also initiated programs which seek to leverage government, industry, and academic institutions through so-called “energy innovation hubs.” These hubs focus on the development and commercialization of specific energy technologies – for instance, one develops the efficiency and sustainability of solar photovoltaic cells. In November 2012, the Joint Center for Energy Storage Research (JCESR), sited at Argonne National Laboratory, was launched. The battery and energy storage hub was created to address performance

deficiencies of storage technology as well as develop new technology and processes to help integrate renewable energy using storage. The initiative brings together governmental and scientific laboratories, universities, and industry partners (including manufacturers) to conduct basic research and provide support and links to partners for commercialization of promising technology. The research focuses on battery technology for grid and vehicle applications and has been funded for 5 years with an award of \$120 million. Industry partners, in addition, are expected to invest up to \$1 billion for manufacturing and R&D facilities (DOE, 2012a; ESJ, 2013).

The inclusion of industrial players and venture capital in the JCESR initiative provides an example of linking basic research with market entry for technologies. While basic science cannot, and should not, be necessarily linked directly to commercialization, the partnership may prove to accelerate the process, creating efficiencies for some types of public investment. The initiative may provide an interesting model for creating networks of innovation with minimal government investment.

In addition to the ESSP and JCESR, the National Renewable Energy Laboratory (NREL) also conducts research and development for storage technologies as part of DOE's Office of Energy Efficiency and Renewable Energy. The majority of NREL's storage research relates to batteries for automotive applications, for example electric and hybrid electric vehicles. However, the agency also launched a wind to hydrogen (Wind2H2) project along with utility Xcel Energy, which each invested \$1 million for process and technological improvements in renewable to hydrogen technology (NREL, 2012b). NREL also models and develops materials, system configuration, interface requirements, and well-to-wheel analyses for storage (NREL, 2012a).

2.1.2 The Advanced Research Projects Agency – Energy (ARPA-E)

ARPA-E is a unique entity within the DOE that promotes the advancement of “game-changing” technology with particular focus on increasing performance and decreasing costs for these technologies. The agency was created in 2007 under George W. Bush as a response to growing concern over U.S. decline in the field of science and technology, and is modeled after the Defense Advanced Research Projects Agency (DARPA), seen as a successful model that has made pivotal developments in defense-related technologies.

ARPA-E has funded its first projects under President Obama with an allocation of \$400 million under the ARRA in FY 2009 (lasting through 2010), and received, for the first time, congressional budgetary allocations of \$180 million in FY 2011 and \$275 million for FY 2012 and 2013. ARPA-E requested \$379 million for FY 2014 (ARPA-E, 2013). A fraction of this budget goes to storage research and demonstration.

ARPA-E is currently conducting several projects related to energy storage technology, including demonstration projects.⁵ GRIDS, or Grid-Scale Rampable Intermittent Dispatchable Storage, along with other projects, have invested in demonstration of storage technologies including batteries, compressed air energy storage, flywheels, and fuel cells. In FY 2010 \$31 million of project funds went towards energy storage projects. Table 1 below displays storage projects funded in FY 2011 through ARPA-E, for a total of \$28 million (Electricity Advisory Committee, 2011).

Table 1: ARPA-E Fiscal Year 2011 Demonstration Projects in Energy Storage

<u>Awardee</u>	<u>Technology / Project Description</u>	<u>Funding (\$ million)</u>
ABB Inc.	Superconducting Magnetic Energy Storage (SMES)	4.2
Beacon Power Corp.	Flywheel: Development of a 100 kWh/100 kW Flywheel Energy Storage Module	2.3
Boeing	Flywheel: Low-Cost, High-Energy Density Flywheel Storage Grid Demonstration	2.3
CUNY Energy Institute	Battery: Low-cost Grid-Scale Electrical Storage using a Flow-Assisted Rechargeable Zinc- Manganese Oxide Battery	3.0
Fluidic Energy Inc.	Battery: Enhanced Metal-Air Energy Storage System with Advanced Grid-Interoperable Power Electronics Enabling Scalability and Ultra-Low Cost	3.0
General Atomics	Flow Battery: GRIDS Soluble Lead Flow Battery Technology	2.0
General Compression	Compressed Air Energy Storage (CAES): Fuel-Free, Ubiquitous, Compressed Air Energy Storage and Power Conditioning	0.8
Lawrence Berkeley National Lab	Flow Battery: Hydrogen-Bromine Flow Batteries for Grid-Scale Energy Storage	1.6
Primus Power	Flow Battery: Low-Cost, High Performance 50 Year Electrodes	2.0
Proton Energy	Fuel Cell: Transformative Renewable Energy Storage Devices Based on Neutral	2.2
United Technologies Research Center	Flow Battery: Transformative Electrochemical Flow Storage System (TEFSS)	3.0
University of Southern California	Battery: A Robust and Inexpensive Iron-Air Rechargeable Battery for Grid-Scale Energy Storage	1.5
Total FY 2011 (\$ million)⁶		27.7

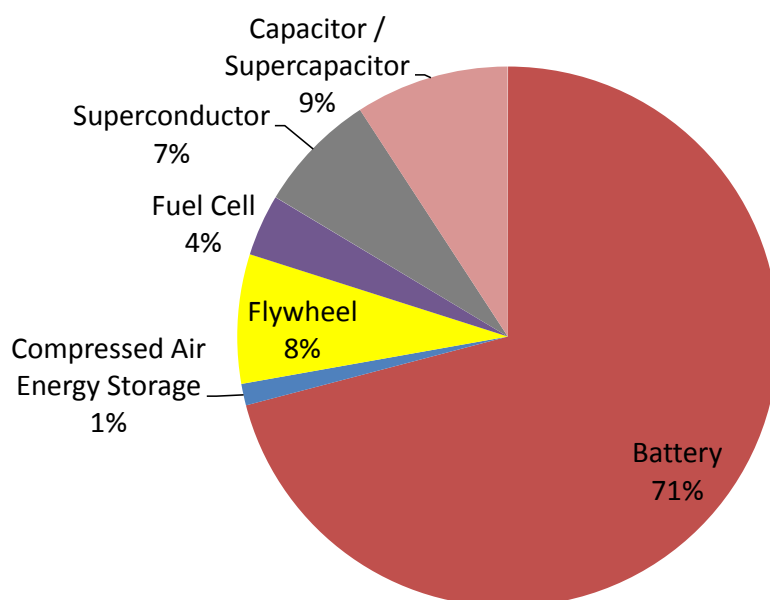
Figure 2 shows investment by funding and technology type for ARPA-E storage projects in FY 2010 and 2011. There appears to be a focus on technologies in early stages of development, for example for advanced battery compositions (i.e. flow batteries and novel compositions),

⁵ Other related programs include Batteries for Electrical Energy Storage in Transportation (BEEST), Green Electricity Network Integration (GENI), High Energy Advanced Thermal Storage (HEATS), and Innovative Materials and Processes for Advanced Carbon Technologies (IMPACCT) (Agency-Energy).

