INNOVATING SMART GRID: A UTILITY CASE STUDY OF "POWERING" PARADOX

By Lawrence Luong[*]

Synopsis: Since enactment of the American Recovery and Reinvestment Act (ARRA) in 2009, billions of public and private investment dollars have gone into deploying smart grid projects which utilities typically consider high risk. This article offers an analysis of utility smart grid innovation through research on U.S. power sector deployment and, specifically, from a case study of how a municipal utility implemented its smart grid with AARA funding. Examining the "SmartSacramento" project that digitized electric distribution infrastructure at the Sacramento Municipal Utility District (SMUD), data gathered from former project team members revealed creative decision-making and adaptive practices functioning to navigate tensions within a risk-averse organization to successfully innovate. SMUD's experience developing its smart grid highlights lessons for electric sector decision-making as utilities pursue innovation pathways to reduce carbon emissions from their operations. Among key implications of this research is that utility sector stakeholders may be well advised to examine ways their organizations might "power" paradoxes to innovate towards a lower carbon future**.**

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I. INTRODUCTION

U.S. federal investment in smart grid innovation that began with the $4.5 billion American Recovery and Reinvestment Act of 2009 (ARRA) has continued under the Bipartisan Infrastructure Law.[1] The Department of Energy (DOE) is currently administering $10.5 billion in grid modernization funding through the Grid Resilience and Innovation Partnerships (GRIP) program of which $3 billion is designated for smart grid projects.[2] The term smart grid used in this article refers to an electric grid operating with networked power meters commonly known as smart meters, sensors, software, and automated system interconnections designed to enhance system reliability by enabling efficient communications, monitoring,

1. The statute also commonly known as the Infrastructure Investment and Jobs Act authorizes the Department of Energy to administer over $62 billion for energy infrastructure investments that includes $14 billion in financial assistance to States, Indian Tribes, utilities, and other entities who provide products and services for enhancing the reliability, resilience, and efficiency of the electric grid. *See Bipartisan Infrastructure Law Grid Resilience*, NAT'L ENERGY TECH. LAB., https://netl.doe.gov/bilhub/grid-resilience (last visited Aug 1, 2024) (citing Bipartisan Infrastructure Law §§ 40,101, 40,103, and 40,107 (Infrastructure Investment and Jobs Act, Pub. L. No. 117-58, §§ 40,101, 40,103, 40,107, 135 Stat. 429, 904, 907, 915 (2021))).

2. *See Grid Resilience and Innovation Partnerships (GRIP) Program*, U.S. DEP'T OF ENERGY, https://www.energy.gov/gdo/grid-resilience-and-innovation-partnerships-grip-program (last visited Jun 28, 2024) [hereinafter *GRIP Program*].

evaluation, and control through information technology.[3] Maturing from the ARRA-funded Smart Grid Investment Grant (SGIG) a decade ago that spurred nationwide upgrades from analog power meters to first generation digital metering systems, national smart grid policy implemented through GRIP aims today to:

> increase the flexibility, efficiency, and reliability of the electric power system, with particular focus on increasing capacity of the transmission system, preventing faults that may lead to wildfires or other system disturbances, integrating renewable energy at the transmission and distribution levels, and facilitating the integration of increasing electrified vehicles, buildings, and other grid-edge devices.[4]

Policy support directed towards smart grid has resulted in widespread adoption of advanced metering infrastructure (AMI) across the nation. The Federal Energy Regulatory Commission's (FERC) 2023 National Assessment of Demand Response and Advanced Metering indicated there were 115.3 million advanced meters operating in the U.S. out of 162.8 million total electric meters in 2021, marking a 70.8% penetration rate.[5] Growth of smart meters has thus been significant considering 2007 figures reported in FERC's first national assessment showed 6.7 million advanced meters used by consumers out of 144.4 million total meters (4.7% penetration rate).[6]

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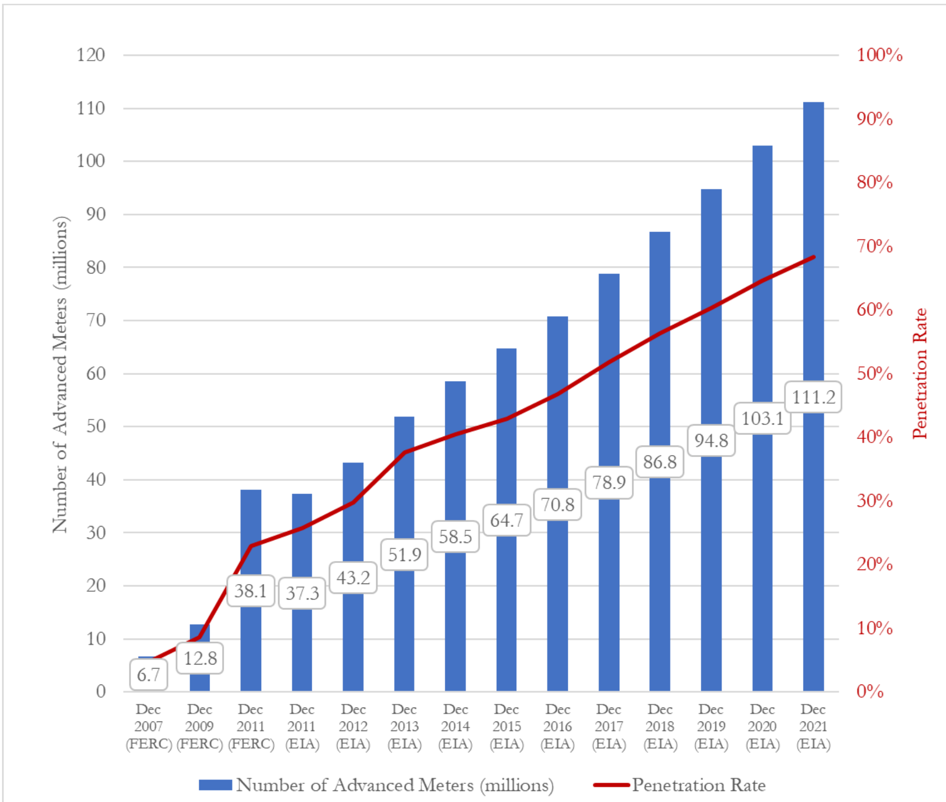
3. For adapting definitions of 'smart grid,' *see* You Zheng et al., *Proceeding with Caution: Drivers and Obstacles to Electric Utility Adoption of Smart Grids in the United States*, 93 ENERGY RES. & SOC. SCI. 1, 2 (2022) ("overlay of networked power meters, sensors, software, and automated system interconnections enabling greater efficiency and reliability of electricity management and use"); Jason Dedrick et al., *Adoption of Smart Grid Technologies by Electric Utilities: Factors Influencing Organizational Innovation in a Regulated Environment*, 25 ELEC. MKT. 17, 18 (2015) ("an electric grid whose operations employ information technology for communications," monitoring, evaluation, and control through information technology).

4. *GRIP Program*, *supra* note 2; *see* Derek Ryan Strong, *Impacts of Diffusion Policy: Determinants of Early Smart Meter Diffusion in the US Electric Power Industry*, 28 INDUS. & CORP. CHANGE 1343, 1345 (2019) (noting that integration of information and communication technologies into power grids is providing deeper levels of situational awareness of grid operations and capabilities through real-time sensing, control, and automation of power flow).

5. *2023 Assessment of Demand Response and Advanced Metering*, FERC 4-5 (Dec. 19, 2023), https://www.ferc.gov/news-events/news/ferc-staff-issues-2023-assessment-demand-response-and-advanced-metering; *Table 10.05 Advanced Metering Count by Technology Type, 2013 through 2022*, ENERGY INFO. ADMIN., https://www.eia.gov/electricity/annual/html/epa_10_05.html (last visited June 17, 2024) (U.S. Energy Information Administration data for 2022 indicates AMI meters installed totaled 118,722,741 out of 164,098,901 (72% penetration rate)).

6. *2023 Assessment of Demand Response and Advanced Metering*, *supra* note 5, at 4-5.

U.S. Advanced Meter Growth (2007-2021)[7]



Tracking the implementation of SGIG, a limited but growing body of research focusing on utility smart grid innovation[8] has emerged over the past decade. Diffusion policies influencing adoption of smart meters[9] within the U.S. power industry has been examined.[10] Scholars have analyzed factors impacting utility

7. *Id.* at 5, Fig. 2-1.

8. *See* Ernest J. Moniz, *Stimulating Energy Technology Innovation*, 141 DAEDALUS 81, 82 (2012) (innovation refers to "an integrated system, comprised of four interrelated components: Invention: discovery, creation of knowledge, and generation of prototypes; Translation: creation of a commercial product or process; Adoption: deployment and initial use of a new technology; and Diffusion: increasing adoption and use of a technology.").

9. Smart meters and 'advanced meters' will be used interchangeably in this article to refer to the same devices. *See* Strong, *supra* note 4, at 1344 (noting smart meters enable dynamic pricing of electricity at the retail level and provide basis for further industry innovation related to consumer engagement on electricity and home automation technology; "Smart meters refer to advanced electric meters based on digital technology that are capable of measuring and recording electricity consumption data in hourly intervals, or less, and capable of two-way communication between the electric power utility and the consumer.").

10. *Id.*

smart grid innovation given the regulated structure of the U.S. power sector[11] as well as those influencing smart grid adoption among investor- and community-owned utilities.[12] The institutional and organizational processes which drive innovation and deployment of smart meters have also been examined in a study of Washington State's utility sector.[13]

This article adds to the smart grid literature with findings from a case study of how such innovation[14] operated at a granular level within an individual U.S. municipal utility that executed a SGIG-funded smart grid deployment. The qualitative study examines SMUD's accomplishment a decade ago of its "SmartSacramento" grid modernization project. The research aims to illuminate decision-making of the teams that achieved SmartSacramento to identify insights assisting utility systems undertaking grid modernization and policymakers involved in advancing smart grid innovation as an energy policy matter. As U.S. electric utilities implement substantial investments of financial and human capital to modernize and upgrade power distribution systems, "know[ing] not only how to innovate but also how to make their innovation processes effective"[15] is essential for industry managers and policymakers to understand. Applying an organizational psychology lens, analysis of SmartSacramento from this study revealed team members practicing what scholars have labelled "paradox mindset," animated by and navigating tensions within the organization to achieve SmartSacramento. The implications of this research could prove strategic as utilities strive to decarbonize[16] at the pace and scale climate scientists predict will be required to avert the worst effects of human-caused climate change. In the highly regulated, organizationally risk-averse environment of the electricity sector, innovation in smart grid technologies provides an opportunity to examine how technology advancement vital to transitioning the electric grid towards a lower carbon future is achieved with resource constraints, siloed business units, resistance to change, and institutional inertia distinguishing utilities in full operation. In short, the research presented here

11. *See generally* Dedrick et al., *supra* note 3.

12. *See generally* Zheng et al., *supra* note 3; Yue Gao et al., *A Spatial Analysis of Smart Meter Adoptions: Empirical Evidence from the U.S. Data*, 14 SUSTAINABILITY 1 (2022).

13. *See* Meghan Elizabeth Kallman & Scott Frickel, *Nested Logics and Smart Meter Adoption: Institutional Processes and Organizational Change in the Diffusion of Smart Meters in the United States*, 57 ENERGY RES. & SOC. SCI. 1 (2019).

14. Guoqiang Peter Zhang et al., *The Payback of Effective Innovation Programs: Empirical Evidence from Firms That Have Won Innovation Awards*, 23 PROD. & OPER. MGMT. 1401, 1408 (2014) ("By definition, innovation implies a deviation from conventional course of behaviors . . . [for which] firms . . . question their own assumptions and premise of existing practices . . . [in a] process [that] forces firms to think about new ways of combining resources[,] [] re-link knowledge components, . . . [and] coordinat[e] among separate units within the firm.").

15. *Id.* at 1418.

16. *For a livable climate: Net-zero commitments must be backed by credible action,* U.N., https://www.un.org/en/climatechange/net-zero-coalition (last visited Jul 14, 2024) ("The science shows [] that in order to avert the worst impacts of climate change and preserve a livable planet, global temperature increase needs to be limited to 1.5°C above pre-industrial levels. Currently, the Earth is already about 1.1°C warmer than it was in the late 1800s, and emissions continue to rise. To keep global warming to no more than 1.5°C – as called for in the Paris Agreement – emissions need to be reduced by 45% by 2030 and reach net zero by 2050.").

sheds light on utility innovation capabilities[17] by analyzing how innovation occurs within a U.S. electric utility, a topic which has yet to be studied in any systematic manner.

Accordingly, the remainder of this article is structured as follows: Section II recaps the federal policy context that led to current support for smart grid innovation. Section III discusses studies of U.S. smart grid deployment highlighting the results of grid modernization policy fostering ongoing smart grid buildout. The case study of SMUD's SmartSacramento implementation will be presented illustrating how team decision-making operated to innovate smart grid. Analysis of the research is informed and framed by innovation literature addressing the interrelated concepts of ambidextrous leadership, skunkworks, and paradox theory. Relying on studies to date of utility smart grid adoption,[18] Section IV discusses the effects organizational features such as size, ownership structure and regulatory choices have on smart grid development. Section V highlights implications of the SmartSacramento case study as utility mangers and policymakers nationwide navigate industry decarbonization efforts. Section VI describes recommendations for utility sector action. Section VII notes the study's limitations and identifies opportunities for additional research, and Section VIII concludes the discussion.

II. U.S. SMART GRID: FEDERAL POLICY CONTEXT

U.S. federal energy policy advancing smart grid technology – the suite of digital power meters, backend control systems, data gathering and processing technologies, and telecommunications utilities rely upon today to manage electric distribution and transmission networks – can be traced to the Energy Production and Conservation Act of 1976 (EPCA).[19] EPCA, enacted as a direct response to the oil embargo and energy crises of the 1970s, required the DOE to develop "design proposals" to promote energy conservation through improved electricity rate design which included reflecting the "marginal cost of service and/or time of use."[20] Time-of-Use (TOU) rates adjust electricity prices based on the time of day when energy is consumed thereby incentivizing consumers to use electricity during off-peak hours, reducing demand during peak times and enhancing grid stability.[21]

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17. *See* Zhang et al., *supra* note 14, at 1417 (noting that "firms' true innovation capabilities are often hard to observe directly").

18. Processes by which innovations are adopted include the transition from evaluation to deployment, routinization, and incorporation into organizational processes. *See generally* Zheng et al., *supra* note 3, at 2.

19. *See* Erwin Rose, *Smart Meters and Federal Law: What Is the Role of Federal Law in the United States in the Deployment of Smart Electricity Metering?*, 27 ELEC. J. 49, 51 (2014).

20. *See* James W. Moeller, *Electric Demand-Side Management Under Federal Law*, 13 VA. ENV'T L. J. 57, 62–64 (1993) (explaining directive to DOE on rate design set forth under 42 U.S.C § 6803 (a)(2)). While EPCA's provisions applied to federal agencies, manufacturers of residential appliances, and state energy conservation agencies, the statute did not impose energy conservation requirements on electric utilities. *Id*. at 63.

21. *See, e.g.*, *What Are Time-of-Use (TOU) Rates?*, CAL. PUB. UTIL. COMM'N, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-rates#:~:text=Time%2Dof%2Duse%20is%20a%20rate%20plan%20in%20which,in%20summer%20months%20than%20in%20winter%20months (last visited Oct. 20, 2024).

A. PURPA

Congress later broadened the basis for federal involvement in electricity under the Public Utility Regulatory Policy Act of 1978 (PURPA),[22] seeking to advance electricity conservation, efficient deployment and use of energy infrastructure by electric utilities, and equitable retail rates for electric consumers while regulating wholesale energy.[23] Title I of PURPA requires that electric utilities consider and potentially adopt as part of their ratemaking processes regulatory standards designed to encourage energy conservation, efficient resource use, and fair consumer rates. The statute mandates that state regulatory authorities and non-regulated electric utilities consider adopting standards to design rates reflecting the cost of providing service, discouraging declining block rates (lower rates for higher consumption) as such rates may not promote energy conservation, encouraging adoption of time-of-day rates reflecting the cost of electricity production fostering off-peak usage, suggesting rate designs reflecting seasonal variations in electricity demand, consider rates for customers willing to have their service interrupted during peak demand times, and encouraging utilities to implement technologies and practices to manage and reduce peak electricity loads.[24] Section 2621, as amended, provides additional "must-consider" standards including integrated resource planning to anticipate future energy needs of utilities, energy efficiency measure to reduce overall power demand and improve system reliability, and programs enabling consumers to adjust energy consumption in response to time-based power pricing information made directly accessible by electricity providers via smart grid applications.[25]

Since its enactment, "PURPA has garnered attention" for the statute's "successful promotion of cogeneration and small power production" yet its "principal target is retail regulatory policy for public utilities."[26] The statute established five standards for retail electric power rates and services summarized as follows:

> First, the provision of services should ordinarily exclude the installation of 'master meters' for multi-unit residential buildings. Second, the rates should not increase

22. *See generally* Public Utility Regulatory Policies Act of 1978, Pub. L. No. 95-617, 92 Stat. 3117 (codified as amended in scattered sections of 16 U.S.C.). General provisions applicable to this discussion can be found in 16 U.S.C. §§ 2601-2645 setting forth definitions, goals, and the specific regulatory and policy provisions introduced by PURPA.

23. Rose, *supra* note 19, at 52 (internal quotes omitted).

24. *See* 16 U.S.C. § 2621(d)(1)-(6) (2024).

