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# BIDEN SCHOOL JOURNAL of PUBLIC POLICY



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# RESEARCH ARTICLES

# EDITORIAL

***BIDEN SCHOOL JOURNAL OF PUBLIC POLICY (Biden School – JPP - formerly called New Visions for Public Affairs, NVPA)* is an interdisciplinary, student-produced, peer-reviewed journal that publishes scholarly material offering new perspectives on public policy and administration. We operate as a student organization within the Biden School of Public Policy and Administration at the University of Delaware.**

## Instructions for submissions

Biden School – JPP produces an annual volume, which is made publicly available at https://sites.udel.edu/cas-nvpa. Individuals interested in submitting manuscripts to Biden School – JPP should abide by our "Guidelines for Submission and Publication," which you can download from https://sites.udel.edu/cas-nvpa/submissions.

Submissions related to all public policy and administration related topics are encouraged, but preference will be given to those that:

- Pertain to relevant and current policy issues
- Provide insightful and novel perspectives to frame policy problems
- Use evidence-based approaches to recommend innovative solutions
- Rely on systematic methodologies and analysis
- Make meaningful contributions to the academic discourse in public policy

Submissions may take the form of; research articles; position papers, commentaries, opinion pieces, book reviews, data visualizations and images, practical experiences, and policy briefs. Submission should be no longer than 25 pages in length, should define clear research objectives/questions, and provide a summary of findings and conclusions. All papers must be submitted in APA style and include in-text citations, a full reference list, and an abstract of not more than 250 words.

After review, the authors are notified of the publication decision. Accepted submissions then receive comments from the Biden School – JPP Editorial and Faculty Boards. The Editorial Board may require each author to sign a publication agreement and may return articles for multiple rounds of revision. The publication agreement may be rescinded if changes made during the editing process are determined to be unsatisfactory by either the board or the author.

***Please address all correspondence to:***

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Biden School of Public Policy & Administration, University of Delaware
111 Academy Street
184 Graham Hall
Newark, DE 19716

***Email:*** nvpajournal@gmail.com
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## Note From The Editors

The 2019-2020 Biden School – JPP Editorial Board is pleased to present the twelfth (12th) volume of Biden School – JPP *(formerly, New Visions for Public Affairs – NVPA).* The articles in this volume were authored by current or former students of the University of Delaware's Biden School of Public Policy and Administration. The content of this journal is reflective of a wide range of topics and methods that students are exposed to during the course of their study programs. It further showcases interdisciplinary research on pressing public policy issues ranging from flood risk management as a driver of public policy in Europe; the dangers of gerrymandering as an ongoing threat to voter equality and fairness to energy efficiency, and the opportunities of battery energy storage systems in the U.S electricity sector.

This publication represents the 12th anniversary issue of the Biden School – JPP, a significant milestone for the students, staff, and faculty members involved in the process of its compilation every year.

Our exceptional editorial board consistently provided feedback and support to the authors, helping them polish their work into structured policy briefs and analytical papers. The Editorial board was led by Danielle Littmann (Executive Director) and Robert Ddamulira (Editor-in-Chief) and included the following members; Momar Cisse; Rebecca Cox (Becky); Eileen Young; Margaret Chesser; Simone Adkins and Pravesh Raghoo. The excellent collaboration between the authors and the Biden School JPP Editorial board was complemented with a dedicated team of faculty board and other faculty members of the Biden School. We are grateful to our faculty board for all the support they provided, these include Prof. Maria Aristigueta (Director of Biden School), Prof. Jonathan Justice, Prof. John McNutt, Prof Leland Ware, Prof. Jane Case Lilly, Prof. Ismat Shah, Prof. Lawrence Agbemabiese, Prof. Yanich Danilo and Prof. Daniel Bottomley. Other Biden School faculty and staff also provided significant support for which we are grateful; these include; Sarah Pragg, Cynthia Brong, Crystal Nielsen and Prof. A.R. Siders. We are also grateful for the support we received from the UD Press team, including Julia Oestreich (Director), Paige Morgan, Alex Galarza.

Lastly, we welcome applications to fill open positions on the Editorial Board for the 2020-2021 academic year, as well as submissions from continuing and incoming students. For more information, please visit our website at www.sites.udel.edu/cas-nvpa, or email us at nvpajournal@gmail.com.

Enjoy the read!

**Robert Ddamulira**
*Editor-in-Chief*

**Danielle Littmann**
*Executive Director*

# Letter From The Director Of Joseph R. Biden School Of Public Policy & Administration

The student journal was started in 2008, my first year as Director of the recently named Joseph R. Biden, Jr. School of Public Policy and Administration. At the time, we had a PhD student named Kerrin Wolf who was a lawyer and was familiar with student-run journals from his law school experience.

A small committee was established to write by-laws and start the journal with a student editorial board and a group of faculty advisors. Most years, the leadership of the journal has gone to a PhD student in the Urban Affairs and Public Policy program. In 2019-2020, the leadership was assumed jointly by a PhD student in Energy and Environmental Policy, Robert Ddamulira, and a Master's in Public Administration student, Danielle Littman.

A particularly well dedicated and committed group of editors have served on the board this year. The changes that they have implemented will have long term effects on the professionalism of the journal. This includes a name change to the Biden School Journal of Public Policy (JPP) from the New Vision in Public Affairs (NVPA) and, a much larger faculty advisory board.

The larger faculty advisory board has allowed for more specialized and diverse expertise from the faculty and includes Jonathan Justice, Leland Ware, John McNutt, Danilo Yanich, Jane Case Lily, Dan Bottomley, Lawrence Agbemabiese and myself, Maria Aristigueta.