⁶ Total does not exactly equal sum of individual projects due to rounding.

supercapacitors, and superconductors. This demonstrates ARPA-E's focus on novel technologies with the potential for innovative improvements.

**Figure 2: ARPA-E Funding for Storage Demonstration by Technology
FY 2010 and 2011**



2.1.3 American Recovery and Reinvestment Act of 2009 (ARRA)

Likely the largest amount of direct funding for energy storage in the U.S. was provided to the DOE through the American Recovery and Reinvestment Act of 2009 (ARRA). Through ARRA, an \$840 billion fiscal stimulus initiative, numerous investments in energy were supported, a small amount of which went directly to the DOE for storage demonstration projects.⁷

The ARRA has provided \$185 million in funding for energy storage demonstration projects. Private counterparts contribute significantly on top of the publicly-provided funds, making total investment in these projects worth over \$770 million. Table 2 summarizes ARRA funded demonstration projects as of the end of 2012 (Electricity Advisory Committee, 2011).

⁷ The stimulus included a \$2 billion initiative for the manufacturing of advanced batteries, \$6 billion in loan guarantees for innovative technologies, \$400 million in funds for the Advanced Research Projects Agency-Energy (discussed previously), \$4.5 billion for electricity delivery, energy reliability and smart grid applications, a portion of which has been applied to energy storage research, and a 30% investment tax credit for facilities "engaged in the manufacture of advanced energy property" including some energy storage technologies (Utah Clean Energy, 2009).

Table 2: ARRA Energy Storage Demonstration Projects

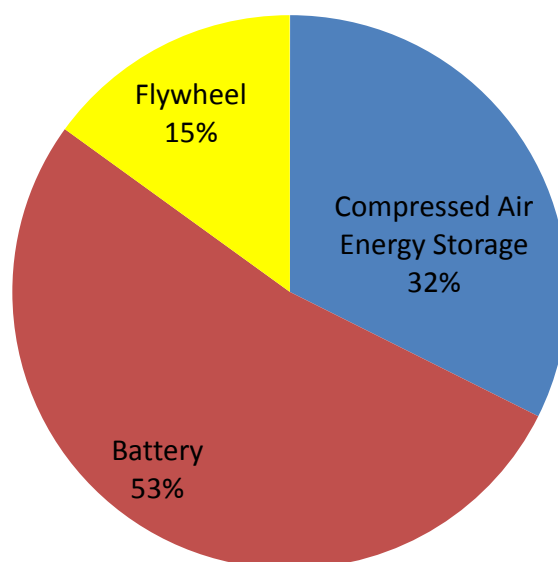
<u>Awardee</u>	<u>Technology / Project Description</u>	<u>ARRA Funding (\$ million)</u>	<u>Total Project Value (\$ million)</u>
Duke Energy ⁸	36 MW battery storage of wind power in Texas to demonstrate how storage can address intermittency.	21.8	43.6
Primus Power	25 MW (75 MWh) zinc-chloride flow battery for wind firming in California. Replaces a fossil fuel plant.	14.0	46.7
Southern California Edison	8 MW (4hrs) utility-scale lithium-ion battery to improve grid performance and help integrate wind generation in California.	25.0	54.9
Beacon Power	20 MW (5 MWh) flywheel frequency regulation plant to provide regulation services for PJM. Exact location to be determined.	24.1	48.1
City of Painesville	1 MW (6-8 MWh) vanadium redox battery demonstration program, to be used with a coal-fired power plant for power output maintenance and reduction of carbon footprint. Exact location to be determined.	4.2	9.7
Detroit Edison Co.	25KW (20 units of 50KWh each) lithium-ion batteries for grid support in communities in New Hampshire and Massachusetts.	5.0	10.9
East Penn Mfg. Co.	3 MW (1-4 MWh) lead carbon 'UltraBattery' to regulate frequency and manage energy demand in Pennsylvania.	2.5	5.1
Premium Power Corp.	5-500kW (6hrs) zinc-bromine batteries for utility grid applications to lower peak energy demand and reduce the cost of power interruptions in California and New York.	6.1	12.5
Public Svc. Co. of NM (PNM)	500kW (2.5 MWh) advanced lead acid flow battery along with sophisticated control system for a PV installation. Intended to mitigate voltage fluctuation and store energy for demand peaks in New Mexico.	2.5	6.3
Iberdrola USA (NY State Elec. & Gas Corp.)	150 MW (2-8 hour) advanced compressed air energy storage (CAES) using an existing salt cavern. Will help improved grid reliability and integrate wind - located in New York.	29.6	125.0
Pacific Gas & Electric Co.	300 MW (10hr) CAES demonstration project using a saline porous rock formation as storage reservoir in California.	25.0	356.0
Aquion Energy Inc.	10-100 kWh demonstration of sodium-ion batteries for grid-level applications in Pennsylvania.	5.2	10.4
Amber Kinetics Inc.	50kW (50kWh) flywheel energy storage demonstration for use in grid connected, low-cost bulk energy storage applications in California.	3.7	10.0
Ktech Corp.	250kW (1 MWh) iron-chromium redox flow battery for smart grid renewable energy applications in New Mexico and California.	4.8	9.5
SEEO, Inc.	25kWh solid state batteries Lithium-Ion batteries to be targeted towards community energy storage projects. Conducted in California.	6.2	12.4
SUSTAINX	1 MW (4 MWh) demonstration of Isothermal CAES to support renewable energy integration. In New Hampshire Massachusetts.	5.4	10.8
Total (\$ million)⁹		185.0	771.8

⁸ See also Duke Energy (2013).

⁹ Total may not equal sum of individual projects due to rounding.

Figure 3 shows the distribution of technologies funded through ARRA. Project funding for ARRA has gone to research and demonstration of various battery compositions, compressed air, and flywheel storage technologies. Generally, the technologies appear closer to commercial viability than those researched under DOE's ESSP or ARPA-E. This technology investment selection should be seen in the context of the level of private investment (over 4 times more private investment than public), and the intent of the stimulus package, namely to stimulate economic activity as quickly as possible. Utilities and private enterprises clearly had the capability to, in a reasonable time-frame, implement the projects and technologies they proposed (though they may not have done so without governmental support). While ARRA is categorized here as a technology-push policy because it focuses on development and demonstration of storage technology, the focus on closer to commercially available technology pushes it towards the boundary of market-pull.

Figure 3: ARRA Public Funding by Storage Technology through May 2011



Significantly, ARRA is a one-time cash outlay that without additional spending legislation will not be repeated. In contrast, DOE programs, among them ARPA-E, are institutionalized, receiving a yearly budget with congressional approval. While DOE's research programs may adjust their focus with the passage of time, a one-time stimulus does not have that flexibility.

Nevertheless, the stimulus also positively benefited DOE and other storage support programs discussed above in recent years. Given the relatively modest levels of funding for storage in these institutionalized programs, funding for federal technology-push programs,

including basic research, development, and demonstration for storage technologies, will be dramatically reduced in coming years relative to ARRA levels.