25. *See id.* § 2621((d)(7)-(9), (16)-(21)).

26. Moeller, *supra* note 20, at 67–68 (noting that "PURPA devotes particular attention to electric power conservation, energy efficiency and equitable rates for utility consumers," reflected prior to its 1992 amendment the six policies for retail electric power rates and services set forth under Section 111 [16 U.S.C. § 2621(d)(1)-(6)]: (i) rates should reflect the actual cost of electric power generation and distribution; (ii) rates should not decline with increases in electric power use unless the cost of providing the power decreases as consumption increases; (iii) rates should reflect the daily variations in the actual cost of electric power generation; (iv) rates should reflect the seasonal variations in the actual cost of electric power generation; (v) rates should offer a special 'interruptible' electric power service rate for commercial and industrial customers; and (vi) each electric utility must offer load management techniques to their electric customers that will be practicable, cost effective and reliable, as determined by the state public utility commission).

> under automatic adjustment clauses, unless specific requirements are met. Third, services should ***provide information to electric utility customers concerning electric power rates***. Fourth, the services may not terminate electric power service except in accordance with specified procedures. Finally, 'no electric utility may recover from any person other than the shareholders . . . of such utility any direct or indirect expenditure by such utility for promotional or political advertising.' [emphasis added] [citations omitted][27]

"Congress designed PURPA to increase competition in wholesale and retail sales, and a key element of that involve[d] providing price signals through improved demand response."[28] The statute "expand[ed] federal reach in part due to the recognition that interstate wholesale markets cannot function efficiently without meaningful and dynamic retail price signals" for which:

> PURPA establishe[d] standards for 'cost of service' that fostered a policy rationale for improved metering, including 'time-of-day' rates, as well as 'interruptible rates' (for industrial and commercial users) and 'load management techniques,' and a general requirement that individual units have their own meters rather than one 'master meter' per building.[29]

Still, given the statute's express time limit of two years from enactment for states to complete determinations of its "must-consider" standards,[30] PURPA's impact on expansion of smart grid infrastructure nationally was arguably limited, particularly in comparison to direct federal funding of AMI buildouts under ARRA.

Subsequent to PURPA, the Energy Policy Act of 1992[31] "increased federal support for integrated resource planning (considering conservation and efficiency along with production), energy efficiency, and [demand side management]."[32] As a consequence, the statute "built up pressure for [advanced metering]" but did not explicitly address metering.[33]

B. *EPAct '05 and EISA*

Direct federal involvement in the promotion of advanced metering was effectuated under the Energy Policy Act of 2005[34] (EPAct '05) which amended PURPA.[35] While it did not mandate consumers receive dynamic pricing, EPAct '05 established new "must-consider" federal standards on "net metering" and

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27. *Id.* at 68–69 (citing 16 U.S.C. § 2623 *et seq*. and noting that Section 113 of PURPA "resembles Section 111 to the extent that the adoption and implementation of the five additional standards by state PUCs is not required," requiring only that the state commissions consider each standard and whether a particular standard should be implemented).

28. Rose, *supra* note 19, at 52.

29. *Id.* (citing 16 U.S.C. § 2623(b)(1)).

30. *See* 16 U.S.C. § 2622(b) (2024) (requiring states begin consideration within one year after the date of enactment of the Energy Policy Act of 2005 (by August 8, 2006) and to complete their determinations within two years (by August 8, 2007)).

31. Energy Policy Act of 1992, 42 U.S.C. §§ 13201-13574 (2024).

32. Rose, *supra* note 19, at 52.

33. *Id.*

34. Energy Policy Act of 2005, 42 U.S.C. §§ 15801-16539 (2024).

35. *See* Rose, *supra* note 19, at 52; *see also* 16 U.S.C. § 2622(b).

"time-based metering and communications" that furthered federal policies promoting advanced metering to deliver such energy use detail to consumers. Section 1252 titled "Smart Metering" specifically provided a standard on "time-based metering and communications" as follows:

> . . . [E]ach electric utility shall offer each of its customer classes, and provide individual customers upon customer request, a time-based rate schedule . . . The time-based rate schedule shall enable the electric consumer to manage energy use and cost through advanced metering and communications technology . . . Each electric utility . . . shall provide each customer requesting a time-based rate with a time-based meter capable of enabling the utility and customer to offer and receive such a rate, respectively.[36]

To carry out federal demand response policy goals, EPAct '05 directed DOE to "educat[e] consumers on the availability, advantages, and benefits of advance metering and communications technologies, including the funding of demonstration or pilot projects" among related steps "in support of demand response."[37] "[U.S. energy] policy has sought to expand the participation of the demand side in electricity markets and for prices in retail markets to reflect the time-varying costs of generating electricity" with "[t]ime-based rates [] intended to incentivize changes in consumption behavior to reduce peak demand."[38]

The Energy Independence and Security Act of 2007[39] (EISA) established smart grid deployment as U.S. policy to support "modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth" and achieve identified energy policy goals[40] collectively constituting "Smart Grid."[41] "Federal policy [] increasingly recognize[d] the need for improved demand response as part of the effort to improve interconnectivity and efficiency."[42] EISA established new federal standards for "'integrated resource planning,' 'rate design modifications to

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36. Rose, *supra* note 19, at 53 (citing EPAct '05 provision codified as 16 U.S.C. § 2621(d)(14)(A), (C) (2024).

37. *Id.*

38. Strong, *supra* note 4, at 1345.

39. Energy Independence and Security Act of 2007, 42 U.S.C. §§ 17381-17392 (2024).

40. 42 U.S.C. § 17381 (2024) ("(1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid; (2) Dynamic optimization of grid operations and resources, with full cyber-security; (3) Deployment and integration of distributed resources and generation, including renewable resources; (4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources; (5) Deployment of ''smart'' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation; (6) Integration of ''smart'' appliances and consumer devices; (7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning; (8) Provision to consumers of timely information and control options; (9) Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid; and (10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.").

41. *See id.*

42. Rose, *supra* note 19, at 53.

promote energy efficiency investments,' 'consideration of smart grid investments,' and 'smart grid information,' further strengthening the imperative for [advanced metering]."[43] Federal policy support for a 'smart grid' as stated in EISA identified "[d]eployment of 'smart' technologies . . . for metering, communications concerning grid operations and status, and distribution automation."[44]

Congress instructed federal agencies under EISA to effectuate smart grid nationally. DOE was directed to set up a federal Smart Grid Task Force[45] and Congress funded a federal program DOE would administer, in consultation with the FERC and other appropriate agencies, electric utilities, states, and other stakeholders, to support "Smart Grid Technology Research, Development, and Demonstration."[46] EISA further required the FERC to publish a "National Assessment of Demand Response" and "National Action Plan on Demand Response."[47]

C. Economic Stimulus Bills of 2008 and 2009

U.S. energy policy support for smart grid shifted to nationwide deployment by the time the U.S. financial crisis took hold in 2007-2008. The Emergency Economic Stabilization Act of 2008[48] (Stabilization Act) provided accelerated tax depreciation for smart meters from twenty to ten years incentivising advanced metering investments.[49] Federal policy by this stage sought to undertake nationally what scholars have called the "digital electricity transition,"[50] the evolution from

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43. *Id.*

44. *Id.*; *see* Strong, *supra* note 4, at 1345 (noting that metering technology is integrally tied to the structure of retail electricity rates which are ultimately limited by capabilities of power meters).

45. 42 U.S.C. § 17383(b) (2022).

46. 42 U.S.C. § 17384(a) (2022) ("(1) to develop advanced techniques for measuring peak load reductions and energy-efficiency savings from smart metering, demand response, distributed generation, and electricity storage systems; (2) to investigate means for demand response, distributed generation, and storage to provide ancillary services; (3) to conduct research to advance the use of wide-area measurement and control networks, including data mining, visualization, advanced computing, and secure and dependable communications in a highly-distributed environment; (4) to test new reliability technologies, including those concerning communications network capabilities, in a grid control room environment against a representative set of local outage and wide area blackout scenarios; (5) to identify communications network capacity needed to implement advanced technologies; (6) to investigate the feasibility of a transition to time-of-use and real-time electricity pricing; (7) to develop algorithms for use in electric transmission system software applications; (8) to promote the use of underutilized electricity generation capacity in any substitution of electricity for liquid fuels in the transportation system of the United States; and (9) in consultation with the Federal Energy Regulatory Commission, to propose interconnection protocols to enable electric utilities to access electricity stored in vehicles to help meet peak demand loads.").

47. 42 U.S.C. § 8279(a)-(b) (2022).

48. Emergency Economic Stabilization Act of 2008, 12 U.S.C. §§ 5201-5261 (2024).

49. *See* 26 U.S.C. § 168(e)(3)(D) (2023) (codifying Section 305 of the Stabilization Act accelerating tax depreciation period from 20 to 10 years for certain energy property including smart meters and smart grid systems); *see also*, Strong, *supra* note 3, at 1347; Rose, *supra* note 19, at 54.

50. Ryan Thomas Trahan & David J. Hess, *Who Controls Electricity Transitions? Digitization, Decarbonization, and Local Power Organizations*, 80 ENERGY RSCH. & SOC. SCI. 1 (2021).

analog to digital technologies within the power sector which "represent[ed] a fundamentally changed approach to electricity management."[51] The following example illustrates that fundamental change established for utility operations:

> In the analog era, responding to an outage often meant relying on the long experience and deep system knowledge of line engineers as a crucial variable in identifying and responding to the issue. Today's outage management systems use [Geographical Information System] GIS and real-time monitoring data (including from [System Control and Data Acquisition] SCADA and AMI systems), together with automated algorithms, to analyze system data to predict the location and sequences of propagating outages . . . if a single customer (or the system) reports an outage, the system may predictively trace the problem to a meter and initiate communication; if two neighbors report outages, then an algorithmic prediction might be made that the issue is traceable to the transformer; and so on up the grid network, fuse, line, and substation breaker. As that data reporting is fed into the master network control, the operator (or system) may communicate with switches, relays, and reclosers to isolate and/or resolve the problem.[52]

In wake of the Great Recession, the federal government began implementing ARRA in 2009 which included $4.5 billion for grid modernization.[53] ARRA specifically provided over $3.48 billion to fund the SGIG administered by the DOE.[54] "[T]he . . . (ARRA) emphasized innovation, particularly in the clean technology and renewable energy sectors . . . [with] the largest ever one-time investment in upgrading the U.S. electrical infrastructure, mitigat[ing] some of the risk of innovation, and support[ing] utilities in sharing their experiences throughout the electric industry."[55] Through the SGIG program, DOE together with industry invested approximately $9.5 billion in 99 cost-shared projects involving more than 200 participating electric utilities and other organizations to "modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect an unprecedented level of data on smart grid operations and benefits."[56] A summary of benefits and costs of smart grid technologies is provided in Figure 1.

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51. *Id.* at 3.

52. *Id.* at 4.

53. American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115 (2009).

54. *See 2009 American Recovery and Reinvestment Act*, U.S. DEP'T OF ENERGY, https://www.energy.gov/oe/2009-american-recovery-and-reinvestment-act (last visited Jun 22, 2024).

55. Kallman & Frickel, *supra* note 13, at 4.

56. *2009 American Recovery and Reinvestment Act*, *supra* note 54.

Figure 1: Benefits and Costs Resulting from Smart Grid Technologies[57]

Technology	**Grid Benefits**	**Benefits Beyond the Grid**		**Investment and Operation & Maintenance Costs**
		Environmental	**Others**	
Advanced Metering Infrastructure	- Lower billing costs due to a more autonomous system; - Lower costs related to billing complaints once the AMI system provides a more timely and accurate billing procedure - Potential infrastructure cost savings once the AMI may help avoid or delay investments and integrated and responsive voltage regulation; - Lower costs related to the theft of electricity; - Potential reduction on network operation costs once AMI allows obtaining helpful information to define a more proper network operation; - Lower electricity quality monitoring costs.	- Benefits resulting from avoided emissions; - Better operation of the networks, namely due to better management of the load flows and to the development of Demand Response technologies; - Energy efficiency in delivery and use of electricity; - Faster integration of distributed renewable generation; - Ability to create a market of emissions.	- Potential lower energy costs once AMI can provide information on electricity prices and consumption patterns; - Potential income resulting from more active participation in electricity markets, as well as in providing system services; - Electricity cost savings resulting from energy sharing in collective self-consumption activity. **Retailers/aggregators:** - Development of new pricing strategies, which can help in attracting new customers; - Possibility of developing new activities such as aggregating production, consumption, or storage capacity. **Society:** - More efficient electricity usage and higher self-generation integration based on renewable resources contribute to less dependence on energy imports.	Deployment of a suitable AMI implies costs related to investment and related to the operation and maintenance of the system. Investment costs are mainly related to: - Smart devices to be installed at user points; - Communication network; - Installation of the devices and communication systems; - Software for data collection, analysis and storage. - Data collection, analysis, storage, and system management result in operation and maintenance costs. Another cost that can be important is associated with the necessary updating of security systems against cyberattacks, which will have to be maintained over the years.
Advanced, Substation, Feeder Automation	- Lower financial losses related to energy not distributed and compensations for violation of quality of service indicators. As well, ASFA allows a faster and more automated and autonomous network reconfiguration after a fault/outage situation; - Optimization of assets and efficient operation of the network; - More intelligent asset management, including better planning of preventive and corrective maintenance; - Ability to prevent potential failures, detect and predict disturbances, fluctuations and monitor equipment health; - Improved management of distributed energy resources, including microgrid operation and storage management; - Easier accommodation of distributed generation (DG) storage systems in a plug-and-play regime.	Avoided emissions resulting from: - A more efficient operation of the networks; - More easy and coordinated integration of DG, mainly renewable generation; - Lower downtime of renewable-based distributed generators due to network unavailability.	**Consumers:** - A more reliable system and high-quality electricity for the digital society; - A more secure system, reducing the possibility of power blackouts. **Society:** - Higher integration of DG, including self-generation, contributing to less dependence on energy imports.	Implementation of an ASFA includes investment costs in hardware and software resources, namely: - **Sensors**: smart relays, phasor measurement units, voltage and current measurement units, remote fault indicators (that detect current and voltages levels on feeders that are outside usual operating boundaries); - **Actuators**: circuit breakers, capacitor bank switches, automatic voltage regulators, reclosers, and load tap changer controllers; - Fast communication platforms - ;SCADA equipment; - Wide range of software applications, including SCADA software, online and offline applications for monitoring and diagnostics of primary substations and line equipment, communication protocols, and Digital Twin software platforms. The maintenance costs are related to the equipment installed to establish the ASFA. ASFA is expected to operate autonomously but with some staff costs. The necessary updating and maintenance of security systems against cyberattacks is another cost to consider.

57. *See* Vítor Marques et al., *Greater than the Sum: On Regulating Innovation in Electricity Distribution Networks with Externalities*, 79 UTIL. POL'Y 1, 3-4 (2022).

According to DOE, the ARRA investments "helped utilities take [] first steps" mitigating risks associated with adopting new smart grid technologies, share learnings preparing the industry to "meet the needs of a growing digital economy, enable greater levels of clean energy deployment, and strengthen the electric grid to be more resilient to natural disasters and cyberattacks."[58] Researchers have commented that deployment of DOE's SGIG funds produced large-scale deployment of smart grid technologies providing utilities "critical operational experience . . . mov[ing] from the cycle of pilot projects to full-scale deployment in utility operations."[59]

Deployment of smart grid technologies, for example, is credited with enabling restoration of electric service within four days to CenterPoint Energy's nearly one million customers in Houston who lost power when Hurricane Harvey hit Texas in 2017.[60] CenterPoint's decade of investment in smart grid technologies[61] allowed the utility to locate, isolate, and repair outages more efficiently.[62]

III. U.S. SMART GRID INNOVATION: DEPLOYMENT STUDIES

The adoption and diffusion of smart grid technology have been the focus of increasing research on smart grid innovation by U.S. utilities.[63] Studies on smart grid advancements have attempted to illuminate technology adoption decisions in highly regulated sectors such as electric utilities.[64] Organizational choices by utilities to pursue smart grid development are made in context of their operations as legal monopolies under state and federal regulation.[65] Utilities face many of the

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58. *The American Rescue and Reinvestment Act Highlights: Jumpstarting a Modern Grid*, U.S. DEP'T OF ENERGY, (Oct. 2014), https://www.energy.gov/sites/prod/files/2014/12/f19/SGIG-SGDP-Highlights-October2014.pdf [hereinafter *Jumpstarting a Modern Grid*].

59. Kallman & Frickel, *supra* note 13, at 5 (citing *Jumpstarting a Modern Grid*, *supra* note 58, at 2).

60. Zheng et al., *supra* note 3, at 1.

61. CenterPoint Energy was awarded a $200 million SGIG grant for its smart grid project completed in 2015 featuring installation of 2.2 million advanced meters, distribution system automation/upgrade for 187 of 1,516 circuits, distribution management systems, supervisory control and data acquisition (SCADA) communications network, equipment condition monitors, and 187 smart relays. *See Jumpstarting a Modern Grid*, *supra* note 58, at 21.

62. Zheng et al., *supra* note 3, at 1. As of the writing of this article, CenterPoint Energy in Houston reported more than 2 million homes and businesses without power in and around the nation's fourth-largest city after Hurricane Beryl swept into Texas on July 8, 2024. Mark Vancleave & Juan A. Lozano, *Beryl Weakens to Tropical Depression after Slamming into Texas as Category 1 Hurricane*, AP, https://apnews.com/article/hurricane-beryl-texas-7dfd5353671ee30d0c6d11518ea5a370 (last visited Jul 9, 2024) (reporting that the utility was bringing in thousands of additional workers to restore power with top priority for places such as nursing homes and assisted living centers).

63. *See generally* Strong, *supra* note 4; Dedrick et al., *supra* note 3; Zheng et al., *supra* note 3; Kallman & Frickel, *supra* note 13.

64. *See, e.g.*, Strong, *supra* note 4, at 1343 (noting "[s]ectoral innovation systems in heavily regulated industries are strongly influenced by public policy, and regulation can play a definitive role in the diffusion of new technologies by either enabling or hindering adoption").

65. *See* Dedrick et al., *supra* note 3, at 20 (noting that "[i]n the case of electric utilities, the role of regulation is pervasive"); Kallman & Frickel, *supra* note 13, at 2 (identifying subject Washington State utilities as "legal monopolies within their established geographic service areas" which "function at the state level as oligopolies within the electricity districts they serve").

same competitive forces that private firms in unregulated industries do as well as constraints on their business and technology decisions.[66] "[Investor-Owned Utilities] IOUs must deliver profits to shareholders as if they operated in a private market[;] [community-owned utilities], on the other hand, are not allowed to earn profits, but they also are not allowed to charge too much or too little for the power they provide."[67] Furthermore, risks associated with technology innovation in a business that powers the lives of its customers are high. "[R]esearchers have noted that smaller LPOs [Local Power Organizations (municipal utilities, local government departments, electricity cooperatives, community choice aggregators)]" tend to take "a conservative position [] based partly on the traditional organizational focus of utilities on reliability and affordability and partly on an imputation of lack of customer demand for sustainable change."[68] "Of greatest relevance . . . is the recognition of the financial barriers that small electricity cooperatives face . . . many [] have fewer than 10,000 end users."[69] Uncertainty with cost recovery for deploying smart meters allowed by state public utilities commissions delay technology adoption decisions of IOUs.[70] "Given the relative lack of competition among utilities, heavy state and federal regulation, and high risks of technological change, utilities have few obvious incentives for developing and implementing new, and largely untested, smart metering technology."[71] Nonetheless, utilities small and large, cooperatives (co-ops), municipal systems, and IOUs have innovated, deploying smart grid infrastructure nationwide. Industry innovation research has sought to explain how utilities achieve smart grid innovation. We now turn to consider what the studies indicate.

A. Washington State Study

Researchers applying an analytic model of "institutional logics"[72] found that ARRA funding was instrumental in helping Washington State's otherwise risk-averse utilities to pursue and complete deployment of smart grid. With electric utilities, "[i]nstitutional norms include reliance on non-utility organizations (e.g. vendors, academic researchers, national labs) to drive innovation, knowledge sharing and cooperation among utilities who do not compete directly with one another, and reliance on public funding to reduce the cost and risk of investment in new

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66. Kallman & Frickel, *supra* note 13, at 2.

67. *Id*.

68. *See* Trahan & Hess, *supra* note 50, at 2.

69. *See id.* at 2, 7 (noting that with respect to broader national energy transition "[d]igitialization presents a fundamental yet separable set of challenges for the [Local Power Organization (municipal utility, local government department, electricity cooperative, or community choice aggregator)] and the community it serves").

70. *See* Strong, *supra* note 4, at 1347.

71. Kallman & Frickel, *supra* note 13, at 2.

72. *Id.* at 4 (defining the term to refer to "shared practices, beliefs and values that govern how a particular social world works.") (quoting PATRICIA THORNTON & WILLIAM OCASIO, INSTITUTIONAL LOGICS 101 (R. Greenwood, C. Oliver, R. Suddaby & K. Sahlin-Andersson eds., SAGE 2008); *see* Zheng et al., *supra* note 3, at 3 (explaining the framework "looks at how cultural schema shape organizational behavior" with individual organizations having their own internal cultures which operates and interacts with larger external cultures).

innovations."[73] "[I]n Washington's electric power field, innovation emerge[d] through collaborative networked partnerships among like organizations, because regulation *prohibits* competition. [emphasis in original]"[74] The study found that collaboration among public, private, and cooperatively owned utilities, institutional processes and organizational changes "nested" across different governance scales (local, state, and federal) "dr[iving] the deployment and adoption of smart meters."[75]

Personnel from the state's IOUs, co-ops, Public Utility Districts (PUDs), and municipal utilities constituted the bulk of the fifty-two respondents interviewed by the researchers.[76] The remainder of those interviewed represented Washington utility trade groups, technology firms, university and national labs, and consumer advocacy groups.[77] The study found that "[a]lthough utilities are the dominant actors in the Washington energy field, they do not act independently . . . their behavior is conditioned through relationships with other organizational actors at other levels, all of whom . . . make decisions guided by institutional logics . . . ."[78]

B. SmartSacramento Case Study

In October 2009, DOE awarded SMUD an SGIG grant totalling $127.5 million to execute its project titled "SmartSacramento." Combined with SMUD's own capital and other grant funding, the project budget totalled nearly $360 million[79] to "[i]nstall a comprehensive regional smart grid system from transmission to the customer that include[d] 600,000 smart meters, dynamic pricing, 100 electric vehicle charging stations and 50,000 demand response controls including programmable smart thermostats, [and] home energy management systems."[80] The scope of SMUD's smart grid work covered the Electric Distribution Systems, AMI, and Customer Systems categories[81] targeted by the SGIG.

1. Innovation Achievements

During the subsequent three-year grant implementation period, SMUD (with approximately 2,100 employees at the time) organized internal teams to complete over fifty subprojects across eight main topic areas (Advanced Metering Infrastructure, Distribution Automation, Consumer Behaviour Study informing electric

73. Zheng et al., *supra* note 3, at 3.

74. Kallman & Frickel, *supra* note 13, at 8.

75. *Id.* at 1-2.

76. *Id.* at app. A.

77. *Id.* at 2-3.

78. Kallman & Frickel, *supra* note 13, at 4.

79. *SmartSacramento: 2009-2014*, SMUD 3 (Aug. 2013), https://www.smud.org/-/media/Documents/Corporate/About-Us/Energy-Research-and-Development/SmartSacramento-Fact-Sheet.ashx (Report pursuant to DOE Award No. OE0000214) [hereinafter SmartSacramento].

80. *Recovery Act Selections For Smart Grid Investment Grant Awards - By Category*, U.S. DEP'T OF ENERGY 7, https://www.energy.gov/oe/articles/recovery-act-selections-smart-grid-investment-grant-awards-category-updated-november (last visited Jun 22, 2024).

81. The four project types under the SGIG were Electric Transmission Systems, Electric Distribution Systems, Advanced Metering Infrastructure, and Customer Systems. *See Jumpstarting A Modern Grid*, *supra* note 58, at 7.

pricing, Demand Response, Customer Applications, Technology Infrastructure, Cyber Security, and Research and Development). Collectively, this smart grid implementation digitized SMUD's power metering infrastructure, facilitating two-way electric meter data flow between the utility and its customers and enabling real-time operations visibility into its distribution operations for the first time in the utility's existence.

The largest portion of the SmartSacramento budget ($137.6 million) went to replacing 620,000 existing analog power meters with new smart meters, a foundational step enabling wireless communication for automated meter reading, improved bill accuracy, remote service connect/disconnect capability, enhanced outage management, and improved power theft detection. The new AMI system helped SMUD transition from manual meter operations mainly through automated meter reading and automated service switching saving the utility approximately $31.8 million in meter operation costs from project initiation through March 31, 2014.[82] Software platforms for meter data management and analysis were installed to organize, analyze, and make AMI data accessible to SMUD's enterprise systems that served to improve load forecasting and capital investment planning.[83]

SmartSacramento enabled SMUD's introduction to customers of time-based rate programs. With its advanced metering infrastructure[84] installed, SMUD created rate programs "based on TOU, critical peak pricing (CPP) [see Figure 2], and TOU combined with CPP."[85] Through early program offerings, selected SMUD customers could opt into the new rate programs or choose to keep their existing rates. Additional customers were placed on the new rates but were able to opt out. SMUD evaluated "the relative merits of these programs in terms of load impacts, customer acceptance, and cost effectiveness . . . aim[ing] [] to provide customers with greater control over their electricity bills and reduce peak electrical loads."[86] In 2018, SMUD defaulted its residential customers to its "Time of Day (TOD)" rate resulting in 98% of that customer group being included, enabling the utility to achieve an 8% (approx. 130 MW) peak customer load shift beginning in 2019.

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82. *Id.* at 58. Additionally, SMUD avoided an estimated 1.2 million vehicle miles previously required to manually read meters from project initiation through March 31, 2013. *Id.* at 59. Based on SMUD's prior use of gasoline cars and light-duty trucks to read meters, and assuming 23.4 miles per gallon per vehicle, SMUD avoided consuming 51,000 gallons of gasoline. *Id.*

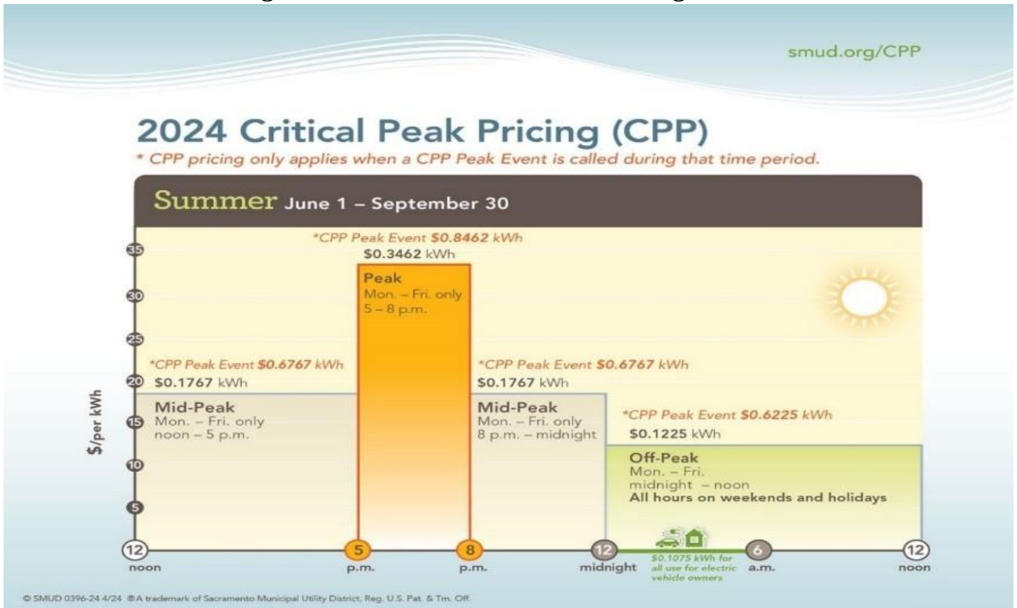
83. *See Jumpstarting A Modern Grid*, *supra* note 58, at 59.

84. SMUD's AMI utilized Landis+Gyr meters operating on Silver Spring Networks' two-way mesh network technology. *See SmartSacramento*, *supra* note 79, at 5.

85. *Jumpstarting A Modern Grid*, *supra* note 58, at 58.

86. *Id.*

Figure 2: SMUD Critical Peak Pricing Illustration[87]



Through SmartSacramento, SMUD modernized its distribution systems by deploying automated sectionalizing and restoration (ASR)[88] "equipment, reclosers, capacitor banks, and remote fault indicators integrated with SMUD's energy management system on 171 distribution circuits."[89] This equipment automatically

87. *Critical Peak Pricing*, SMUD, https://www.smud.org/Rate-Information/Residential-rates/Critical-Peak-Pricing (last visited Aug 1, 2024) ("CPP is designed to allow SMUD's customers to help reduce demand on the electric grid during times when energy demand is at its highest or there are emergency conditions with the power system." "Customers on CPP receive a discount of $0.020 on Time-of-Day off-peak and mid-peak prices from June 1 to September 30. The peak price is the same as the Time-of-Day peak price. During CPP Peak Events, an additional charge is added to the current time period's price. CPP Peak Events can be called any time of the day during the summer months (June 1 through September 30), including weekends and holidays, and only one event can be called per day. Events last 1 to 4 hours with a maximum of 50 hours total per summer. Events may span more than one time-of-day period. For example, an event may start during the mid-peak time period and end during the peak time period." SMUD notifies "participating customers a day in advance before a CPP event is called, though the utility may call the event with shorter notice during emergency situations." The following "prices and time periods are only for summer months." "Customers on CPP will have the same Time-of-Day Rate time periods and prices during non-summer months (October - May). All prices are measured in kilowatt hour (kWh): Off-Peak, Midnight – noon, Monday through Friday, all day on weekends and holidays ($0.1225 per kWh). This is a discount on the standard Time-of-Day off-peak price of $0.1425 per kWh; Mid-Peak, Noon – 5 p.m. and 8 p.m. – midnight, Monday through Friday ($0.1767 per kWh). This is a discount on the standard Time-of-Day mid-peak price of $0.1967 per kWh; Peak, 5 p.m. – 8 p.m., Monday through Friday ($0.3462 per kWh); EV discount, Midnight – 6 a.m., every day, all year long, including weekends and holidays ($0.1075 per kWh); CPP Peak Events ($0.5000 kWh + the price of the applicable time period when the event occurs. (Example: Peak price of $0.3462 + CPP Peak Event price of $0.5000 for a total of $0.8462 kWh)").

88. This equipment is commonly known in the power sector as fault location isolation and service restoration (FLISR).

89. *Jumpstarting A Modern Grid*, *supra* note 58, at 58.

responds to power disruptions by isolating faulted sections of circuits and rerouting power to customers. Among evaluations SMUD conducted with its SGIG funding, the utility determined that if the ASR and line automation upgrades deployed through SmartSacramento had been implemented in 2007–2012, the measures would have reduced the impact of outage events by 37% in terms of customer-minutes interrupted (a reliability metric of the total number of customers and the minutes they were without power known as SAIDI[90]), and the proportion of customers impacted (known as SAIFI[91]) by 41% based on historical reliability performance of SMUD's distribution grid and the observed performance of the ASR system.[92] Evaluating outage data over eighteen months from April 2013 through September 2014, a follow-up assessment showed that fully installed and operational[93] ASR and line automation upgrades would have achieved comparable reductions of 32% and 36% in SAIDI and SAIFI, respectively.[94]

Other improvements generated from the SGIG-funded SmartSacramento project included (i) system efficiency gains achieved through integrated voltage control from capacitor controllers and increase in distribution capacity through reduced energy losses on SMUD's distribution system, (ii) installation of nearly 10,000 residential and small commercial home area network (HAN) devices to provide customers with options to more conveniently manage their energy use, (iii) implementation of advanced energy management control systems with automatic demand response capability at customer facilities, (iv) deployment of programmable communicating thermostats and load-control switches that support load reduction or load shifting during periods of peak demand, and (v) installation of electric vehicle charging stations and advanced metering equipment at twenty parking spaces on college campuses and sixty residences across SMUD's service territory.[95]

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90. SAIDI is the "System Average Interruption Duration Index." SAIDI is calculated by summing the customer minutes of interruption (CMI) for sustained outages over a given period of time and dividing that total sum of CMI by the total number of customers served. CMI is determined for each sustained outage by multiplying the number of customers interrupted by the minutes they were interrupted for each outage/outage step. A sustained outage at SMUD is any outage greater than one minute.

91. SAIFI is the "System Average Interruption Frequency Index." SAIFI is calculated by summing the number of customers impacted by sustained outages over a given period of time and dividing that total sum of customers impacted by the total number of customers served. A sustained outage at SMUD is any outage greater than one minute.

92. *Theoretical Reliability Improvement: Line Automation & Automatic Sectionalizing and Restoration (ASR) Projects, Selected Feeder Outages from 2007 – 2012*, SMUD 4-5 (Dec. 27, 2023) (Report pursuant to DOE Award No. OE0000214).

93. Issues with communication systems caused line automation inoperability in 16 out of the 46 outages evaluated. Of the 30 outages where line automation was operable, the report noted "devices performed their automatic protective function and isolated the faulted section when applicable" resulting in actual reductions of 28% and 19% of SAIDI and SAIFI, respectively.

94. *2013-2014 Reliability Improvement Summary: Line Automation & Automatic Sectionalizing and Restoration (ASR) Projects*, SMUD (Dec. 23, 2014) (Report pursuant to DOE Award No. OE0000214, 9, Table 12).

95. *See generally SmartSacramento*, *supra* note 79; SMUD's service territory covers the geographic region encompassing California's capital city of Sacramento across approximately 900 square miles that includes Sacramento County and portions of Placer and Yuba Counties.

In short, SmartSacramento marked SMUD's transition from an analogue-metered electric utility to a modern smart grid-based system. The municipal utility which began service in 1946 was able in 2012 to detect lights were out in its service territory without someone reporting the outage. Before SmartSacramento's implementation, real-time visibility into functioning of SMUD's distribution system (i.e., SMUD's grid operators could tell instantly when power was out at a customer's location) and day-to-day distribution operations did not co-exist. SmartSacramento changed that by implementing a utility-wide innovation effort that transformed SMUD's power distribution system.