2.2 Market-pull Programs in the U.S.

2.2.1 Loan Program

The DOE's loan program office provides loans and loan guarantees for the deployment of advanced clean energy technologies. A loan guarantee ensures that in the event of default, the U.S. government must repay the borrowed funds in full, mitigating risk for the creditor and lowering interest rates for loan recipients. Such a program is intended to provide commercial and nearly-commercial technologies with financing that would not otherwise be available in the private market. DOE's loan program office has three primary programs, two of which may be applied to the implementation of energy storage projects.¹⁰ Section 1703 was authorized under the Energy Policy Act of 2005 and gave the DOE authority to provide loan guarantees for innovative clean energy technology projects in the U.S., subject to various conditions. Through September 2011, these guarantees have primarily gone to nuclear power projects. This initial authority was enhanced in 2009 under the American Recovery and Reinvestment Act, creating loan guarantee section 1705 and authorizing an additional \$18 billion in loan guarantees (DOE-LPO, 2011). While section 1705 loan guarantee authority expired in September 2011, section 1703 loan guarantees can still be applied. The DOE is permitted to make up to \$34 billion in guarantees, and has committed and conditionally committed to \$30 billion of this total as of the end of September, 2011 (GAO, 2012).

Loan guarantees issued under section 1705 have been applied to numerous clean energy technology projects, the vast majority (92%) went to energy generation projects such as wind and solar projects (Jenkins et al., 2012). Projects under 1705 related to storage included a \$43 million guarantee to Beacon Power Corporation for a flywheel energy storage project and a \$17 million guarantee to AES Energy Storage LLC for a 16 MW Lithium-ion battery in New York (GAO, 2012). Section 1705 provided guarantees for projects that completed due diligence, closed on their loans, and started construction on or before September 30, 2011. Many projects that applied under section 1705 were unable to qualify due to this time constraint, and are now being considered under section 1703. Section 1703 also received an additional \$1.5 billion in loan guarantee authority for projects which pay a fee to cover potential future losses (called a credit subsidy) to the government from companies that go bankrupt (GAO, 2012). Under Section 1705, applicants did not have to pay this fee as the government provided these funds. The future outlook for the U.S. DOE loan program is uncertain; the failure of some companies in the government's portfolio (such as a solar panel manufacturer called Solyndra) has created political challenges for continuation of the program.

¹⁰ The other loan program is called the Advanced Technology Vehicles Manufacturing (ATVM), which provides loans to support the development of advanced technology vehicles.

Once again, the influence of the ARRA stimulus package has had a large effect on this program. Further, though the loan program was institutionalized under a previous administration, it is not impervious to political whims. In order for this market-pull initiative to survive it will likely need to be renewed or replaced by a different program or collection of financial tools to aid market conditions (namely access to capital) for near-commercial and commercially available storage technology.

2.2.2 Regulatory Framework for Ancillary Services

FERC is a federal-level independent agency that regulates interstate transmission of electricity, natural gas, and oil, as well as licensing activities. Orders discussed below relate to FERC's role in regulating electricity transmission and electricity sales in wholesale markets when related to interstate commerce, as well as ensuring reliability standards and economic efficiency in these markets.

FERC Order 890, issued in February 2007, instructs RTOs and ISOs to consider intermittent generators for ancillary markets and specifically alter payment tariffs to remunerate non-generating capacity for ancillary services (FERC, 2007; CA-ISO, 2008). This clears a path for energy storage (as well as demand response) to play an increased role in these markets.

FERC Order 755 was issued in October 2011 to address "undue discrimination" in wholesale ancillary markets, specifically for fast-response units. FERC found that fast-acting resources in wholesale markets were not compensated when they provided greater amounts of up and down frequency regulation (FERC, 2011). Further, the use of faster-ramping resources may result in efficiency gains leading to lower costs for frequency regulation and ultimately a reduced cost of electricity, something which, according to FERC, was not adequately considered under current market structures. Compensation of opportunity costs for regulation services were also considered "unduly discriminatory" because they are not uniformly applied across technological resources and (in some instances) are paid to some resources and not others (FERC, 2011). In light of the preceding market issues, FERC required Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) to apply a two-tier payment for ancillary services. First, the payment should remunerate the resource for the capacity set aside, including opportunity cost. The second payment relates to performance of the resource, and should take into account MWh up and down regulation and accuracy in responding to a system operator's dispatch signal (FERC, 2011).

FERC's order may encourage investment in energy storage such as batteries and flywheels, which can provide such fast response and would benefit from additional compensation for this service. The ruling was received positively by the Electricity Storage Association, an advocacy group for energy storage (ESA, 2013). As an example of potential effects from the regulation, it has allowed Beacon Power, a flywheel energy storage provider emerging from bankruptcy, to initiate projects in several ISOs throughout the U.S (Wesoff, 2013).

2.2.3 California – Select State-Level Initiatives

In addition to the federal policies and regulations that are the focus of this report, state-level initiatives may also play an important role in the implementation and regulatory framework governing storage implementation. One state with relevant policies is California. California's Self Generation Incentive Program (SGIP) provides monetary incentives for the implementation of numerous forms of energy production¹¹ including advanced energy storage projects, such as battery storage. Projects smaller than 1 MW receive \$1.80/Watt, installations from 1 MW to 2 MW \$.90/Watt (or 50% of the base rate), and 2 MW to 3 MW installations \$.45/Watt (or 25% of the base).¹² Through April 2011, average system costs for 8 projects and almost 12 MW of storage installed was about \$1/W (PGE, 2011). Thus, the SGIP potentially provides a healthy incentive for smaller projects. However, other regulatory barriers have historically impeded small storage systems (i.e. batteries with PV), including energy storage's inability to participate in net metering and metering installation costs (Duda et al., 2013). Incentive payments are limited by various factors, including minimum customer investment of 40% of eligible project costs and a \$5 million cap per project. The storage system can be stand-alone or coupled with solar photovoltaic (PV) systems, fuel cells, or wind turbines which also receive separate subsidies either through SGIP or through other incentive programs. Storage is defined as being able to convert excess electricity into another form and then back into electricity; the program explicitly excludes power to gas technology (CPUC, 2013a; DOE et al., 2013).

While a capacity of only 5 MW worth of storage projects applied for the program in 2011 (for \$10 million in incentives), in 2012 almost 28 MW applied for installation incentives of \$53 million. Administration of the program is set to expire at the beginning of 2016 and is authorized for \$83 million for all technologies covered under the program from 2012 to 2014 (Duda et al., 2013), distributed among the state's large utilities for implementation of the program.