2. The Paradoxical Matter of Utility Innovation

SmartSacramento also marked SMUD's nearly seventy years of operations before the utility modernized its distribution system. Slow and incremental technological change is customary in the power sector. Utilities are risk averse. This reality juxtaposed with the fact SmartSacramento was executed on schedule as promised by SMUD raised the question addressed in the present research: How does a risk-averse utility innovate? Perhaps those who joined the teams implementing this grid modernization represented technical experts and staff more inclined to take risks conducive to innovation. Some of the interview data gathered for this study corroborated this theory, supporting the narrative that their achievement established the foundational grid infrastructure and customer programs SMUD today is building upon to become the first large utility in the U.S. to achieve a 100% carbon-free power generation portfolio by 2030.[96] However, a less obvious but more instructive issue is presented in the question itself: risk-aversion *and* innovat(ion) are contradictory yet interdependent concepts. SMUD's achievement of SmartSacramento represents paradox, a contradiction that demonstrated itself to be interdependent with the risk-averse utility culture from which the smart grid innovation project emerged. The research presented here sought to explain this and other related paradoxes characterizing the electric utility industry.

SMUD's goal to become carbon-free by 2030 is itself paradoxical. Utility-scale long-duration battery storage beyond four hours needed to achieve such goal is not currently feasible (reflecting underlying paradox of reality and fantasy). SMUD's target also assumes achievement of innovation magnitudes greater than it has ever achieved given its risk averse company culture (risk aversion – risk-taking). The utility aims to reach "Zero by 2030" keeping customer rate increases in coming years to less than inflation while managing mounting operational cost pressures (financial security – financial risk). Such interrelated, conflicting demands and expectations generate tension. For SMUD, there is considerable tension between its current reality and the zero-carbon power portfolio it strives to realize.

Today, SMUD is among utilities nationwide grappling with decarbonization, shifting from reliance on fossil fuel-powered electricity production to low- and even non-carbon-emitting generation. SMUD is one of over 2000 public power

96. *See generally 2030 Zero Carbon Plan*, SMUD (Apr. 2021), https://www.smud.org/-/media/Documents/Corporate/Environmental-Leadership/ZeroCarbon/2030-Zero-Carbon-Plan-Technical-Report.ashx.

systems[97] serving a quarter of the U.S. population including major metropolitan areas such as Los Angeles, New York, Seattle, Orlando, Austin, and Phoenix. In SMUD's case, its annual carbon emissions from power generation totals approximately 2 million metric tons.

The utility's strategic plan to reach Zero by 2030 calls for its natural gas plants, which SMUD relies upon to keep the lights on for 1.5 million residents to be re-designed to run on low- or non-carbon emitting fuel sources such as hydrogen. Utility-scale batteries currently still in early development would need to provide power when intermittent energy such as wind and solar are unavailable. Carbon emitted from natural gas-fired power generation would need to be piped into the ground and stored with carbon capture and sequestration to be demonstrated at utility scale. SMUD's plan to reach Zero by 2030 thus relies on technologies dependent on innovation to create solutions and scale them for wide use among the 3,000 electric utilities both public and private operating in the U.S. power sector.

In short, achieving Zero by 2030 requires that SMUD innovate – creating new solutions to operate carbon-free – at an unprecedented scale and speed. Yet, major tensions exist to accomplish such innovation: What resources—i.e., financial and staffing—are available to undertake the R&D needed? Why is SMUD busy with tomorrow's technology when it has a grid to manage today? How does any particular SMUD project make sense for an employee's career? The SMUD teams that executed SmartSacramento more than a decade ago faced many, if not all, of these same dilemmas. This study attempted to unpack their experience to provide strategic considerations for utility managers and policymakers involved in electric utility innovation efforts such as sector decarbonization.

3. Analytic Framework

This section summarizes the analytic framework applied in the research.

a. Ambidextrous Leadership

Within organizational psychology, the concept of "ambidextrous leadership" refers to the ability to both *explore*[98] creative ideas necessary for innovation and to *exploit*[99] innovations to materially benefit the organization.[100] This theoretical model posits that organizations that innovate with sustained success do so balancing demands for *exploration* of new alternatives, investing for future gains, and

97. *See* Stephanie Lenhart et al., *Municipal Utilities and Electric Cooperatives in the United States: Interpretive Frames, Strategic Actions, and Place-Specific Transitions*, 36 ENV'T INNOVATION & SOCIETAL TRANSITIONS 17, 18 (2020) (noting that along with municipal systems, there are over 900 cooperative utility systems serving towns and localities across the U.S. "founded on shared principles of democratic accountability, local governance, and local rate regulation").

98. Kathrin Rosing et al., *Explaining the Heterogeneity of the Leadership-Innovation Relationship: Ambidextrous Leadership,* 22 LEADERSHIP Q. 956, 957 (2011) ("Explore" in the literature refers to organizational behavior associated with "increasing variance, experimentation, searching for alternatives, and risk taking.").

99. *See id* ("Exploit" refers to organizational behavior that features reducing variance, adherence to rules, alignment, and risk avoidance).

100. *See, e.g.*, *id*; Shuanglong Wang et al., *A Double-Edged Sword: The Effects of Ambidextrous Leadership on Follower Innovative Behaviors,* 38 ASIA PAC. J. MGMT. 1305 (2020).

exploitation of current capabilities seeking to maximize present profits.[101] *Exploration* features experimentation and ideation for 'radical' innovation typified by research and development (R&D) work; *exploitation* involves implementing ideas through processes and routines required for planning, performance of day-to-day operations, and for incremental innovation.[102]

Exploration involves learning that is "generative" (knowledge creation departing from a firm's existing knowledge base); "divergent" (generating multiple solutions from various perspectives of problem domain, seeing connections to provide meaningful 'gestalt' whole of domain); and "individual" (individual-based, intuitive).[103] In contrast, exploitation involves learning that is "adaptive" (incremental knowledge building based on firm's existing knowledge base), "convergent" (efficient, practical problem solving), and "organizational" (collective).[104] Researchers have observed that "[t]ension between divergent and convergent learning exists because creative energy without effective organizational control could lead to a fragmented organization without any synergy that is needed when exploiting opportunities."[105]

Studies have found numerous factors influencing organizational ambidexterity. "[P]sychological safety has a significantly positive impact on innovation performance."[106] CEO "transformational leadership" "can drive close to half of the organizational innovation outcomes" in a company.[107] Management able to "reconcile the contrasting and often conflicting definitions of exploration and exploitation" facilitates innovative work behavior of employees through knowledge-sharing.[108] Absent such knowledge-sharing, research has found ambidextrous leadership *negatively* impacts innovative work behavior.[109] "Distributed leadership" where multiple leaders throughout a firm "manage [] existing tensions that

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101. Andrea Fosfuri & Thomas Rønde, *Leveraging Resistance to Change and the Skunk Works Model of Innovation*, 72 J. ECON. BEHAV. & ORG. 274, 276 (2009).

102. *See, e.g.*, Syed Arslan Haider et al., *How Does Ambidextrous Leadership Promote Innovation in Project-Based Construction Companies? Through Mediating Role of Knowledge-Sharing and Moderating Role of Innovativeness*, 26 EUR. J. INNOVATION MGMT. 99, 103 (2021) (explaining that gaining new external or tacit knowledge in the form of research and development is linked to irregular innovation and change, which is called 'exploration,' while developing current and overt knowledge is associated with incremental innovation known as 'exploitation').

103. Catherine L. Wang & Mohammed Rafiq, *Organizational Diversity and Shared Vision*, 12 EUR. J. INNOVATION MGMT. 86, 88-89 (2009).

104. *Id.* at 95-96.

105. *Id.* at 95.

106. Fuqiang Zhao et al., *Impact of Ambidextrous Human Resource Practices on Employee Innovation Performance: The Roles of Inclusive Leadership and Psychological Safety*, 26 EUR. J. INNOVATION MGMT. 1444, 1457 (2023).

107. Abdelrahman Zuraik & Louise Kelly, *The Role of CEO Transformational Leadership and Innovation Climate in Exploration and Exploitation*, 22 EUR. J. INNOVATION MGMT. 84, 96 (2019).

108. Haider et al., *supra* note 102, at 112.

109. *Id.* at 111 (finding that "leadership support without knowledge-sharing cannot cope and attain the desired results at the workplace [citation], as knowledge is an integral part of spreading awareness throughout the organization at almost every level of department through affective participation of a project leader in order to bring innovativeness to projects").

are based on different managerial [,][] knowledge capabilities and leadership functions" has been found to "boost[] ambidextrous innovation."[110]

b. Skunkworks

Separate and relatedly, "skunkworks" refers to innovation by teams operating in secret and/or separately outside typical organizational rules or norms.[111] The concept is named after the "Skunk Works" unit of Lockheed Martin, which functioned autonomously in complete secrecy within the company after WWII, developing cutting-edge military technology including "Stealth" fighter jets which evade radar.[112] Technology firms including Apple, IBM, Intel, and Siemens have implemented skunkworks to develop breakthrough technologies. Scholars have observed skunkworks "gives researchers the necessary autonomy, independence and freedom to escape the established lines of thought and to produce novel ideas" and "help to overcome the resistance that radical innovations meet inside the organization."[113]

F-117A Nighthawk Stealth Fighter aircraft flies over Nellis Air Force Base, Nevada, during U.S. Air Force joint service experimentation process dubbed Millennium Challenge 2002.[114]

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110. Sarra Berraies et al., *Distributed Leadership and Exploratory and Exploitative Innovations: Mediating Roles of Tacit and Explicit Knowledge Sharing and Organizational Trust*, 25 J. KNOWLEDGE MGMT. 1287, 1305, 1308 (2021); *accord* Ruiqian Jia et al., *Ambidextrous Leadership and Organizational Innovation: The Importance of Knowledge Search and Strategic Flexibility*, 26 J. KNOWLEDGE MGMT.781 (2022).

111. *See* Shane Greenstein, *What Does a Skunk Works Do?*, 36 IEEE MICRO 70 (2016).

112. *See* BEN R. RICH & LEO JANOS, SKUNK WORKS: A PERSONAL MEMOIR OF MY YEARS AT LOCKHEED (1994).

113. *See* Fosfuri & Rønde, *supra* note 101, at 281.

114. *F-117A Nighthawk*, WIKIMEDIA COMMONS, https://en.wikipedia.org/wiki/File:F-117_Nighthawk_Front.jpg (last updated Aug. 11, 2021).

While research on actual skunkworks are rare, Donada et al. gained access to European automaker Peugeot's skunkworks group to study their development of a secret, low-emission vehicle propulsion system known as *Hybrid Air*.[115] Directors from different R&D departments were instructed by management to "make expertise available [for the project], even if it disrupted their department; this project was priority, even though they could not know what it was."[116] The Hybrid Air team operated without formal rules or organizational structures to foster speed and agility. An engineer in the study noted that, "[i]t was a phenomenal cohesion . . . [w]e trusted one another and developed a team spirit."[117] The team drew more than 100 people throughout the main organization and from external partners that "came together in a cross-functional platform, representing competencies in vehicle integration, powertrain development, marketing, and after-sales support."[118] Within two years, the Hybrid Air team delivered a Citroen model fully equipped with the newly invented Hybrid Air technology.

While the project demonstrated successful *exploration*, the lesson of Hybrid Air was failed *exploitation*. Electric mobility became the market choice for low emission transportation as Hybrid Air was being developed. Peugeot shut down its skunkworks unit shortly after Hybrid Air's unveiling and its participants were returned to positions within the main organization. "[T]he Hybrid Air team not its achievements have been reintegrated into the main organization because of 'not invented here' syndrome," the researchers noted.[119] "Hybrid Air members became 'skunks' to others, who avoided them."[120] Donada et al. thus observed a "double tension between the employees of the main organization who rejected Hybrid Air team members and the latter who no longer accepted the processes of the central organization."[121] "Skunkworks projects leave traces that can be hard to cope with threatening the feasibility of exploitation at the wider organizational level," an equipment manufacturer interviewed told the researchers.[122]

c. Paradox Theory

Paradox theory posits that actors need to accept, engage, and navigate tensions rather than attempt to resolve them. This organizational management theory assumes that competing demands and tensions cannot be resolved because they are contradictory, interdependent, and persistent over time. "[U]nderstanding and

115. *See* Carole Donada et al., *Managing Skunkworks to Achieve Ambidexterity: The Robinson Crusoe Effect*, 39 EUR. MGMT. J. 214 (2021).

116. *Id.* at 218.

117. *Id.* at 219.

118. *Id.* at 218.

119. Donada et al., *supra* note 115, at 219-20.

120. *Id.* at 220.

121. *Id.*

122. *Id.*

managing these tensions is central to successful innovation."[123] The nature of such tensions and their management can produce outcomes akin to a double-edged sword, sparking innovation and spurring anxiety from increased stress. Early paradox theorists treated the nature of competing demands as a matter of trade-offs and dilemmas involving choices among options.

Smith & Lewis (2022) defined paradox as "interdependent, persistent contradictions that lurk within our presenting dilemmas" that often leads to "reductionist thinking" reflecting a mindset that limits the ability to find more "holistic solutions" to difficult problems.[124] A more productive and sustainable way for people and organizations to address issues holistically the authors argue is to apply a "paradox mindset" – the extent to which one is accepting of and energized by tensions.[125]

4. Research Questions and Methodology

This study sought to answer the following questions:

> (1) What does the achievement of innovation demonstrated by the SmartSacramento teams reveal about the effect of navigating paradoxes at SMUD?
> (2) What are the practical implications for decision-making at SMUD and the U.S. power sector as utilities innovate towards a low carbon future?

In-person interviews of thirteen current SMUD employees randomly selected from a list of former SmartSacramento project team members[126] were conducted for the study. Data from twelve interviews were included in the results.[127] Each of the interviews lasted 30-35 minutes. While they were all involved in SmartSacramento, the employees interviewed varied in their roles, responsibilities, level of seniority within the organization, and departments at SMUD from which they participated on the project.

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123. Ronald Bledow et al., *A Dialectic Perspective on Innovation: Conflicting Demands, Multiple Pathways, and Ambidexterity*, 2 INDUS. & ORG. PSYCHOL. 305, 306 (2009).

124. WENDY K. SMITH & MARIANNE W. LEWIS, BOTH/AND THINKING: EMBRACING CREATIVE TENSIONS TO SOLVE YOUR TOUGHEST PROBLEMS 5, 26 (2022).

125. *See id.* at 92-95 (explaining that "[t]hose with a high paradox mindset tend to accept tensions as natural, valuable, and energizing" such that when confronted with dilemmas, they ask "how can I accommodate A and B at the same time"); *see also* Craig L. Pearce et al., *Toward a Theory of Meta-Paradoxical Leadership*, 155 ORG. BEHAV. & HUMAN DECISION PROCESSES 31 (2019); Ella Miron-Spektor et al., *Microfoundations of Organizational Paradox: The Problem Is How We Think about the Problem*, 61 ACAD. MGMT. J. 26, 29-30 (2018) (finding that when employees experience tensions those with a paradox mindset are more likely to approach tensions as opportunities, gaining energy as they search more broadly for integrative solutions, and thereby enabling superior in-role job performance and innovation).

126. Staff members who were not members of executive management during SmartSacramento's implementation were selected since the study sought to assess decision-making at the project team level distinct from executive management decision-making for the project.

127. Data from one former team member was excluded from the research because the participant lacked sufficient knowledge of team decision-making.

The interviews were completed between June and October 2022 via MS Teams. At the start of each interview, participants were informed that their responses would remain confidential with no attribution by name, job title, or role to anything they shared to elicit candid responses. The interviews were recorded with permission of participants and transcribed using the voice-to-text software, *Otter.ai*. The video camera of the interviewer was turned off during interviews to avoid influencing responses given by participants who might otherwise react to the interviewer's facial expressions.

During the semi-structured interviews, all participants provided comments, reflections, and examples of their own and their team's operations, decisions impacting their portion of the project, and personal impressions from their experience on the project. Participants were asked to recall the reporting structure of their teams, their respective roles and responsibilities, how their teams made decisions, whether conflicts arose and if so how those were dealt with, what they attributed to their team's performance, and their impressions of SMUD management's role in their teams' ability to execute their work. In December 2022, participants received via email a final inquiry, asking each to complete the following sentence: "SMUD is in the business of _________." Responses were received from seven participants.

Additionally, managers at two other municipal utilities, one from the Pacific Northwest (Pacific Manager) and another located in the Southeastern U.S. (Southeast Manager) were interviewed to illicit feedback on how innovation has operated to implement innovations at their respective systems. Each of the managers were interviewed separately for sixty minutes via MS Teams to obtain background on innovations at their respective utilities and answers to questions regarding how decision-making operated at the team level of their organizations to realize their projects. Their confidentiality was assured as well to ensure candid responses. Interviews were recorded with permission of both managers with video camera of the interviewer turned off and transcripts generated by *Otter.ai*. Information from those interviews provided a reference point to compare and gauge responses of the SMUD participants.

Interview data was coded using categories based on organizational innovation literature. Coding was based on timeline (pre-, during-, post-SmartSacramento), ambidextrous organizations (exploitative, exploratory, innovative result(s)), skunkworks (management support, autonomy, individual empowerment), and paradox (conflicts/tensions/dilemmas, navigation, outcomes) (see Figure 3).

Secondary sources of information obtained internally from SMUD as well as public sources were reviewed for this research to triangulate the data gathered including SMUD's SGIG grant application submitted to the U.S. DOE, reliability evaluation reports generated pursuant to the grant, SMUD's post-project summary report also submitted to DOE, DOE post-SGIG summary reports, and SMUD's "Zero Carbon by 2030 Plan."

Figure 3: Interview Data Coding

Coding Chart [Excerpts]

Ambidex	Skunk	Paradox	Description	Examples	outcome(s)
Explore	empwrmt.	employee vs. management	Being given authority as senior manager to make decisions generated sense of empowerment [during]	What worked [with SGIG] was allowing our small team full reins, full authority to figure out solutions. (SMUD #2, 8/22/22)	software app syncing device communicatio ns
Explore	Autonomy	freedom v. regulation	Reflecting on freedom in organization that is usually hierachical, risk averse [during]	It's abnormal at SMUD...This was a lot more innovative, a lot more trusting, a lot more authority to make decisions. (SMUD #12, 10/27/22)	work fed infrastructure upgrade work
Exploit	Autonomy [exercised to create rules]	rules vs. autonomy; combine rules into autonomy	Project charter development [during project]	[C]ame up with idea of...project charter so that you know exactly what you need to do or what the team's goal is. (SMUD #5, 10/10/22)	SGIG teams management
Explore & Exploit	Autonomy; Mgmt Support	rules vs. autonomy; combining rules into autonomy	Resourcing support; running decisions through steering committee [during project]	I felt I had pretty much the run of it. You know, whatever it took to get it done. There was something I couldn't get done within my control. It was bringining it up to the steering committee, and they would be there to support and get me what I needed. (SMUD #10, 10/13/22)	work contributing to distrib. automation
Explore & Exploit	Mgmt support	individual v. group decisions; mixing explore/expl oit methods	Decision-making practice at SGIG team level [during project]	At the individial team levels, decisions were made using a collaborative effort with input from various SGIG subject matter experts, and also check-ins with oher parts of the organization here at SMUD. (SMUD #9, 10/12/22)	customer programs development
Explore	Autonomy	risk taking vs. risk maanageme nt	Commenting on scope of decision making within teams [during project]	I was given a huge amont of freedom to develop the tools and documents that we needed to be successful. I was given a lot of freedom within the sandbox that were were operating...confident that the risks could be constrained within that sandbox of decisions that we madee. (SMUD #4, 10/07/22)	work fed connecting customer apps
Exploit		empwrmt vs. mistakes/cos ts	Identifying tension between empowering team members and dealing with concerns with associated mistakes/costs. [post project]	A tension point that I've observed absolutely is empowering people to make decisions give people more creativity and freedom, which then can enable innovation. I think what I have observed is where there is concern about...going out to left field or things like that, or that there's budgetary constraints that people don't think about, then that's where SMUD tends to micromanage. (SMUD #3, 8/23/22)	Commentary re empowermen t of decision making at SMUD

5. Findings

Decision-making tensions permeate the daily work lives of utility personnel. They deal with tensions at the organization level. "We can talk about decision-making . . . [i]t's really just in futility," one SMUD interviewee remarked.[128] "Decision by committee can be death by a thousand swords," another commented.[129] Pacific Manager characterized a decision made by an executive that had lasting impact on the utility's innovation project as follows: "The grid has worked this way . . . for the last fifty years, dammit if we're gonna put anything new in it."[130] Utility employees also manage team tensions. ("[I]f I got involved . . . it would have just been . . . extra . . . entropy within that [team decision-making] process.")[131] They struggle with personal choices that reflect tensions. ("I remember people even asking me specifically about [SmartSacramento] . . . asked if I was sure I wanted to [work on the project] because . . . it was a career risk";[132] "that job comes up only . . . once in your career . . . I knew that I needed to interview . . . I got it and I left the [SmartSacramento] project."[133])

In short, the SmartSacramento teams were emersed in competing demands, tensions, dilemmas, and conflicts to execute their work contributing to the overall innovation effort. Underlying those discomforting, anxiety-provoking situations interviewees experienced paradox: risk aversion – innovation requiring risk taking; resource need – resource creation; micro-management – autonomy. Data from interviews revealed that the SmartSacramento teams worked to advance the project with, rather than against, these tensions that exist at SMUD.

a. Teams Created Resources Within A Resource-Constrained Organization

To the question of "what challenges did the SmartSacramento teams face?" the predominate response from interviewees centered on resources – staffing, time, and tools to complete project deliverables. Few had the fortune as one interviewee shared of being "empowered with staff resources"[134] to execute additional work associated with SmartSacramento. Within utilities, innovation projects are in addition to, rarely in lieu of an employee's existing duties. "Everything still had to get done,"[135] explained one former project team member. "All that [existing work] couldn't get dropped. We just had to manage that."[136] Organizational researchers

128. Interview with former SmartSacramento team member No. 1, SMUD (Aug. 22, 2022).

129. Interview with former SmartSacramento team member No. 3, SMUD (Aug. 23, 2022).

130. Interview with Pacific Manager, SMUD (Oct. 24, 2022).

131. Interview with Southeast Manager, SMUD (Nov. 1, 2022).

132. Interview with former SmartSacramento team member No. 11, SMUD (Oct. 14, 2022).

133. Interview with former SmartSacramento team member No. 5, SMUD (Oct. 10, 2022).

134. Interview with former SmartSacramento team member No. 2, SMUD (Aug. 22, 2022).

135. Interview with former SmartSacramento team member No. 10, SMUD (Oct. 13, 2022).

136. *Id.*; *see also*, Gail Reitenbach, *Vermont Electric Cooperative Takes Wise Approach to Smart Grid Projects*, 155 POWER 44, 46 (2011) (explaining Vermont Electric Cooperative's experience developing solution enabling energy usage display for customers to view their usage details by "[w]orking part time, in addition to their regular responsibilities, VEC's IT staff wrote the software" given lack of affordable vendor option).

have noted that "[t]ensions intensify under conditions of resource scarcity."[137] SMUD committed to a thirty-six-month project completion timeline. Under that deadline, the teams found themselves tackling one resource dilemma after another.

During the implementation, the SGIG project manager hit a roadblock with a senior manager. The project team had identified a staffing need critical to the project's progress. The team informed the project manager of the senior manager's refusal to help. One of the SMUD interviewees recalled the incident as follows:

> [The Project Manager] met with the director . . . at the time. It was a senior director . . . and said 'if we're not getting the support, we're going to hire our own.' He said 'go ahead' . . . We did. We actually hired [] internal[ly] [from] SMUD. So I posted some limited term positions, and we hired two people directly from [the director's group], and they moved over onto the team and it really did speed up some of the things that we were working on . . . I was very proud of [Project Manager] when she did this.[138]

While the Project Manager's actions might seem expected, utility culture is highly differential to organizational hierarchy. SMUD's management practice typically does not condone managers confronting senior managers on resourcing decisions of which staffing is generally paramount.

"We are very risk averse," another interviewee put it.[139] Group decision-making among managers at SMUD typically follows a "consensus" model pursuant to which managers from across the organization engage in collective decision-making. Commenting on the inefficiencies and delays such consensus decision making can create, another interviewee characterized this feature of SMUD's processes as "too many cooks in the kitchen."[140] Decisions requiring senior leadership approval follows a "layered' approach" as one former team member described it:

> Typically, at SMUD and I think many . . . utilities . . . there's a layered approach to approvals. The team comes up and give three options and they go to their next layer up and ask, 'Hey, we got these three options.' Oftentimes, they're afraid to actually even make a recommendation, they just want to lay out 'here's my three options.' Only say which one they prefer if they're asked, and there's a discussion and a group discussion. Not always super clear who gets to make the decision. Then it goes that way back up through the next layer.[141]

Hence, upon receiving the senior manager's response, the SmartSacramento team hired staff needed directly from the manager's group. The comment of being "proud" that the project manager stood up to secure needed resources for the team indicates this served to foster team morale. Still, the solution the project manager found did not resolve the underlying paradox embedded in SMUD's culture favoring status quo (tradition) while SmartSacramento teams were asked to innovate quickly (change). In this instance, hiring internally adapted an effective, albeit temporary, solution to the dilemma of technical expertise needed on the SmartSacramento team at that time to move the project forward.

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137. Miron-Spektor et al., *supra* note 125, at 27.

138. Interview with former SmartSacramento team member No. 11, *supra* note 132.

139. Interview with former SmartSacramento team member No. 2, *supra* note 134.

140. Interview with former SmartSacramento team member No. 3, *supra* note 129.

141. Interview with former SmartSacramento team member No. 12, SMUD (Oct. 27, 2022).

Another project team found itself in a struggle between two departments over a software solution. The team was responsible for securing software that would run new distribution automation devices, and thus turned to SMUD units using existing software that had elements of the application the team sought. However, the units each viewed their own software as competing and superior to the other. Caught between the two, the SmartSacramento team negotiated their way to a solution.

> [W]e would go to [Department 1], we would say 'we'd like to do this' and they would say 'no', and then we'd go back and we would talk to . . . [Department 2] and say 'this is what we'd like to do to change this and [Department 1] would like to do that.' So, we became this kind of almost foreign affairs negotiator between departments . . . to develop a project or a process that would work for both organizations.[142]

The team thus faced a zero-sum resource conflict between warring business units. The primary underlying paradox involved existing versus new technology. Those in the SmartSacramento team effectively paved an alternate path to obtaining the software needed to run new meters by mediating between the two business units each of which saw only their own technical solution operating at SMUD. "We found a way through difficult problems,"[143] another team member put it. "Difficult problems didn't linger and iterate . . . [as] sometimes this happens within our utility today."[144] The SmartSacramento teams created resources in a resource-constrained environment that moved the project along to completion.

b. Teams Adapted Exploitative Measures To Leverage Their Exploratory Reach

SmartSacramento team members cited "autonomy" – being able to make decisions independent of SMUD's regular processes – for their ability to perform their best work to complete projects. "What worked . . . was allowing our small teams full reigns, full authority to figure out solutions,"[145] recalled one former team member. Another said, "I was given a huge amount of freedom to develop the tools . . . we needed to be successful."[146] And still another commented, "not having a tremendous amount of oversight structure – that was key to being able to do things quickly, to make adjustments as . . . we needed."[147] Paradoxically, these same SmartSacramento team members who identified autonomy as a driver of their success imposed structure and rules on themselves.

SMUD management had the SmartSacramento teams self-organize. Free to choose how they would operate, the teams established a steering committee composed of department leads from across the organization. Project decisions were brought to the steering committee for discussion during regularly scheduled project update meetings. Interviewees credited the steering committee for providing

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142. Interview with former SmartSacramento team member No. 7, SMUD (Oct. 11, 2022).

143. Interview with former SmartSacramento team member No. 4, SMUD (Oct. 7, 2022).

144. *Id.*

145. Interview with former SmartSacramento team member No. 2, *supra* note 134.

146. Interview with former SmartSacramento team member No. 4, *supra* note 143.

147. Interview with former SmartSacramento team member No. 10, *supra* note 135.

guidance from multiple relevant business units on project decisions. "I think there was a real value of having that steering committee because there are multiple perspectives,"[148] recalled one former team member. "There were people very focused on customer experience . . . [others] . . . were focused on marketing communications, people on the grid side . . . you weren't just relying on a single person making a decision based on their perspective. We're getting input from a bunch of folks."[149]

The teams also established written "charters" setting forth each of the team's respective project missions. These "charters" originated from a dilemma in the nature of the SmartSacramento projects. Some projects had clearly defined specifications such as installation of particular number of reclosers, which are switches on the utility's power distribution network. Other projects lacked a defined scope or objective. The operative underlying paradox here was ambiguity and definitiveness. "[T]hat's where we came up with the project charters to at least come up with some guidelines to be able to help direct people on what that the result would be."[150]

From an organizational ambidexterity view, the teams adapted exploitative measures (guidelines, definitions, date-certain installation schedules, decision-oversight processes) and applied them to their exploratory context (radical innovation sought through SmartSacramento, autonomous decision-making, taking "full reigns" to figure out solutions). The effect of combining these team governance features was – freedom. "I felt like I had the authority and the advocacy and support to do anything within . . . the charter of SmartSacramento to explore,"[151] noted one interviewee. In other words, the structure that the SmartSacramento teams set up for decision-making empowered team members to take risks to accomplish their project goals. Another former team member put it this way: "I was given a lot of freedom within the sandbox that we were operating but at the same time there was an organization with the appropriate and necessary path or mission where we did feel confident that the risks could be contained within that sandbox of decisions that were being made."[152]

Hence, by establishing written guidelines and ceding decision review to the larger group at SMUD (group-control), the SmartSacramento teams helped themselves by reinforcing their autonomy (self-control). The team's decision to implement a formal oversight process in the steering committee provided a means to establish leadership buy-in of project decisions. That in turn provided team members confidence that their exploratory work innovating had the blessing of leadership even if only through a cursory review process ("I would just tell [the steering committee] this is what I'm going to do, any comments, questions?"[153]). The SmartSacramento teams essentially operated as an ambidextrous unit able to both

148. Interview with former SmartSacramento team member No. 12, *supra* note 141.

149. *Id.*

150. Interview with former SmartSacramento team member No. 5, *supra* note 133.

151. Interview with former SmartSacramento team member No. 7, *supra* note 142.

152. Interview with former SmartSacramento team member No. 4, *supra* note 143.

153. Interview with former SmartSacramento team member No. 12, *supra* note 141.

innovate and implement within the larger utility focused on exploitative work necessary to keep the lights on.

c. Teams Experimented As Cross-Functional Innovation Units

"We were not set up for testing anything like this,"[154] one interviewee shared. Dilemmas arising from resource constraints were compounded for the SmartSacramento teams with complications of trying to operate outside of SMUD's existing electric grid the way it was designed (manifesting underlying paradox of present and future).

SmartSacramento was an effort to transform the way the SMUD's electrical distribution worked. The promise of a "two-way," interconnected system of "smart" meters through which the utility could measure customer energy usage was just that: a promise requiring creation of real-world technology to realize it. The tension under which the SmartSacramento teams worked stemmed in significant part from the need to create solutions under time constraints of the project schedule. And so, they improvised, drawing from their collective expertise.

A former member of the meter replacement team explained their predicament needing to test new meters being installed without a proper testing tool. The team "jerry-rigged" one. "[T]he first [tool] was kind of a 'belt and bootstraps' thing,"[155] described the former member. A meter technician "evolved" a meter testing device in the form of a small meter box into which a meter socket could be placed allowing the meter being tested to communicate within SMUD's meter shop. The device "pinged" the new meter to ensure its proper functioning. This prototype "ping" device formed the basis of a scaled version later built to test entire banks of meters allowing the team to replace existing units with new meters assured that they functioned properly once installed. The meter testing tool developed by the team continues to be used today at SMUD.

154. *Id.*
155. *Id.*

"Ping" testing devices (attached to middle row of smart meter bank) in operation and on display at SMUD's offices.

Iterating the "ping" testing device to address their dilemma of having to test new meters without an existing tool is noteworthy because the teams operated under tight constraints of time and resources. In SmartSacramento's case, teams had the benefit of funding made available by the SGIG grant to undertake the research and development. That was the point of the grant. Yet, creating solutions such as the ping tool under deadline underscores the type of ingenuity that national smart grid policies have sought to incent among utilities such as SMUD. The teams that worked on SmartSacramento functioned as an innovative unit able to draw on expertise at SMUD as needed to further adapt to dilemmas that came their way throughout the project.

The former team members interviewed cited the decision to "centralize" SmartSacramento team members into one physical location within SMUD as being critical to the teams' effective operation. A core set of approximately a dozen staff members (there were dozens of other team members spread across SMUD business units involved in project implementation) working on the project were grouped into a cluster of office cubicles on the same floor of SMUD's headquarters building. Interviewees noted that their physical proximity with one another fostered team cohesiveness and cross-function. "Everyone was brainstorming and innovating new ideas . . . that is the result of the energy that is created when you have a dedicated 'moonshot' team."[156]

Others identified "empowerment" of decision-making by SMUD leadership. From SMUD's publicly-elected Board, to executive management, through team leads managing day-to-day work of the project teams, the project was made a priority. This empowerment, which interviewees understood from their own experience at the utility to be unprecedented, was cited by one interviewee as the basis of creative solutions for conflicts their team encountered.

A customer claimed SMUD's meter changeout as part of SmartSacramento cut power to his house, killing his expensive pet fish. SMUD's designated customer care team typically handles such complaints. Given options spanning potential negative press from the complaint, prospect of getting management involved, and addressing an issue within the team member's control, the team member went out to an aquarium shop where workers there said the fish that the customer claimed died couldn't have been in the same tank, "they'd kill each other."[157] "Interesting," the team member recalled thinking before buying a $300 gift certificate and personally delivering it to the customer's house.[158]

The SmartSacramento teams navigated paradoxes at SMUD in part by finding 'win-win' solutions. Resolving the customer's fish casualty claim is the SMUD customer department's job *and* the team will help them accomplish it; jerry-rigging a meter testing tool is slow to help test meters *until* the tool is proven to work allowing teams to move fast after testing; rules and procedures can bog down decision-making *and* teams exercised autonomy within those parameters.

d. Teams Discovered Navigating Utility Paradoxes Is Paradoxical

The SmartSacramento teams had to work through competing ideas and resolve differences to progress. As one former team members put it: "Yeah, it wasn't easy . . . [t]here were a lot of hard decisions . . . spirited debate if not arguments even sometimes yelling matches to figure out how to move forward."[159] Innovating for SmartSacramento "wasn't easy." Teams had to make "a lot of hard decisions." They even had "yelling matches" to decide how to proceed. In other words, the teams navigated tensions with the larger organization and in their own teams.