Further, the state passed assembly bill 2514 in 2010, which mandated the consideration of energy storage procurement targets by October 2013 "if determined to be appropriate." The California Public Utilities Commission (CPUC) recommended a possible framework and procurement targets, guided by the goals of the program – optimization of the grid, the integration of renewable energy, and the reduction of greenhouse gas emissions in line with California's state goals. Auctions would be held every two years, with increasing acquisition targets over the time period in anticipation of learning curves (CPUC, 2013b). The CPUC has set forth potential targets for the large investor-owned utilities in the state (Southern California Edison, Pacific Gas and Electric, and San Diego Gas and Electric) for every two

¹¹ Including fuel cells, gas turbines, combined heat and power, and wind turbines.

¹² The incentive is paid upfront for systems less than 30kw after project completion. Systems greater than 30kw receive 50% upfront and 50% through performance based incentives (per kWh), paid within the first 5 years of the project. The system must also meet requirements for on-site peak demand reduction and other technical requirements.

years between 2014 and 2020, for a total of 1.3 GW of additional storage by 2020 (CPUC, 2013b) compared to less than 4 GW of existing pumped storage capacity in California (EIA, 2013).

2.3 Summary of U.S. Policy

Table 3 provides a summary of major policy initiatives related to energy storage in the U.S., described in previous sections of this paper.

Table 3: Summary of Major Storage Policy Support Programs,, U.S.

Category of Support	Entity / Program / Regulation	Description	Funding
<i>Technology-push</i> - R&D	Department of Energy (DOE) Energy Storage Systems Program (ESSP), Joint Center for Energy Storage Research (JCESR), and National Renewable Energy Laboratory (NREL),	The ESSP conducts basic research, system analysis, and support for demonstration of multiple energy storage technologies. JCESR links basic research with commercialization for battery and energy storage. NREL conducts power to gas and battery research.	\$15-\$20 million per year (2012, 2013) for ESSP. JCESR awarded \$120 million over 5 years in 2012. NREL's power to gas project spent \$1 million and incurs ongoing costs.
<i>Technology-push</i> - P&D	American Recovery and Reinvestment Act of 2009 (ARRA)	The US stimulus bill supports storage demonstration projects matched by private funds.	Spent \$185 million through May 2011.
<i>Technology-push</i> - R&D/P&D	Advanced Research Projects Agency - Energy (ARPA-E)	Supports and develops multiple storage demonstration projects. Also received funds from ARRA.	Spent \$31 million in FY 2010 and \$28 million in FY 2011 for energy storage projects.
<i>Market-pull</i> - Low-interest loans	DOE Loan Program Office	Provides loans and loan guarantees to clean energy technology projects, some of which have been used for storage projects.	Authorized for \$34 billion (2005) and \$18 billion (2009), the majority of which is accounted for. A small portion went to storage projects.
<i>Market-pull</i> - Regulatory framework	FERC Order 890	Clears a path for energy storage (as well as demand response) to play an increased role in ancillary markets.	N/A
<i>Market-pull</i> - Regulatory Framework	FERC Order 755	Rewards fast-reacting ancillary service technologies (like batteries and flywheels) for accuracy and speed.	N/A
<i>Market-pull</i> - Investment incentive	California Market Incentives	The Self Generation Incentive Program (SGIP) provides monetary compensation for energy storage projects in California. The state is also considering procurement targets for energy storage.	\$1.80/W for projects less than 1 MW, \$0.90/W for 1-2 MW, \$0.45/W for 2-3 MW projects. \$83 million per year authorized for all technologies, 2012-2014.

In recent years federal initiatives have focused on technology-push while market-pull policies have played a smaller role. By far the largest and most impactful support came

through the U.S. government's federal stimulus program, ARRA. Funding from the program had an impact on every federal initiative discussed here, other than the regulatory orders from FERC. Though ARRA has clearly enhanced research, development, and implementation of less-developed storage technologies in the U.S., the disappearance of ARRA funds after 2011 will slow down this momentum as institutional storage funding remains relatively low. Further, the primary market-pull policy at the federal level other than regulatory incentives, low-interest loans, will likely disappear without pro-active governmental action. Perhaps some of this momentum can be regained through initiatives like JCESR, which, with modest governmental support, additionally tap private resources and know-how for technological development and eventual commercialization.

3 Germany

Across the Atlantic, Germany's "Energiewende," or energy transformation, is fundamentally changing the German power system. Two primary components of the Energiewende are a complete nuclear phase-out by 2022 and the integration of large amounts of renewable energy. By 2020, electricity generated from renewable sources should deliver at least 35% of gross German power consumption (BMW_i and BMU, 2010). In 2012, this share was around 23%. The targets for 2030 and 2050 are 50% and 80%, respectively. Due to limited potential of dispatchable hydro power and biomass in Germany, the largest part of renewable power generation will come from variable sources like wind and solar. In this context, storage is expected to play an increasing role in the medium and long-term, complementary to the development of additional pumped-hydro storage capacity and interconnection to countries with large hydro capacity. Thus, Germany has also committed to the research, development, and demonstration of less-developed storage technologies. Several regulatory impediments to storage deployment and utilization have also been modified in recent years.

3.1 Technology-push Programs in Germany

There are several ways for German ministries on both the federal and the Länder (state) level to promote research, for example by project-based funding or by institutional funding of universities and other research institutions. Whereas data sources on project funding are dispersed and partly incoherent, institutional funding of universities and research institutes in principle cannot be clearly assigned to storage. Notwithstanding, in the following we present such publicly available data that can be clearly linked to storage-related research.

Federal support for energy research is generally organized within the 6th Energy Research Programme of the Federal Government (BMW_i, 2011). Between 2011 and 2014, the program has a projected budget of nearly €3.5 billion. A part of the budget is financed by the Energy and Climate Fund, which in turn is funded by revenues of certificate auctions within the European emissions trading system. Within the 6th Energy Research Programme, funding energy storage research is regarded as an inter-ministerial task. The Federal Ministry of Education and Research (BMBF) is in charge of basic storage research, for example regarding new materials or electrochemical and thermochemical processes. The Federal Ministry of

Economics and Technology (BMW_i) is responsible for applied storage-related research without direct linkage to renewable energy, including storage for mobile applications. In contrast, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (referred to as BMU or Federal Ministry for the Environment in this paper) is in charge of applied storage research in the context of renewable energy.

3.1.1 Energy Storage Funding Initiative

Perhaps the most significant initiative directly related to the development of storage technology is Germany's "Förderinitiative Energiespeicher," or Energy Storage Funding Initiative. As part of the 6th Energy Research Programme, the initiative is coordinated among the three ministries BMBF, BMW_i and BMU and is funded with €200 million between 2011 and 2018.¹³ Project participants are expected to share in at least 50% of the costs for the project (BMBF, 2011a).

The initiative is intended to be technology neutral, including all forms of energy storage that are considered promising for Germany's energy system, with a focus on stationary storage. Priority example projects include power storage like Lithium batteries, power to gas, thermal storage, and general topics like management and communication of distributed storage or simulation studies.