Additionally, project team members explained that after SmartSacramento ended in 2013, they experienced personal tensions. "[O]nce we left that project and started going back to our organizations, a lot of us felt somewhat lost because we didn't have that cohesiveness going forward . . . we kind of went back to difficulties,"[160] recalled one former team member. Another team member described feeling that "problems sounded hard again"[161] after the project's end.

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156. Interview with former SmartSacramento team member No. 7, *supra* note 142.

157. Interview with former SmartSacramento team member No. 12, *supra* note 141.

158. *Id.*

159. Interview with former SmartSacramento team member No. 4, *supra* note 143.

160. Interview with former SmartSacramento team member No. 8, SMUD (Oct. 12, 2022).

161. Interview with former SmartSacramento team member No. 4, *supra* note 143.

"Feeling lost" and going "back to difficulties" following the achievement of a significant innovation undertaking is noteworthy. The SmartSacramento team members rejoined the main exploitative SMUD organization after living in an exploratory SmartSacramento world in which teams experienced autonomous decision-making and even physical grouping into a designated location akin to operations of a skunkworks unit within the company. This suggests that navigating paradoxes woven into SMUD's culture is itself paradoxical. The experience of the SmartSacramento teams indicates that by executing the project, SMUD generated innovation along with emotional dissonance among participating employees. Thus, similar to the findings from research on Peugeot's Hybrid Air team, the data provided by former SmartSacramento team members suggests that there is both gain *and* pain from innovating.

Still, the feedback from team members was not that SmartSacramento harmed them. On the contrary, team members saw themselves as growing with and from the project. The former team member who had heard comments from a colleague that SmartSacramento was a risky career move recalled personally reflecting "who even thinks that?"[162] Indeed, SmartSacramento drew employees onto project teams who were the "doers" as another former member called them – "folks who get stressed out but then think about how [they] can make [] things happen."[163] Several team members who worked on SmartSacramento were later promoted to senior management positions within SMUD, with a few even being promoted to become executives. "It was a renaissance time,"[164] recalled another former team member of the SmartSacramento period.

IV. FACTORS IMPACTING UTILITY SMART GRID INNOVATION

SMUD was one of eighty-one utilities funded by the SGIG that installed over 16.3 million smart meters nationwide.[165] The policy goal of SGIG to deliver grid efficiencies and modernization through smart grid technologies seems to have grown more acute given the frequency and severity of extreme whether events today associated with climate change and consequent demands placed on the power grid. For context, the U.S. averaged 8.5 weather/climate disasters resulting in at least $1 billion in damage from 1980–2023 (CPI-adjusted); the annual average for the most recent five years (2019–2023) is 20.4 events (CPI-adjusted).[166] The power sector is now the U.S. economy's third-highest emitting sector of greenhouse gases, having been first as recently as 2016.[167] Understandably, utility

162. Interview with former SmartSacramento team member No. 11, *supra* note 132.

163. Interview with former SmartSacramento team member No. 1, *supra* note 128.

164. Interview with former SmartSacramento team member No. 7, *supra* note 142.

165. *See AMI and Customer Systems: Deployment Status*, U.S. DEP'T OF ENERGY (2019), https://www.smartgrid.gov/archive/recovery_act/deployment_status/ami_and_customer_systems (last visited Jul 13, 2024).

166. *U.S. Billion-Dollar Weather and Climate Disasters, 1980 - Present*, NAT'L CTRS. FOR ENV'T INFO., https://www.ncei.noaa.gov/archive/accession/0209268 (last visited Jul 8, 2024).

167. *2024 Sustainable Energy in America Factbook*, BLOOMBERGNEF & BUS. COUNCIL FOR SUSTAINABLE ENERGY 24 (Feb. 28, 2024), https://assets.bbhub.io/professional/sites/24/2024-BCSE-BNEF-Sustainable-Energy-in-America-Factbook.pdf.

researchers have noted that "neither firms nor regulators can afford to ignore the potential value and risks of smart grid technologies, nor to make poorly informed decisions about their adoption."[168] Utilities and industry regulators understand that "intelligent monitoring, communication, control, and self-healing technologies are the core of the modernization of the distribution network . . . a crucial step in responding to the increasing demands for electricity and services from the digital society while reducing the environmental impacts at the lowest cost."[169] Yet, smart grid technologies can deliver such value to electricity providers and the customers they serve only if their systems choose to expend limited financial and technical resources for smart grid innovation i.e. adoption and deployment of AMI.

With industry now undertaking investment of billions of dollars in public and private funding to upgrade existing U.S. smart grid infrastructure under the DOE's GRIP program, a practical question arises: are utilities and regulators making decisions involving smart grid informed by evidence of how innovation operates at utilities? Federal grants supporting development of next generation smart grid infrastructure and applications, for instance, will be awarded to perhaps dozens of utilities. Learnings from those federally-subsidized smart grid innovation projects is intended to demonstrate and apply technology solutions that help modernize through smart grid technologies utility distribution systems across the country. Whether and how quickly the latter goal can be accomplished assumes utilities ranging from large IOUs serving tens of millions of ratepayers to co-ops that may serve a few thousand customers are prepared as organizations to innovate, e.g. replace existing smart grid infrastructure with grid-edge enabled metering devices. This then begs the question: What organizational capabilities enable a utility to innovate?

Kallman & Frickel (2019) alluded to this issue in their study of AMI deployment by Washington State utilities, noting that one branch of literature contends innovation "happen[s] within organizations" while another "argue[s] that innovation is distributed across, and predicted by, inter-organizational networks and systems."[170] Both appears to be the case for the U.S. electric utility sector. Studies have identified as drivers of utility smart grid innovation falling into broad categories of organizational and regulatory factors.

A. Organizational Factors

1. Utility Size, Ownership Form, and Management

"In terms of organizational factors, larger utilities have higher adoption rates," observed Zheng et al. (2022) who conducted a combination qualitative and

168. *See* Zheng et al., *supra* note 3, at 8.
169. Marques et al., *supra* note 57, at 2.
170. Kallman & Frickel, *supra* note 13, at 3.

quantitative study of factors impacting utility smart grid deployment.[171] Evaluating both investor- and community-owned utilities nationwide, the researchers tested the influence of utility size, ownership form, regulatory and organizational factors on adoption of smart grid technologies.[172] Through interviews with professionals from co-ops (thirty-seven individuals), municipals (thirty-eight), and IOUs (seventy-eight) and online survey responses of 132 utility representatives from these three sub-sectors, they found "[u]tility size [] was significant and positive in each model [tested], indicating that larger utilities had more extensive adoption of smart grid technologies."[173] Moreover, after controlling for size, the study also found that "IOUs have higher levels of adoption than their cooperative and municipal counterparts."[174] The researchers found in an earlier smart grid study "smaller and more nimble cooperatives and municipals are more innovative than their larger and highly-regulated IOU counterparts."[175] They attributed the difference to the ownership form of utilities: because IOUs are subject to lengthy approval processes to set prices or make investment decisions, "their decision-making autonomy is constrained"; municipals, on the other hand, do not typically need regulator approval for rate setting or infrastructure investments, resulting in "greater autonomy to invest in smart grid and use pricing to create incentives for customers to reduce peak demand."[176] However, in their subsequent study of smart grid deployment by utilities, the group found results consistent with predictions by other scholars associating larger utilities and IOUs with "greater financial and technical resources."[177]

Organizational innovation research clarifies the 'greater financial and technical resources' explanation for innovative outcomes. The size of an organization impacts innovative results because "larger agencies are more likely than their smaller counterparts to use . . . innovation support strateg[ies] [fostering] introduc[tion] [of] novel innovations, and gain large benefits from their innovation efforts."[178] The "financial, human and intellectual resources" leveraged by larger innovative agencies "enable them to spread and absorb the risk and cost involved in innovation, compared to their smaller counterparts."[179] "[B]y dint of their size, larger agencies are more bureaucratic and formalized" which "can make it harder

171. Zheng et al., *supra* note 3, at 8; *accord* Strong, *supra* note 4, at 74 (noting that "[d]iffusion research has typically found a positive association between firm size and the initial adoption of a technology").

172. Zheng et al., *supra* note 3, at 8.

173. *Id.* at 6.

174. *Id.*

175. *Id.*; *see* Dedrick et al., *supra* note 3, at 22 (finding from industry interviews "a few utilities regarded their smaller size as an advantage, enabling them to respond more flexibly and to try out technologies without facing bureaucratic delays").

176. Dedrick et al., *supra* note 3, at 24.

177. Zheng et al., *supra* note 3, at 8.

178. Nuttaneeya (Ann) Torugsa & Anthony Arundel, *Rethinking the Effect of Risk Aversion on the Benefits of Service Innovations in Public Administration Agencies*, 46 RES. POL'Y 900, 906 (2017) (finding that small public service agencies of between 1 to 49 employees achieved high benefits from their service innovations only in a low risk-averse organizational culture combined with an integrated risk management strategy).

179. *Id.* at 902.

to experiment with new ideas, but these same processes can make it easier to manage risk by enhancing predictability and reducing uncertainty, for instance when decisions are repeatedly scrutinized and responsibility shared through formal approval processes."[180] In smaller agencies by contrast, "the limited resource base and lesser formalization of decision-making processes (which make managers bear the cost of potential failure [citation omitted]) could constrain organizational learning opportunities and consequently make it difficult for managers to minimize the negative effects of risk and hence to effectively operate in a high risk-averse culture."[181] The findings from SmartSacramento which featured teams establishing a formal steering committee that reviewed and approved workgroup decisions as well as customized team charters for individual project groups illustrate such use of formal innovation risk management processes.

Researchers from the Zheng et al. group found in their earlier study of investor-owned and municipal utilities that "[l]eadership by top management was mentioned consistently by utilities that have advanced farthest in smart grid adoption."[182] They noted that "[o]ne manager argued that the kinds of organizational changes required can only be made through top-down mandate."[183] In SmartSacramento's case, former project team members expressed recognition that SMUD management directed business units to dedicate personnel to the project's execution, and that SMUD's leadership from the utility's Board of Directors down through work group managers prioritized successful execution of the SGIG-funded project.[184] Thus, data from the former SmartSacramento teams lends support to the notion that utility leadership can and does influence utility-wide innovation efforts.[185]

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180. *Id.*

181. *Id.* (explaining that research suggests small agencies with high risk aversion would less likely be able to obtain high benefits from their innovations even with the use of appropriate strategies that allow them to manage risk).

182. Dedrick et al., *supra* note 3, at 21-22 (reporting results from qualitative study qualitative study involving 15 interviews with 20 representatives of 12 utilities between IOUs and municipals); *see* Zheng et al., *supra* note 3, at 8-9 (Interestingly, the researchers later found the opposite when surveying a larger group of utilities, that "[t]op management leadership was not a significant predictor of smart grid adoption . . . ."). The disparate findings may reflect fact that the researchers surveyed respondents from utilities regarding smart grid innovation at their systems without focus on their participation in SGIG projects years before the survey whereas respondents from utilities interviewed for their initial study were comprised of AARA grant recipients whose smart grid projects involving management overseeing their utility's execution of federal funding as was the case for SmartSacramento.

183. Dedrick et al., *supra* note 3, at 22.

184. Among comments shared, interviewees noted that "[t]he best decision SMUD made was putting all of the different work groups that touched SGIG under one executive…[that] allowed us to be nimble" (Interview with former SmartSacramento team member No. 2, *supra* note 134), that "[m]anagement…pull[ed] together a team of subject matter experts throughout the district that had expertise…to deliver on the…scope in that [SmartSacramento] application" (Interview with former SmartSacramento team member No. 8, *supra* note 160), and that "uniform messaging from…our Board, to our CEO to all of our executives, the SGIG project portfolio, was [that] our strategic and tactical focus for the three years [] we were planning and operating those pilots (Interview with former SmartSacramento team member No. 4, *supra* note 143).

185. *See id.*; Zuraik & Kelly, *supra* note 107; see *generally* Haider et al., *supra* note 102; Berraies et al., *supra* note 110; Jia et al., *supra* note 110.

Consistent with findings from SmartSacramento, the earlier study by the Zheng et al. group indicated that among the utility respondents "interviewees discussed the need for changes such as breaking down organizational barriers and siloes, and creating cross-functional teams to implement different projects."[186] Similar to the disorientation expressed by former SmartSacramento team members at the conclusion of the project, representatives from both IOUs and municipal systems interviewed "spoke of challenges in managing change in organizations unaccustomed to rapid transformational change."[187] This indicates that at minimum, utility-wide innovation efforts such as SmartSacramento are not an emotionally neutral exercise for utility personnel and can actually result in employees experiencing dissonance undertaking innovation within existing risk-averse organizational cultures of electricity providers.

2. Risk Aversion

The smart grid literature addresses power sector innovation from the understanding that utilities are risk averse.[188] "This internal risk aversion is reinforced by the status of most utilities as local monopolies working within external rules and norms that constrain them from using innovation to pursue potentially profitable business options . . . as firms in other industries do."[189] More generally, innovation in public services such as electricity provision "inherently involves risks" with costs (risks) of such innovation "almost certainly measurable, specific, and traceable to the decisions of individuals" while "benefits . . . are often uncertain, difficult to measure and diffused over numerous recipients."[190] For the electric sector under pressures to innovate towards decarbonized operations, this poses a problem since "[r]isk aversion, together with the uncertainty avoidance[191] associated with the results of innovative processes, raise barriers to innovation and the transition to other technological paradigms."[192] However, the lesson from utility adoptions of smart grid is that innovation by investor- and community-owned systems alike appears to be that implementing risk management measures tailored to a given utility's culture enables innovation outcomes.

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186. *Id.* at 26 ("In the words of one respondent, organizational siloes need to be smashed, which can only be accomplished with top management leadership.").

187. *Id.*

188. *See, e.g.*, Zheng et al., *supra* note 3, at 8 (concluding "smart grid adoption was mainly motivated by the desire for operational improvement, including reliability, efficiency, and cost reduction . . . consistent with [their] interviews and with prior research [citations] showing that utilities as organizations tend to be risk averse").

189. *Id.*

190. *See* Torugsa & Arundel, *supra* note 178, at 901 (explaining how risk dynamics at issue with public service innovation results in underestimation of relative gains together with higher penalties for failure compared to rewards for success, negatively impacting risk perception and undermining incentives to innovate).

191. *See* Logan L. Watts et al.,, *Uncertainty Avoidance Moderates the Relationship between Transformational Leadership and Innovation: A Meta-Analysis*, 51 J. INT'L. BUS. STUD. 138, 139 (2020) (using the term "uncertainty avoidance" to refer to "the extent to which the members of a culture feel threatened by uncertain or unknown situations").

192. *See* Marques et al., *supra* note 57, at 5.

While convention may hold that "risk-averse culture in public agencies is a cause of management ineffectiveness and a significant barrier to successful innovation,"[193] research involving public service organizations throughout the European Union revealed public managers "work[ed] effectively around risk and achieve[d] high benefits from [their] innovations."[194] Of the 3,699 agencies surveyed in the study, 54% reported a risk-averse culture they associated with either high or medium importance in preventing innovation and yet 71% of those identified risk-averse agencies introduced a service innovation.[195] Moreover, "a significantly higher percentage of agencies with a high risk-averse culture (34.4%) develop[ed] a novel innovation than agencies with a low risk-averse culture (28.2%)."[196] The researchers concluded that an organization's level of risk aversion "is a relevant but not deterministic condition for high innovation benefits; rather, the ability of managers in risk-averse agencies to implement appropriate combinations of strategies for managing risk is what drives innovation success."[197]

The data from U.S. smart grid studies supports this argument that risk management drives innovation success. On the IOU side, decisions to undertake smart grid innovation depends on whether regulatory environments under which they operate provide sufficient planning security. Cost recovery allowed by an applicable state public utilities commission is consistently mentioned as a deciding factor for smart grid deployments.[198] Federal grants made available to utilities through ARRA provided financial incentive for IOUs "to be able to plan long-term" mitigating the financial risk of smart grid investments.[199] SmartSacramento team members responded to the utility's risk aversion by adapting measures practiced within the organization to manage an inherently risky process to innovate. At the institutional level, the "nested institutional logics" observed in Washington State's smart grid deployment was in a practical sense a spreading of innovation risk across organizations such that IOUs "joined forces with other smaller regional utilities . . . effectively creating an inter-organizational innovation network through incentives offered at the federal level . . . to move one Washington city

193. Torugsa & Arundel, *supra* note 178, at 901.

194. *Id.* at 909 (recommending policies fostering effective innovation in public services by providing support and training of managers to assist in developing context specific sets of strategies for agencies with varying levels of risk aversion and transitioning from risk aversion to risk awareness for management).

195. *Id*. at 902; *see id.* at 903 (defining 'service innovation' as "introduction of a service that is new or significantly improved with respect to its characteristics or intended uses . . . ranging from highly novel or transformative innovations that make significant changes to current services to minor incremental changes"); *see also id.* at 903 (explaining example of incremental service innovation could be the replacement of diesel buses with electrical buses in a transportation system whereas a transformative service innovation might introduce a zero emissions public transport system closely integrated with other policies to significantly reduce carbon and nitrogen oxide emissions).

196. Torugsa & Arundel, *supra* note 178, at 902.

197. *Id.* at 901.

198. *See, e.g.*, Dedrick et al., *supra* note 3, at 23 (quoting IOU interviewees explaining their utilities decided on smart grid project cancellation or proceeding based on PUC cost recovery determinations).

199. *See* Kallman & Frickel, *supra* note 13, at 5.

towards "Smart City"[200] status."[201] By implementing their respective innovation risk management measures, IOUs, the SmartSacramento teams, and utility partners in Washington State were able to successfully execute their smart grid innovation projects. "Managers in high risk-averse organizations exhibit a higher propensity to develop an integrated [risk management] strategy and consequently they are likely to be able to work effectively around risk [and] to develop novel innovations . . . ."[202]

Research has also found that "[i]n risk-averse organizational environments, managerial attitudes to risk play a vital role in influencing staff perceptions and behaviors concerning risk."[203] Data from former SmartSacramento team members to the effect that they felt "empowered" by SMUD management to make decisions suggests that the attitude towards innovation risk which management applied at SMUD framed risk in a manner that fostered innovative performance.[204]

3. Subject Matter Expertise

Zheng et al. found from their study of investor- and publicly-owned systems that while "[a] utility's internal knowledge and skill base were not found to influence [smart grid] adoption" the quantitative data from their research showed that internal expertise "emerged as the third most important barrier to adoption."[205] This apparent dichotomy in the study's findings, the researchers determined, "suggest that new skills are needed for smart grid adoption, but that internal skill levels may not be a critical factor if needed skills are available externally through contractors or consultants."[206]

However, data obtained from the former SmartSacramento team members underscored that subject matter expertise within SMUD was pivotal to their ability to navigate innovation obstacles. Faced with the dilemma of testing new smart meters without existing tools, team members of the metering team created and tested a "belts-and-bootstraps" prototype "ping" device which once proven to work was scaled to test banks of meters. Likewise, team members developing software to run new distribution automation devices developed a solution that met the needs of warring business units by mediating between them. In the case of

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200. *Id.* (explaining that goal of project was to create regional smart grid that included updated and automated distribution systems, roll out AMI at homes and businesses, and to pilot a Smart Home project).

201. *Id.*

202. Torugsa & Arundel, *supra* note 178, at 909 (finding that among surveyed agencies "the share of high risk-averse innovators that possess[ed] high levels of process and communication innovations, deploy an active management strategy, and more importantly have an integrated strategy in place, [was] significantly higher than the share of low risk-averse agencies").

203. *Id.* at 903 (citing Barry Bozeman & Gordon Kingsley, *Risk Culture in Public and Private Organizations*, 58 PUB. ADMIN. REV. 109 (1998) (testing and refuting assertion that public managers are inherently more risk averse than their private sector counterparts)).

204. *See, e.g.*, Interviews with former SmartSacramento team members, *supra* notes 128-135, 141-143, 160.

205. Zheng et al., *supra* note 3, at 9.

206. *Id*.

SmartSacramento, subject matter expertise was combined with creativity and ingenuity to generate solutions moving the smart grid project along to completion with utility tensions in operation.

While assistance from contractors or consultants may be an option available if budgets and project timelines allow, the experience conveyed by SmartSacramento team members and even co-ops that implemented smart grid projects indicates that innovation within utilities depend on internal subject matter experts expanding their existing work duties to accommodate the organization's effort. When Vermont Electric Cooperative (VEC) needed software developed to connect the utility's network server to software managing their AMI data so that their members could view energy usage data, the co-op found few vendors that could do the work, and bids beyond what the organization could afford.[207] "Working part time, in addition to their regular responsibilities, VEC's IT staff wrote the software between late 2008 and May 2009" for the 35,000 member-customer system serving 74 towns throughout more than 2,000 square miles of rural northern Vermont.[208] As one former SmartSacramento team member relayed the realities of innovating within SMUD, "[e]verything still had to get done" and that those involved in supporting SmartSacramento "just had to manage" their expanded workloads.[209]

B. Regulatory Factors

"Federal and state policies and regulations[210] prominently shape the adoption environment of utilities with respect to technology choice in general and smart meters in particular."[211] Federal policies have supported national adoption of smart meters and TOU rates "despite the lack of legal jurisdiction, which rests with the authority of state to regulate the distribution and retail sale of electricity."[212] "[R]ecognition of demand response as a viable and important resource in electricity markets has been a persistent, overriding policy objective [driven by] [t]he Federal Energy Regulatory Commission [which] has acted as a change agent for the diffusion of demand response in wholesale markets . . . ."[213] The acceleration of tax depreciation for smart meters from twenty to ten years under EESA and

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207. Reitenbach, *supra* note 136, at 46 (recounting VEC's investment in smart grid upgrades of the co-op's system before a DOE grant under ARRA was awarded in 2009 to complete remaining 20% of their smart meter installation).

208. *Id.* at 44, 46.

209. See Interview with former SmartSacramento team member No. 10, *supra* note 135.

210. *See* Rahmatallah Poudineh et al., *Innovation in Regulated Electricity Networks: Incentivising Tasks with Highly Uncertain Outcomes*, 21 COMPETITION & REG. NETWORK INDUS. 166, 185 (2020) (commenting that the task of regulation is to devise scheme which balances risk sharing with incentives because on the one hand, the regulator wants the firm to undertake innovation, but for this to happen, [the regulator] needs to renumerate the firm for its costs when undertaking risky activity; on the other hand, the regulator does not want to distort the firm's incentives by giving it full insurance for activities whose risks are actually manageable by the firm).

211. *See* Strong, *supra* note 4, at 1347.

212. *Id.*; *see* Section II discussion of U.S. federal smart grid policy development background.

213. *See* Strong, *supra* note 4, at 1347.

the nearly $3.5 billion of ARRA funding DOE deployed through the SGIG catalyzed utility installation of over 16 million smart meters.

Along these lines, state legislation and regulatory rulings have directly supported or mandated deployment of smart meters by IOUs. State legislative actions have been found to have a "significant and positive impact on smart meter adoptions" by mandating utility cost recovery frameworks for metering projects and reducing policy uncertainty for utilities through data security and customer information privacy legislation.[214] For example, California requires that its large IOUs develop detailed smart grid plans. Other policies that can indirectly affect smart meter adoption include the power market structure within a particular geographic region. Because "[s]mart meters enable time-varying pricing at the retail level," in states where competitive wholesale and retail markets exist, "utilities . . . may be more likely to adopt smart meters in order to reflect these costs in prices."[215] Additionally, regulatory allowance of lost revenue recovery via mechanisms such as lost margin recovery (e.g. "de-coupling") "removes disincentives for investments in energy efficiency."[216]

From interviews of both IOUs and community-owned system personnel, researchers found that "regulatory factors were very important for IOUs, while only of minor importance to municipals and cooperatives."[217] "[R]egulatory environment matters strongly to IOUs [because their] investments require approval by state-level utility regulators [whereas] [m]unicipals and cooperatives were concerned with reducing costs . . . and empowering customers . . . ."[218] The approval of state public utilities commissions of smart grid projects were determining factors for IOUs interviewed in another study. "We requested a rate increase, but the commission only approved one-third of it," recounted one IOU respondent who added, "this caused us to cancel a pilot project on smart grid."[219] In contrast, another IOU interviewee noted that their PUC "encouraged [the utility] to submit the application for [] ARRA smart grid funding" and once obtained the IOU "got the regulatory approval for moving forward" on the adoption.[220] Consequently, the researchers reported that "[a]mong our interviewees, the regulatory environment ranged from obstacle to driver."[221] More specifically, the study noted that a "characteristic comment" from IOU respondents was, "[w]e try to be proactive in our discussion and relationship with the public utility commission so that we are open and transparent to what we're doing . . . Those relationships are always key, internally and externally."[222] Evaluation of their data revealed that "formal aspects of

214. *See* Gao et al., *supra* note 12, at 10.

215. Strong, *supra* note 4, at 1348.

216. *See id.*

217. Zheng et al., *supra* note 3, at 5 (noting survey data revealed that meeting legislative or regulatory requirements was the second-most important motivator to pursue smart grid innovations for IOUs while it was near the bottom of the list for municipals and co-ops).

218. *Id.*

219. Dedrick et al., *supra* note 3, at 23.

220. *Id.*

221. *Id.*

222. Zheng et al., *supra* note 3, at 6-7.

regulation (e.g. published evaluation criteria) may matter less than the quality of relationships between utility representatives and regulators in smart grid adoption."[223]

V. Implications for A Decarbonizing Power Sector

Innovating for a lower carbon future poses huge dilemmas for utilities nationwide. The system deliverables involved are specific (e.g. a 'micro-grid' that keeps a section of town lit when the rest of the city goes dark) and general (e.g. ensure regional grids can recover from weather-related disasters becoming more destructive and frequent with climate change); incremental (e.g. training workers needed to maintain the modern utility) and radical (e.g. running a utility's natural gas plant using hydrogen produced from electrolysis of water); as well as technical (e.g. engineering solutioning) and social (e.g. people solutioning). Such innovations involve billions of dollars of capital investment. "[W]e as a [municipal] utility . . . have to be prudent in our expenditures . . . we have ratepayers and obviously want[] to be judicious in our rates," noted Southeast Manager, who explained that funding of their dedicated innovation projects requires management's "buy-in" for requests are typically met with "a lot of skepticism."[224]

SMUD is among the largest municipal utilities in the country. The community-owned utility, established under California law and governed by a publicly-elected Board of Directors, is guided in its operations by competing interests and considerations of the utility's stakeholders, management, other utilities including its neighboring investor-owned utility (Pacific Gas & Electric) and the organization's values past and present. Yet, in terms of innovation, the conflicting and often contradictory demands and tensions generated therefrom are not themselves the challenge. As paradox academics have put it: "the problem is not the problem; the problem is in the way we think about the problem."[225]

The issues raised by this study are particularly relevant to utilities such as SMUD which generally spend little time analyzing their innovation initiatives. Surfacing, let alone analyzing, tensions that may very well cause anxiety and discomfort is not typical management practice even in a forward-thinking utility such as SMUD. SmartSacramento thus highlights a potential blind spot for leadership of utilities such as SMUD – the need to diagnose paradoxical dynamics that may be restricting their utility's ability to innovate, and how those challenges might be managed and leveraged to move the utility productively over time towards a low-carbon future.

The challenge of accomplishing SmartSacramento teams faced a decade ago contextualizes the obstacle SMUD now faces as an organization moving towards Zero by 2030. As a former team member recalled, "we were trying to solve very difficult and complex things and in sometimes very short time periods."[226] Legal

223. *Id.* at 7.

224. Interview with Southeast Manager, *supra* note 131.

225. Miron-Spektor et al., *supra* note 125, at 27 (citing PAUL WATZLAWICK ET AL., CHANGE: PRINCIPLES OF PROBLEM FORMATION AND PROBLEM RESOLUTION (1974)).

226. Interview with former SmartSacramento team member No. 8, *supra* note 160.

scholars have criticized the "lack of progress to date" by "utilities and their regulators" to transition away from fossil fuel power generation and reduce carbon emissions, "continu[ing] to dig the climate hole deeper while they are operating."[227] SMUD is today trying to solve "very difficult and complex things" within a "very short time period." The persistent paradoxes such as resource scarcity and urgency to innovate with which SmartSacramento teams grappled over a decade ago is today cast in the form of its Zero by 2030 goal.

Yet, unlike SmartSacramento, Zero by 2030 is SMUD's company mission, not simply a priority project involving cross-functional teams. The SmartSacramento teams as this research has found developed "organic" solutions themselves to address day-to-day conflicts and dilemmas. In doing so, they managed to secure staffing needed for the project, "jerry-rigged" solutions, combined exploitative and exploratory practices to maneuver their way to project completion, and they also explored their way to "win-win" solutions, leveraging SMUD's existing exploitative operations processes to execute SmartSacramento. After deftly pivoting, adjusting, and adapting to myriad conflicts, demands, and pressures to accomplish the smart grid project, they experienced costs exacted on the organization. Team members returned to the main organization after SmartSacramento feeling "lost" and problems became "hard again." In essence, SmartSacramento demonstrated SMUD teams functioning as a 'complex adaptive system'[228] – containing a large number of agents which "interact, learn, and, most crucially, adapt to changes in their selection environment in order to improve."[229]

This research is not intended to imply that SmartSacramento represents a model of how innovation ought to happen for SMUD or any other utility. Each utility, its culture, and innovation project is unique. Moreover, the paradox of innovation success has been studied and research indicates it exists. "Success motivates us to stick with that option, until we get stuck in a rut," noted Smith & Lewis (2022), citing research on the "S" curve depicting "how choices lead us from progress to stagnation and, ultimately, decline."[230] Without getting afield of this article, utilities such as SMUD are well advised to think creatively to start new "S" curves while traversing the one they may be on rather than reapplying innovation playbooks that worked in prior contexts.[231] The more pertinent lesson to be drawn, it seems, is whether utilities individually and the electric sector at large are

227. *See, e.g.*, Joel B. Eisen & Heather E. Payne, *Rebuilding Grid Governance*, 48 BYU L. REV. 1057, 1079-1080 (2023) (commenting that "[u]tilities are enthusiastic about 'grid modernization' programs and large . . . (AMI) installation, but there is no big climate payoff as yet").

228. Tim Sullivan, *Embracing Complexity*, 89 HARV. BUS. REV. 89 (2011); *see* Gokce Sargut & Rita Gunther McGrath, *Learning to Live with Complexity: How to Make Sense of the Unpredictable and the Undefinable in Today's Hyperconnected Business World*, 89 HARV. BUS. REV. 68 (2011).

229. *See* Edward J. Oughton et al., *Infrastructure as a Complex Adaptive System*, COMPLEXITY (2018), https://www.proquest.com/scholarly-journals/infrastructure-as-complex-adaptive-system/docview/2135024893/se-2.

230. SMITH & LEWIS, *supra* note 124, at 46.

231. *See generally* Bledow et al., *supra* note 123; GREG SATELL, MAPPING INNOVATION: A PLAYBOOK FOR NAVIGATING A DISRUPTIVE AGE (2017).

gathering pertinent data on how innovation operates to maintain sustained innovation efforts necessary to meet challenges such as sector decarbonization. As one innovation scholar put it, “[e]ven if a company has the resources for [rapid innovation], how can [] teams be freed to move quickly enough and be motivated to sustain a focused effort long enough to build a sustainable advantage” in their arena of operation.[232]

Nonetheless, the implications of this study can assist utility stakeholders in approaching their innovation endeavors in more strategic and productive way. Two primary lessons emerging from this research can be summed up as follows: (1) The Battery Paradox, and (2) Innovation Learning Paradox.

A. *The Battery Paradox*

A battery has a positive and negative charge, yet that is irrelevant to whether either is subjectively “good” or “bad.” Both charges are needed to produce power. Moreover, the value that a battery offers is not in the power it provides so much as when its stored energy can be tapped. For utilities, the promise of batteries lies in their ability to provide instant back-up power for intermittent generation resources (e.g. when the sun is not shining on solar panels, or when the wind is not turning wind turbines). Thus, a battery’s “power” as an energy resource hinges on its ability to deliver electricity instantly when needed.

Data from this study revealed that the frame – assumptions and beliefs – which utility personnel apply to innovation is that it is positive (good) while risk aversion is negative (bad). The data indicates that this frame has prompted the wrong questions to be asked. There is sound reason in the electric utility industry to be risk averse.[233] The performance of a utility is measured not only in terms of reliability and affordable rates, but in also in terms of ensuring the safety of employees handling high voltage electrical equipment. Decisions can at times be matters of life or death. In the U.S., utilities face regulatory liabilities upwards of $1 million per day if the lights go out due to utility negligence. Risk aversion is, therefore, adaptive in the power sector and cannot be segregated from what may deemed its opposite – innovation. To innovate as an electric utility in any sustainable manner is to also simultaneously tend to the system’s competing demands to ensure reliability and safety. The point here is that utilities pursing projects for a low carbon future should determine what frame they are applying to innovation.

Electric utilities such as SMUD are today undertaking R&D to expand the duration of utility-scale batteries to upwards of 10 hours so that energy and timing of demand can coincide to deliver reliable power. ‘Long-duration’ battery storage is a technological and engineering challenge that will cost millions of dollars and countless research hours to solve. “It’s a very complicated business that that we

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232. Jerome S. Engel, *Accelerating Corporate Innovation: Lessons from the Venture Capital Model*, 54 RES. TECH. MGMT. 36, 37 (2011).

233. *See* Kallman & Frickel, *supra* note 13, at 2 (noting “risks associated with technological innovation in electricity provision are very high: if not successfully designated and implemented, changes to the electrical grid could produce catastrophic energy loss, consumer dissatisfaction and a host of other problems”).

operate,"[234] noted one former SmartSacramento team member. Innovating solutions such as long-duration batteries is neither simple nor certain.

Yet, certainty and simplicity constitute the frame utilities apply to innovation. "INNOVATION" is emblazoned across sleek images of solar panels and towering windmills amidst green fields featured in utility advertisements. Messaging utilities such as SMUD convey outside their organizations portray innovation not only as destined but already here. Internally, the innovation task is posed as achieving SMUD's "Zero Carbon vision." Such framing belies the organizational dilemma faced by public power systems, exploitative in operating complicated utility systems to provide electricity, and exploratory in developing radical innovations needed to decarbonize the grid. That exploration as SmartSacramento illustrated involves the utility functioning as a 'complex adaptive system'[235]. For a utility, that system features "[m]any stakeholders [] involved in [the] organization['s] innovation . . . emerg[ing] through processes in which [] contributions of different actors are integrated"[236]. In this sense, the utility 'emerges' as an innovation organization by its individual teams making decisions and quickly improvising[237] through interaction with others both in exploratory and exploitative capacities. Therein lies the battery paradox. While the battery may be presented as simple, with utilities applying an innovative frame of certainty, delivering the promise of battery solutions requires the utility adapt to complexities posed by underlying paradoxes.