As of July 2013, over €165 million Euros have been granted to 194 projects. As an illustration of the projects funded through this initiative, Table 4 displays the ten projects that have received the greatest amount of funds through July 2013.¹⁴

¹³ While most projects started in 2012, some started in 2011 or 2013. Funds are provided for 3-5 years, such that most funds should be spent by 2016-2017.

¹⁴ Translated from German. Full list of projects sent to authors via email by project facilitator Jülich (PtJ) on July 9, 2013.

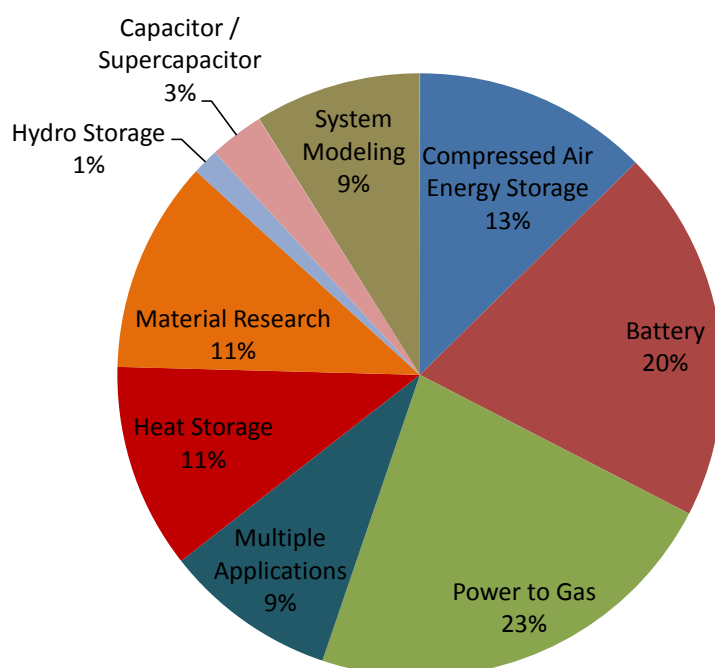
Table 4: German Energy Storage Funding Initiative, Top Funded Projects through July 2013

<u>Awardee</u>	<u>Technology / Project Description</u>	<u>Federal Funds (€ million)</u>
RWE Power Aktiengesellschaft	Project ADELE-ING: Engineering projects for the construction of the first adiabatic compressed air storage demonstration plant.	9.2
Ed. Züblin AG – Direktion Zentrale Technik	Joint project ADELE-ING: Engineering projects for the construction of the first adiabatic compressed air storage demonstration plant.	9.0
Christian-Albrechts- Universität zu Kiel	Joint project ANGUS+: Effects of the use of geological subsurfaces as thermal, electrical, or material storage in the context of the "Energiewende"	5.6
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	TEZEL - Test and development system for PEM electrolyzers	4.9
Forschungszentrum Jülich GmbH	Electrochemical metal-metal-oxide high temperature storage for central and decentral stationary applications	4.5
Siemens Aktiengesellschaft	Joint project Energy Park Mainz: Hydrogen electrolysis as energy storage. Construction and operation of an electrolysis system	3.9
Leibniz-Institut für neue Materialien gGmbH	Research Group 3D Nanostructured Electrical Energy Storage Systems (nanoEES3D)	3.6
Technische Universität Bergakademie Freiberg	Joint project CryPhysConcept: Using a crystal physics concept for future electrochemical energy storage.	3.6
Westfälische Wilhelms- Universität Münster	Joint project Insider: development and construction of an innovative Anion- inner-storage battery system	2.8
Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)	Joint project development work of alkaline pressure electrolysis for the conversion of electricity into hydrogen	2.8

Overall, the initiative's funding (through July 2013) has gone to multiple technological applications, with a focus on power to gas, various battery compositions, and compressed air energy storage (Figure 4).¹⁵ The large research investment for seasonal storage technologies reflects Germany's middle and long-term plans for electricity to come primarily from variable renewable sources, wind and solar power.

¹⁵ Projects were categorized by the authors according to the primary application for the research.

Figure 4: German Energy Storage Funding Initiative, Funding by Technology through July 2013



3.1.2 Research and Demonstration through Ministries, Universities, and other Institutions

Aside from the federal “Förderinitiative Energiespeicher”, there are numerous storage-related research projects funded by federal or Länder ministries. For example, as of May 2013, BMU funds 641 research projects in the field of renewable energy, of which 31 (5%) include storage as an important feature (BMU, 2013).¹⁶ Overall project support amounts to €482 million, of which the storage related projects account for about €22 million (also 5%).¹⁷ Table 5 shows the ten projects that have received the greatest amount of funds. Other federal ministries like BMBF and BMWi also fund project research; however, data on the budget of storage-related projects is not available. In addition, several Länder ministries support storage research. For example, Baden-Württemberg currently supports five storage projects with a budget of €3 million (Ministerium für Umwelt, 2013).

¹⁶ We count all projects that include at least one of the following keywords in their title (translated from German): storage, power to gas, electrolysis.

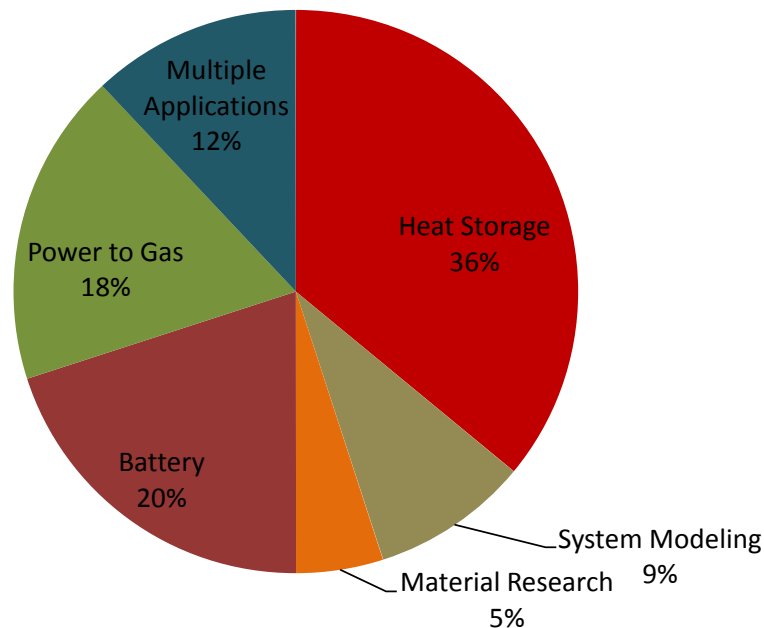
¹⁷ In an earlier list of BMU-funded projects as of February 2013, projects were present that are now funded under the Förderinitiative, the Energy Storage Funding Initiative. In addition, some replication of projects was found between the Förderinitiative list and BMU funded projects – in such cases they were removed from the list of BMU projects.

Table 5: Funding of Storage-related Research Projects by BMU, Top Funded Projects

Awardee	<u>Title / Project Description</u>	<u>Total Funds (million €)</u>
Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)	Joint projects, power to gas: Construction and operation of a research facility for the storage of renewable electricity as methane at the 250KWe scale.	3.5
Helmut Schmidt Universität Hamburg	Development of a measurement device to determine the frequency-dependent line impedance on the high voltage level to 110kV, in order to evaluate the availability of network capacity as system size to determine the dimensions (size) of energy storage.	2.4
FH Aachen	HiTexStor II: Development of a high temperature moving bed heat exchanger for the storage of sensible heat in bulk materials – demonstration and test	2.1
Steca Elektronik GmbH	Photovoltaic island system with long lasting storage systems based on lead and lithium-ion batteries.	1.5
Deutsches Zentrum für Luft- und Raumfahrt (DLR)	Joint Project: DSG Store – development and industrial implementation of a thermal storage system for solar thermal power plants with direct steam generation – phase 1.	1.2
Bayerisches Zentrum für Angewandte Energieforschung (ZAE Bayern)	Establishment of a laboratory for characterization and evaluation of thermochemical storage materials.	1.1
Evonik Industries	LionGrid: Net integration of decentralized energy production with help from lithium-ion battery storage.	0.9
SMA Solar Technology AG	LionGrid: Net integration of decentralized energy production with help from lithium-ion battery storage.	0.9
Bayerisches Zentrum für Angewandte Energieforschung (ZAE Bayern)	Component and system development: solar heating and cooling with cold absorption facilities and latent heat storage.	0.9
RWTH Aachen	Storage and interconnection requirements with consideration of the entire European area with a high proportion of renewable energy – development of simulation programs and investigation of energy supply scenarios.	0.5

Through May 2013, BMU storage funding has concentrated on heat, battery, and power to gas storage technology (Figure 5). Storage projects funded by BMU tend to be smaller in scale and overall funding when compared to the much larger Energy Storage Funding Initiative. This is evidenced by the focus on heat storage, which tends to be smaller in scale compared to the large-scale power storage projects of the Förderinitiative.

Figure 5: BMU Funding by Technology through May 2013



In addition to German ministries, universities and other research institutions play an important role. Finding solid data for storage-related research budgets of these institutions is particularly challenging. BMBF publishes some numbers based on voluntary disclosure of the institutions (BMBF, 2011b). Following this database, German universities¹⁸ have a yearly storage research budget of up to €68 million, which equals around 10% of universities' overall energy research budget (2011 data). Other institutions like Fraunhofer-Gesellschaft (FhG), Helmholtz-Gemeinschaft (HGF), Leibniz-Gemeinschaft (WGL) and Max-Planck-Gesellschaft (MPG) have a yearly storage research budget of up to €65 million, accounting for around 8% of these institutions' overall energy research budget (2010 data). Among these institutions, FhG has the largest storage budget (around €33 million), followed by HGF (€22 million), MPG (€7 million) and WGL (€4 million).

3.2 Market-pull Programs in Germany

3.2.1 Investment Support Through KfW bank

The state-owned KfW bank has a long history in its role to German development, with a stated mission of advancing the country's development through a variety of programs. The bank serves as a promotional bank for individuals as well as for enterprises, cities, and municipalities. Through various programs, it provides low-interest loans and passes government subsidies on to recipients. Amongst other business areas, the bank is particularly active in financing renewable energy projects.

¹⁸ Universities include both German "Universitäten" and other "Hochschulen."

Two municipal energy supply programs of KfW explicitly target low-interest loans for storage projects in Germany. Project number 203 applies to municipalities and promotes extension and new construction of pumped hydro, compressed air or hydrogen storage as well as the utilization of the natural gas infrastructure for hydrogen storage and/or synthetic methane (KfW, 2013a). As of July 2013, interest rates ranged from around 0.6% to 1.3%, depending on the loan period (between 10 and 30 years). The related project number 204, which has a €50 million credit limit and higher interest rates, targets municipal utilities and medium-sized public-private partnerships. Other KfW programs promote energy storage in the context of new renewable energy investments. For example, the “standard” program for renewable energy (number 270) focuses on installations for renewable power generation, but may also cover power storage that is combined with such renewable installations, or heat storage that is not covered by other KfW programs.¹⁹ Likewise, the “premium” programs for renewable energy (271 and 281)²⁰ focus on renewable heat, but also cover large-scale heat storage. These programs also provide additional investment grants for particularly innovative heat storage facilities (KfW, 2012a; KfW, 2013b).

In addition, there is a new program for financing large-scale investments of large enterprises in the context of the German Energiewende (number 291). Loans range between 25 and 100 million Euros, with a focus on innovation in energy supply, efficiency, storage and transmission (KfW, 2012b). Program 230 complementarily provides grants up to 30% of a project’s costs and low-interest loans to support foreign and domestic companies conducting innovative large-scale pilot projects with substantial potential for environmental improvement. Although this program does not focus on storage, a portion of these grants and loans could benefit pilot storage projects in Germany (KfW, 2012c).

3.2.2 Subsidy Program for PV Battery Storage

Recently, a new program dedicated to investment support of decentralized battery storage for solar energy (PV) has been introduced. The emergence of this policy, which is institutionalized through KfW program 275, exemplifies the constant shift and adjustment of policies according to perceived efficacy as well as political calculation. According to the current status of Germany’s Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG), PV facilities between 10 and 1000 kW receive a fixed feed-in tariff for only 90% of the facility’s yearly output (EEG Amendment, 2012). Moreover, feed-in tariffs for PV have dropped below the average electricity price level for households. In addition, self-consumed electricity from PV is exempt from the EEG surcharge, network tariffs and taxes. All of these factors incentivize onsite consumption of PV electricity, which can be increased through the use of onsite battery storage. Even with these incentives, however, increasing a household’s self-consumption by means of on-site battery storage is not yet economic due to the high capital cost of batteries. Seemingly to address this setback for on-site PV storage, BMU has

¹⁹ The related program 274 focuses on PV installations.

²⁰ Program 281 applies to small enterprises with less than 50 employees or yearly revenues of less than 10 million Euro.

proposed a new market incentive program intended to boost adoption of decentralized PV storage, worth €25 million in 2013 (BMU, 2013c). There is an investment grant for 30% of the battery system's cost; the remaining 70% is covered by a low-interest loan through KfW Bank (KfW, 2013c). PV installations must be smaller than 30 kWp, and batteries must be used for at least five years. In addition, the maximum feed-in of the PV installation to the grid may not exceed 60% of its nominal power rating over its whole lifetime, or at least for 20 years. This provision is intended to provide an incentive to operate the storage system in a mode that is beneficial to the stability of the grid (BMU, 2013c).²¹

3.2.3 Support of Heat Storage

The Marktanreizprogramm, or “Support of Measures to Utilize Renewable Energies in the Heat Market”, is an incentive program intended to foster renewable energy technologies in the heat market, and at the same time to improve their cost-effectiveness (BAFA, 2012). The program has been in place for more than a decade and is sponsored and funded through BMU. It is administered by the Federal Office of Economics and Export Control (BAFA), which hands out investment grants for small installations, and the KfW Bank Group, which offers long-term low-interest loans, and partly also redemption grants, for larger installations.