Keeping the lights on while concurrently pursuing yet-to-exist solutions to operate reliably is not self-evident. The worlds from which utility employees show up for work is anything but conducive to connecting with that apparently self-evident concept. These worlds include a parent choosing between working extra hours or spending time with their child; a world in which an employee juggles meeting a supervisor's expectations and those of executives; worlds in which keeping the lights on is all that employees have capacity to do because they are dealing with personal health issues. Those worlds are filled with competing demands. Tensions employees bring to SMUD, which is a culturally risk-averse institution, and those Zero by 2030 creates in their lives do not mesh for many SMUD employees. Expecting them to mesh assumes the underlying paradoxes can be resolved. Can resource scarcity, for instance, be definitively reconciled with innovation within a utility such as SMUD? Perhaps a more productive approach may be to acknowledge as utility managers or energy sector policymakers as the case may be that the two concepts are irreconcilable, which generates tension, and still the organization will persist in exploring paths to develop resources

234. Interview with former SmartSacramento team member No. 4, *supra* note 143.

235. *See, e.g.*, Sullivan, *supra* note 228.

236. *See* Oughton et al., *supra* note 229.

237. *See* Hugh M. Pattinson & Arch G. Woodside, *Capturing and Reinterpreting Complexity in Multifirm Disruptive Product Innovations*, 24 J. BUS. & INDUS. MKTG. 61, 73 (2009) (concluding that subject technology company's success innovating relied on "[b]rilliant and fast improvising" demonstrating its skill to "create-apply-destroy-recreate-apply applications quickly with little time during the process for focusing long on mistakes and obstacles" reflecting "try this now" doing instead of "what if" thinking).

necessary to execute innovation projects by managing tensions[238] while continuing to keep the lights on.

SmartSacramento highlights a utility operating as a complex adaptive system innovating within the main organization oriented towards maintaining power for customers. The teams that achieved SmartSacramento executing a comprensive grid infrastructure upgrade project prioritized by the entire leadership chain at SMUD. They self-structured, even self-selected their participation in projects. They leveraged autonomy to adapt approaches that grew out of the needs of that particular innovation project. They were empowered to develop their own pathways to adjust to and work with competing demands and dilemmas that characterize innovative work at SMUD, work that itself generates additional tensions for team members and the organization. Those elements combined, changed, and were adapted to achieve SmartSacramento whose value was greater than the sum of its parts. Operationalizing these lessons from SmartSacramento to inform SMUD's decision-making to achieve Zero by 2030, therefore, is in not simply a matter of trying to re-create steps taken to achieve SmartSacramento. Based on this study, SMUD and other electric utilities may want to practice innovating for a low carbon future from the vantage of *powering paradoxes* – dealing with rather than attempting to eliminate competing demands, tensions, and conflicts – experienced by its employees who live and work in a paradoxical electric sector.

B. Innovation Learning Paradox

Identifying the costs of a business, applying tried and true processes to track where costs are being generated, developing assumptions of cost drivers and analyzing how costs ought to be properly allocated to make budget decisions – these are quintessential exploitative functions, essential to properly running a public power utility. A utility's financial controller must trace costs to their origins based on data gathered, assembled, and analyzed to build a case for budget decisions.

The stories utilities tell themselves about how innovation happens within their systems are based on frames – sets of assumptions and beliefs through which people perceive the world. Data from this study suggests SMUD has internalized its version of the story of SmartSacramento; the utilities employing the managers from the Pacific Northwest and Southeast have their own for their respective innovation projects. While each utility has stories fitting their respective innovation journeys, the operative issue for SMUD and public power systems nationwide as they execute plans for a low-carbon future harkens back to the inconspicuous yet vital role of the financial controller: What is the data giving rise to those stories? Is the utility making innovation decisions involving major investments of its already-limited financial and strained staff resources based on evidence rather than stories developed from frames operating within their organizations?

Thus, another key implication of the findings from this research is that power utilities ought to assess whether their systems are making evidence-based decisions to build toward a low carbon future. This can be labeled the Innovation Learning Paradox – innovation is both forward and backward looking.

238. *See* SMITH & LEWIS, *supra* note 124.

SmartSacramento highlights forward thinking. Visioning, planning for that vision, and executing steps of that visions to create the future we seek – these are all part of the exploratory exercise of innovation.

Backward thinking includes work such as this study, probing innovation projects to find nuggets of wisdom from heavy lifts to innovate. Utilities such as SMUD, and federal energy policy stakeholders for that matter, have a challenge to collect and analyze data from the past to inform the future they seek to innovate towards. For instance, DOE's implementation of its current GRIP program will involve collection of technical outcomes to be detailed copiously by grant recipients through compliance reporting, yet information on how utility teams actually achieve the innovations U.S. energy policy seeks from the power sector could remain ignored. Gathering such team functioning information is an exploitative exercise requiring deliberate processes such as the utilities research highlighted in this article. SMUD's ability to operate ambidextrously in this regard could provide significant strategic insights as it proceeds with plans the utility estimates could cost upwards of $4 billion to achieve Zero by 2030, a paradoxical goal by an electric system not unlike power systems across the country that operated for decades before smart grid provided transparency into their distribution grid to know lights were out without someone calling in to inform the utility. Hence, a consideration for energy policymakers is whether valuable data on how innovation functions at the utility level instructive for effectuating and accelerating innovation required to meet decarbonization goals are going unnoticed.

Tackling increasingly complex, seemingly intractable problems in the electrical utility industry such as eliminating carbon emissions requires taking stock of the frame(s) through which innovation challenges are perceived. Learning from SmartSacramento that working with conflicting and contradictory dilemmas SMUD faces is a big part of how that innovation happened seems to be a critical lesson. Just as a controller must conduct proper analysis to determine actual cost drivers within a utility to figure out what to do about them, innovation requires proper diagnosis to assess what makes it work within an organization to determine how lessons learned can be leveraged and, in turn, how that might help create the low carbon future utilities and policymakers envision.

VI. RECOMMENDATIONS

A. Utility Managers

This article has attempted to illuminate through SmartSacramento the tensions, conflicts, dilemmas project teams lived during its implementation. Based on the data gathered from former project team members, the overall theme that emerged involved teams facing, dealing with, and even internalizing the tensions inherent in a large-scale innovation effort within SMUD. This article argues that SMUD and other U.S. utilities may want to approach innovation from a vantage of managing paradoxes which is a leadership challenge for any utility moving toward a low carbon future.

To assist managers of utilities to think through their innovation challenges, the following P-O-W-E-R framework is offered:

- **P** stands for paradox. What is/are the paradox(es) at play with a given innovation challenge? If all a utility sees is the conflict between grid operations and R&D, it is likely missing the point. Get to the paradox to unwind often intertwined, conflicting, and contradictory issues that have companies, teams, and individuals intractably stuck.
- **O** is for opposition. Innovation roadblocks and/or or hang-ups are in the eyes of the utility perceiver. Instead of succumbing to a given conflict/dilemma, managers may want to ask how their system might re-cast the challenge. Can you view the opposition from a different vantage that allows your system to apply a paradox mindset to the problem?
- **W** is for wins. These must be diagnosed as carefully as any major failure (it's a paradoxical world). SmartSacramento was a success for SMUD on multiple levels. At the same time, a more complete story of SmartSacramento can be revealed if SMUD is deliberate in uncovering why things worked. That knowledge should be incorporated into the thinking that goes into strategizing for the next innovation endeavor. In other words, mine your wins for nuggets of wisdom.
- **E** is for energy. How much time/effort is your team or utility pouring into wasted spinning over conflicts and tensions. Accepting the contradictions and competing demands can relieve wasted energy. Become more energy efficient and energy effective by acknowledging tensions before moving on to directing your utility's energy at innovating with those tensions in existence.
- **R** is for retry. SmartSacramento underscores the value of iterating solutions. We might not have the killer app for every problem we hit with innovative effort. For utilities facing daunting prospects of moving to net zero or zero carbon, remember that innovation is not about perfection. Greg Satell in his book, "Mapping Innovation" put it this way:

> We expect innovations to be well dress, smooth talking, and brilliantly executed, but the reality is that the innovation process is anything but those things. It is not smooth or shiny. It stutters. It is often overweight and poorly groomed, with dark circles under its eyes from overwork. It comes into the world stumbling and falling, only later to gain Olympic prowess.[239]

B. Utility Innovation R&D

Likewise, federal stakeholders, particularly DOE, should consider the gap in utility innovation R&D highlighted in this article. National innovation undertakings such as DOE's administration of the $3 billion in smart grid funding under GRIP for cost-shared projects will involve utilities deploying next generation smart grid technologies. These projects will produce a plethora of utility technical data similar to information reported by utility awardees of SGIG a decade ago

239. SATELL, *supra* note 231, at 195.

informing decisions by federal energy stakeholders impacting grid reliability, functioning of grid management applications building upon existing smart metering infrastructure, and potential returns on current investments in U.S. smart grid upgrades. Just as the agency accomplished with SGIG,[240] DOE will likely be gathering and documenting 'lessons learned' from implementation of GRIP. Yet, along with the technical information from GRIP implementation, scores of project teams throughout the electric sector will be generating qualitative data from their experiences executing federally-funded smart grid development that illuminate how and why utilities are able to innovate. These insights could prove particularly important to understand as utilities and U.S. energy policy steer power sector innovation towards low and even non-carbon emitting operations. Absent deliberate research and analysis of utility team data, decisions on how billions of dollars of public and private funding to modernize grid distribution and transmission will be spent based could rely on rather consequential assumptions about how innovation supposedly works or fails to work within the highly regulated power sector. Thus, in addition to capturing and summarizing technical details from utilities learned from connecting, integrating, and operating next generation smart grid technologies, DOE has an opportunity to study the workings of utility team innovation nationwide through the GRIP program. This type of utility-level research provides a more complete data set for policymakers and industry making substantial grid investments to try innovating solutions to operate reliably in a low carbon future.

To this end, DOE should consider developing through its administration of GRIP reports on not only what is being innovated – e.g. AMI systems equipped with grid-edge technologies,[241] integration of Distributed Energy Resource Management Systems with utility Outage Management Systems, end-to-end secure communications network between edge-enabled consumer devices and utility systems – but the 'how' and 'why' of utility innovation based upon evidence from utility innovation implementations. As the federal agency most directly involved

240. *See generally Smart Grid Investment Grant Program Final Report*, U.S. DEP'T OF ENERGY (Dec. 2016), https://www.energy.gov/sites/prod/files/2017/01/f34/Final%20SGIG%20Report%20-%202016-12-20_clean.pdf (detailing major findings and key results of national execution of SGIG program); *see id.* at 52 (Of particular relevance to the point made here, DOE explains under Section 5 of the report titled 'Deployment Lessons learned and Conclusions' that "SGIG project experiences produced a wealth of information and lessons learned that can be applied by all utilities developing and deploying smart grid systems" which "cover the gamut of smart grid program implementation, from management and planning, to technology deployment and cybersecurity, to consumer engagement and education.").

241. *See Communications with the Grid Edge: Unlocking Options for Power System Coordination and Reliability*, U.S. DEP'T OF ENERGY 2 (June 2023), https://www.energy.gov/sites/default/files/2023-07/Communications%20with%20the%20Grid%20Edge%20-%20Unlocking%20Options%20for%20Power%20System%20Coordination%20and%20Reliability_0.pdf (defining 'grid edge' to be the "boundary zone where the utility ends and customer premises equipment [] starts . . . begin[ning] at the meter interface (the utility demarcation point) . . . [and] contain[ing] all equipment, software solutions, and controls owned by the customer . . . [which] could be homeowners, businesses, and industrial or commercial facilities"). Integration of grid edge devices including rooftop solar systems, electric vehicle charging stations, and energy storage solutions into grid operations given the increasing magnitude of these edge loads (both positive and negative) is the vision of grid edge technologies. *See id.*

with industry smart grid innovation, DOE is in position to build a nationwide dataset gathered from utilities on their respective team decisions, organizational structuring, and interactions between and among members. Utilities awarded GRIP funding for instance could host project-based DOE research fellows to perform data gathering and analysis on innovation practices by leveraging DOE's existing workforce development initiatives through Oak Ridge National Lab's ORISE[242] program. In partnership with other national labs, DOE could commission studies to be undertaken post-project similar the research presented in this article documenting key data points and themes to be drawn from individual GRIP-funded projects. The project-based information gathered from the ground level of innovation processes can inform regulatory decision-making on grid modernization by DOE or other government agencies, identify where implementation challenges exist, and design programmatic solutions addressing issues based on data generated by project-based experience of a broad representation of utility systems. By capturing such project-specific data, DOE would develop intelligence on power sector innovation that could prove pivotal for sustained industry innovation needed to effectuate federal energy policy targeting decarbonization by utilities.

VII. LIMITATIONS AND FURTHER RESEARCH

Because the SmartSacramento study addressed a smart grid project completed over a decade ago, there is a potential for recall bias – systemic error that occurs when participants do not remember previous events or experiences accurately or omit details. Recall of events by interviewees were consistent across the interviews conducted. For instance, the firing of a vendor that had performed poorly during the project came up during multiple interviews. Each person who commented on this event independently provided generally similar explanations as to the circumstances of the situation and outcomes, and even similar commentary to the effect that it was not something usual for SMUD to fire a vendor. Likewise, while interviewees recalled events specific to their individual roles and project involvement, similar themes emerged across responses including decision autonomy, solution iteration, integrative solutioning as tensions arose, and experiencing personal tensions from working on the project after it was completed. Thus, to the extent there was recall bias, the relative coherence of themes and information interviewees independently provided suggested that recall bias did not materially impact the veracity of the data in this research.

Separately, confirmation bias – seeking and paying attention to information which confirms one's beliefs and assumptions – may have influenced this research. As an employee of SMUD, I as author of this study carried my own frames into these interviews reflecting sentiments shared regarding decision-making tensions many experience at SMUD. While I attempted to mitigate bias of which I was aware (e.g. turning off video during interviews) and took measures to control them, my research methodology may have nonetheless introduced bias by virtue

242. *See generally STEM Internships and Fellowships*, OAK RIDGE INST. FOR SCI. & EDUC., https://orise.orau.gov/internships-fellowships/index.html (last visited Aug. 5, 2024).

of turning the microscope so to speak on my employer. The findings presented in this article should be viewed with these limitations in mind.

Further study of utility-specific innovation is warranted. Qualitative studies of other utilities, empirical evaluation of systems undertaking innovation are the types of research that will be needed to gain the comprehensive perspective on innovation practice still largely academic and non-actionable for the average utility. Studies addressing challenges presented by novelty and uncertainty that is core to innovation along the lines of research by Thayer, et al. (2018)[243] within the electric sector is ripe for further research.

For example, participants in this study spoke in very positive terms of SmartSacramento colleagues being "decisive" and "visionary" and generally antithetical to the "consensus" relied upon to make decisions. The consensus culture acknowledged and uniformly scorned by SMUD interviewees raises an interesting question: is this a "bad" thing? It has developed over time at SMUD for a reason. What are those reasons and, applying paradox theory, might lessons underlie another paradox SMUD could leverage to its advantage.

Research conducted by Rothman and Melwani (2017) on emotional ambivalence – feeling pulled in different directions, feeling uncertain, having mixed emotions – posits that "leaders experience emotional complexity in the face of contradictions between stakeholders and demands."[244] Uncertainty and difficulties may help people be "cognitively flexible," which refers to thinking more broadly about concepts in comprehensive and inclusive manners.[245] In other words, perspectives on decisiveness may inadvertently be undermining accuracy in judgement when making decisions. The consensus that SMUD teams revert to in their decision-making, paradoxically, could have adaptive characteristics conducive to organizational innovation.

VIII. CONCLUSION

As part of the study, participants were asked via email to complete the following statement: "SMUD is in the business of **________**." The following represent the responses provided: providing reliable electricity service at reasonable rates; making sure that our customers have cheap and reliable power; continuously innovating solutions to meet our community's evolving energy needs.

Such statements are accurate in that they describe purposes SMUD serves as a municipal utility. It is noteworthy how concepts such as "cheap and reliable power," as conflicting and contradictory as they may be, are normal to those at SMUD. Given the findings from this research, an argument could be made that as

243. *See* Amanda L. Thayer et al., *Addressing the Paradox of the Team Innovation Process: A Review and Practical Considerations.*, 73 AM. PSYCH. 363 (2018).

244. Naomi B. Rothman & Shimul Melwani, *Feeling Mixed, Ambivalent, and in Flux: The Social Functions of Emotional Complexity for Leaders*, 42 ACAD. MGMT. REV. 259, 264 (2017).

245. *Id.* at 269 (summarizing research suggesting on the one hand that state emotional complexity can lead to more cognitive flexibility, and other literature suggesting that emotional complexity can lead to more rigidity). What appears to differentiate these two paths the researchers noted is whether individuals become preoccupied with trying to cope with and reduce their feelings of conflict and contradiction or whether they stay open to their contradictory feelings. *Id.*

far as innovation is concerned, a utility such as SMUD engaged in the type of company-wide innovation endeavors such as SmartSacramento is in the business of "managing tensions to innovate."

Innovation at the scale needed to decarbonize utilities being undertaken by utilities nationwide involves substantial investments of labor and financial resources. SMUD is one of thousands of U.S. public power systems who likely share many of the organizational tensions revealed by the utility professionals interviewed for this research. The question for these utilities is whether they can find ways to make their paradoxical worlds work for them to realize a lower carbon future.