Various technologies and innovative processes are supported, including solar thermal heating systems, heat pumps, and heat networks supplied from renewable sources. Importantly, the program also covers several types of heat storage, including buffer storage for solar collectors and installations for biomass combustion, and large innovative heat storage facilities. Private persons, municipal companies and organizations, small to middle-sized companies, and energy services companies (as contractors) are eligible to apply for grants and loans. Grants are provided through the German ministry BAFA, and low interest loans through KfW bank (see above). In 2012, the conditions of the program were adjusted. From 2009 through 2012 the program was funded with up to €500 million per year (BAFA, 2012). The program's budget, however, was rarely exhausted in the past.²²

In 2012, €144 million was distributed by BAFA, whereas €113 million went through KfW Bank. According to BMU, these funds stimulated total investments of €1.33 billion in 2012. The largest part of BAFA grants in 2012 supported biomass and solar thermal installations (BMU, 2013a; BMU, 2013b). Whereas both of these may include heat storage devices, it is not possible to clearly attribute storage-related funds. KfW funds were largely used for heat networks (redemption grants of €95 million in 2012), and only to a very minor part for heat storage (€2 million).

²¹ As distribution network operators cannot control these distributed battery storage facilities, grid-optimal utilization is rather unlikely. The provision may nonetheless incentivize battery operation that is not too detrimental to grid stability.

²² In fact, since 2009 applications for all technologies have gone down. Around 31,000 applications were approved in 2009 for heat pumps, supported with €78 million. In 2012, only 4,000 application were approved (out of just 5,700 who applied), for support of around €10 million. Data on applications received in email to authors from BAFA on September 3, 2013.

In addition to basic funding, participants may receive a “combination bonus”²³ for a combination of various measures such as solar thermal heating and heat pumps, an “efficiency bonus”²⁴ for projects that achieve cost savings due to lower primary energy needs from the use of renewable energy, or an “innovation bonus” for especially innovative applications (BMU, 2012a).

The revised act on combined heat and power (CHP) of July 2012 (Kraft-Wärme-Kopplungsgesetz (KWKG)), provides additional incentives for heat storage facilities linked to CHP installations. Heat and cold storage facilities with at least 1 m³ water volume equivalent or at least 0.3 m³ per kilowatt installed electric power receive a grant of 250 Euros per m³ up to 30% of the total investment. BAFA distributes these grants if the installation satisfies certain conditions (BAFA, 2013).

3.2.4 Regulatory Framework

An important regulatory adjustment that affects the utilization of storage in Germany is the partly exemption from grid tariffs. Power storage is generally exempt from network tariffs for electricity fed back into the grid; as for power drawn from the grid (for storage loading), new storage facilities that feed electricity back to the grid are exempt from grid tariffs for a period of twenty years, whereas existing pumped hydro facilities that have increased their power rating or energy capacity can be exempt for ten years (§113 EnWG). Likewise, storage facilities can be exempt from EEG levies (§37 EEG). In addition, there are electricity tax exemptions for pumped hydro storage, but not for other storage technologies (§9 StromStG). Whereas such exemptions can generally add to the profitability of new storage projects, it appears that pumped storage is slightly privileged compared to other, less-developed technologies.

3.3 Summary of German Policy

Summing up, public funding of research and development focused on energy storage has increased in recent years. In the technology-push category, the federal Energy Storage Funding Initiative is particularly noteworthy with a budget of €200 million through 2018. It is supplemented by ministerial funding of storage research projects and by institutional funding in the field of storage research by both federal Germany and the Länder (states). BMU alone spends around €22 million on ongoing storage-related research projects. Moreover, universities and other research institutions have storage-related yearly research budgets of more than €60 million each. Compared to the overall budget of the 6th Energy Research Programme (around €3.5 billion), however, public funding of storage-related research still appears to be relatively low. Regarding market-pull measures, investment incentives are provided by KfW and BAFA in the form of subsidized loans and investment grants for various types of storage. After the recent introduction of a new support scheme,

²³ For instance, €500 for solar and biomass or solar and heat pumps.

²⁴ 50% of base funding.

distributed PV-connected battery storage can also receive subsidies. Table 6 provides an overview.

Table 6: Summary of Major Storage Policy Support Programs, Germany

Category of Support	Entity / Program / Regulation	Description	Funding
<i>Technology-push - R&D/P&D</i>	Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment (BMU), Federal Ministry of Education and Research (BMBF) - <i>Energy Storage Funding Initiative</i>	Research, development, and demonstration of multiple storage technologies through grants and privately matched funds for relevant projects / institutions.	€200 million through 2018.
<i>Technology-push - R&D/P&D</i>	BMU, Länder, and other ministries, universities, and research institutions (i.e. Fraunhofer-Gesellschaft, Helmholtz-Gemeinschaft, and others).	Basic research and demonstration for storage projects.	Around €22 million in ongoing BMU projects. Yearly storage-related budgets over €68 million from universities and €65 million from other research institutions.
<i>Market-pull - Low-interest loans</i>	KfW Bank	Provides access to low-interest loans and grants subsidized and authorized by the government.	N/A.
<i>Market-pull - Investment incentive</i>	Incentives for battery storage connected to photovoltaic (PV) solar panels	Investment grants and low-interest loans for PV-connected storage with grid connection and data management systems.	€25 million for 2013, potential €25 million for 2014.
<i>Market-pull - Investment incentive</i>	BMU, Federal Office of Economics and Export Control (BAFA), KfW Bank- <i>Support of Measures to Utilize Renewable Energies in the Heat Market</i>	Encourages the production and use of renewable energy (and storage) in the heat market.	Up to €500 million per year since 2009. A portion of these funds have been applied to heat storage.
<i>Market-pull - Investment Incentive</i>	BAFA, <i>Combined Heat and Power Act of 2012 (KWKG)</i>	Heat and cold storage facilities of CHP plants with at least 1 m ³ water volume equivalent or at least 0.3 m ³ per Kilowatt installed electric power receive a grant.	250 Euros per m ³ water up to 30% of the total investment.
<i>Market-pull - Regulatory framework</i>	Exemption from network fees, EEG levies, and electricity tax	Electricity storage facilities can be exempt from grid tariffs, EEG levies and, in the case of pumped hydro, also electricity taxes.	N/A.

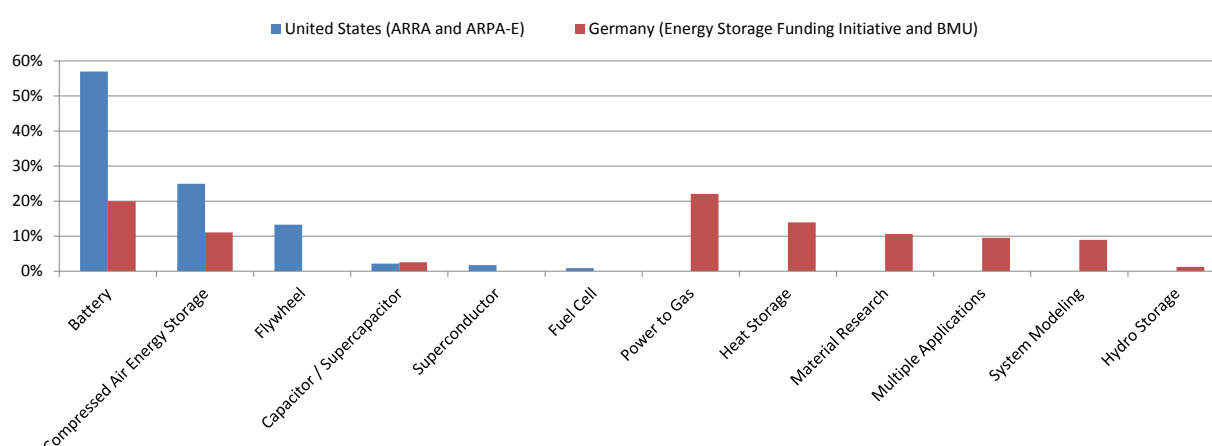
4 Comparison and Conclusions

In summary, fundamental research and market incentives have increased in recent years for storage technologies in both the U.S. and Germany, reflecting increased interest for storage in electrical grids. Nevertheless, storage remains a relatively low priority for both governments' energy budgets.

Both the U.S. and Germany employ technology-push and market-pull policies intended to foster storage technology development as well as market integration. This reflects the state of transition storage technology currently finds itself. While some technologies, such as power to gas, are still primarily in the initial demonstration and technology development stage, others, such as some battery technologies, have the potential to be integrated into specific markets today. At the same time, many battery technologies still require basic research and development or are considered capable of substantial efficiency improvements. Thus, the fact that storage technologies range considerably in maturity is reflected in the multiple policies employed by the U.S. and German governments. In both countries emphasis appears to be placed on technology-push programs over market-pull.

For instance, the largest and most significant programs for storage development in both countries in recent years have come through the American Recovery and Reinvestment Act (ARRA) in the U.S. and the Energy Storage Funding Initiative in Germany, which emphasize research, development, and demonstration of storage technologies. These initiatives, along with ARPA-E in the U.S. and BMU project funding in Germany, provide a perspective on the different storage technologies currently focused on for research and development in the two countries. The technology types by amount of funding (percentage of total in each country) for the recent initiatives are displayed in Figure 6.²⁵

Figure 6: U.S. and Germany Major Initiative Funding by Technology (% of Country Total)



Battery storage and compressed air energy storage research play an important role in both programs; however, there are also fundamental technological differences between the two.

²⁵ ARPA-E includes demonstration projects from FY 2010 and 2011. Energy Storage Funding Initiative data through June 2013 and BMU data as of May 2013.

While the U.S. focuses primarily on battery technologies as well as on compressed air and flywheel storage, Germany distributed funds amongst a wider variety of technologies, including basic research in the fields of material research and multiple applications. The U.S. program includes flywheel technology while the German programs examined here have no flywheel projects. By contrast, power to gas projects are highly funded in the German initiative while none received funding for U.S. programs examined. This reflects the short-term character of the ARRA stimulus, which should favor technologies that are closer to commercialization. At the same time, the U.S. has focused on technology that enhances grid reliability through ancillary services. In contrast, renewable integration issues dominate research and development priorities in Germany. In particular, power to gas is considered a possible option for seasonal energy storage that, with large amounts of fluctuating renewable energy, may become important in the German system.

As mentioned earlier, U.S. dependence on funding from the fiscal stimulus, ARRA, and namely the exhaustion of these funds, represents an impediment to continued momentum for storage development in coming years. Without additional appropriation or a new spending bill, research, development, and demonstration of storage technologies will dramatically decrease in comparison with recent levels.

Market-pull programs also demonstrate a focus on storage applications unique to characteristics of the two countries' electricity grids and overall energy policy. In the U.S., federal efforts tend to bolster storage applications for grid stability, particularly FERC Orders but also issued loan guarantees. In Germany, heat storage for market-pull programs is emphasized given the importance of combined heat and power and renewable heat in Germany. In addition, there is a market-pull program for PV-connected battery storage, related to Germany's rapid PV deployment.

From the perspective of public policy, these similarities and differences point to the same conclusion: increased data-sharing and cooperation between the two governments and research institutions could help enhance the efficacy of both countries' storage research. Private and public institutions in both countries could gain from mutual cooperation and information sharing. From a public welfare perspective, heightened formal cooperation may serve to increase the effectiveness and productivity of publicly funded research. As a starting point, we propose to define storage research as a key area of cooperation in the context of the intergovernmental Agreement on Science and Technology Cooperation, which was signed in February 2010.

In certain areas a policy comparison reveals insights from which U.S. and German policy makers can learn and enhance or modify currently implemented policy. For instance, FERC Order 755 in the U.S., which requires resources such as battery storage to be compensated for faster response and performance in ancillary markets, may be an approach from which the German system could benefit, particularly as increasing amounts of renewable energy are added to the German grid. Under the current market rules in Germany, participants are

not rewarded for faster response time. Therefore, a regulatory incentive in the spirit of FERC Order 755 may serve to increase the efficiency of Germany's ancillary markets and integrate fast response technologies like battery storage.

Additionally, institutions unique to the U.S. side are ARPA-E and JCESR, which bridge technology-push and market-pull policy. In the context of the German "Energiewende," which prescribes ambitious renewable energy goals until 2050, the linking of novel technology research with market integration seems sensible and necessary to promote innovation. ARPA-E may be a useful model for Germany as it organizes and supports novel technology along with commercialization goals under one institution – in Germany, this type of research is spread over multiple ministries and institutions. In addition, JCESR explicitly brings research, industry, and commercialization partners together, in an effort to create a kind of "Silicon Valley" for extraordinary innovation through collaboration and pooling of resources and know-how. Again, such an effort may be helpful in Germany, particularly in the context of its long-term goals. We thus conclude that institutions which link market integration with technology research and development ought to be considered in Germany.

Unique to Germany is KfW Bank, which provides access to credit and low-interest loans. Compared with the U.S. DOE loan program, which is relatively new and far less stable than KfW, the bank provides an example for the U.S. of an institution that reliably provides subsidized credit to industry, lowering barriers to market integration. The one-off nature of DOE's current loan programs (also affected by the one-time nature of ARRA funds) diminishes its long-term effectiveness; such extreme difficulties for government-subsidized grants and loans have not been seen in Germany. While this likely has more to do with the differing politics around energy issues in the two countries, the KfW's relative long-term success merits attention from U.S. programs and can inspire the U.S. to either re-invigorate the DOE loan program or develop alternative market-pull mechanisms to remain an innovator in this field.

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