Much credit should be given to Danielle Littman and Robert Ddamulira for their tireless leadership of the board and journal. The students who served on the editorial board and spent a great deal of time working with those who submitted manuscripts to make sure editing occurred before it went to the faculty board: Momar Talla Cisse, Rebecca Cox, Eileen Young, Pepper Chesser, Simone Adkins, and Pravesh Raghoo. And last but not list, Cindy Brong who provided administrative support to the Journal.

I congratulate the editorial board and the authors of the timely articles on the production of the Biden School Journal of Public Policy and Administration and I wish you all a nice reading of the excellent scholarship from our students which is contained in these pages.

**Prof. Maria P. Aristigueta**

Director, Joseph R. Biden School of Public Policy and Administration

**Charles P. Messick Chair for Public Administration**

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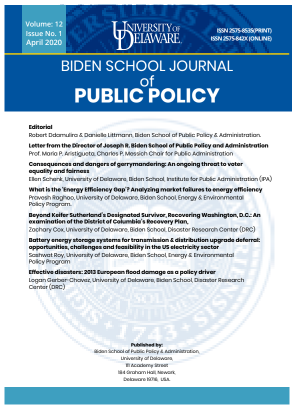

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# Consequences and dangers of gerrymandering: An ongoing threat to voter equality and fairness

**ELLEN SCHENK**, University of Delaware, Biden School, Institute for Public Administration (IPA)

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**ABSTRACT**

Despite the many movements and organizations dedicated to fighting against gerrymandering, gerrymandering and its various forms remain a current issue in elections. While gerrymandering has been an issue consistently brought before the Supreme Court, there has been no established measure to identify a gerrymandered district. There is a broad scope of literature surrounding suggested measures, such as the efficiency gap, the mean-median gap, and the seats-to-votes curve. Gerrymandering presents a clear and present threat to the equality of elections due to the lack of competition and an unfair process of redistricting. Reforms such as guidelines for commissions and the 2020 census need to be undertaken to ensure a fair and just reapportionment process.

## 1.0 INTRODUCTION

In his 2016 State of the Union, President Barack Obama warned of the dangers of gerrymandering and called for change:

But, my fellow Americans, this cannot be my task—or any President's—alone. There are a whole lot of folks in this chamber who would like to see more cooperation, a more elevated debate in Washington but feel trapped by the demands of getting elected. I know; you've told me. And if we want a better politics, it's not enough to just change a Congressman or a Senator or even a President; we have to change the system to reflect our better selves. We have to end the practice of drawing our congressional districts so that politicians can pick their voters and not the other way around. (The White House, 2016).

Gerrymandering, or the deliberate drawing of election district lines to skew an election, is a continuous threat to fair elections. Although efforts have been made to reduce its occurrence, gerrymandering still occurs at all levels of government. This research article aims to explain different types of gerrymandering, ways to identify it, and suggest how to reform the system to avoid unfair elections. The article starts with a background, then provides a brief review of literature, followed by analysis and discussion, and finally, the conclusion.

# 2.0 BACKGROUND

## 2.1 History of Gerrymandering

The term "gerrymandering" is a combination of "salamander" and the last name of Elbridge Gerry, the governor of Massachusetts in 1812, who signed into law a plan to change voting districts to benefit his political party (Barasch, 2012). Gerry, a Republican, was upset that the Federalist Party was critical of James Madison's foreign policy, so he created a reapportioning plan that favoured the Republicans and concentrated the Federalists into a few districts (Davis, 2017). As a result of this plan, the Republicans won 29 seats, while the Federalists won 11. A month after the law was passed, the *Boston Gazette* published a map of the districts, comparing its shape with that of a salamander and coined it a "gerrymander" ("The Gerrymander. A New Species of Monster," 1812). It was then that an important election term was born.

## 2.2 Current Laws Relevant to Gerrymandering

### 2.2.1 The Voting Rights Act of 1965

The Voting Rights Act of 1965 (VRA) is a federal law that ensures that legislatures at all levels of government reflect the racial and ethnic diversity of the people they represent. It prevents state and local governments from drawing lines that prevent minorities from electing a candidate of their choice. It also prevents racially polarized voting, which is when all the minorities vote for their candidate that they want to win, and all the majorities vote for their candidate (Pérez & Agaraharkar, 2013). There are two relevant sections of the VRA. Section 2 states that if there is racially polarized voting and if a minority opportunity district can be drawn, then it must be drawn. Section 5 states that certain jurisdictions must clear any electoral changes with the Department of Justice or the District Court of DC before being implemented (Department of Justice, 2011).

### 2.2.2 "One person, one vote."

The concept of "one person, one vote" was first articulated in the Supreme Court case *Reynolds v. Sims*. In this case, the Court held that a failure to update boundary lines after changes in population violated the Equal Protection Clause (Ruley, 2017). In the majority opinion, Chief Justice Warren questioned how "one person [can] be given twice or ten times the voting power of another person in a statewide election merely because he lives in a rural area or because he lives in the smallest rural county… all who participate in the election are to have an equal vote" (Warren, 1964). This standard of voter equality and equity is a common theme in the Supreme Court cases that have challenged gerrymandered districts.

# 3.0 LITERATURE REVIEW

## 3.1 How Lines Are Drawn

### 3.1.1 State legislatures

The majority of states leave the power to draw district lines to the state legislature. Members are in charge of passing laws to create boundaries. Just like any other law, the governor can be allowed to veto. There are currently 30 states who are responsible for drawing state legislative districts, and 31 states responsible for drawing congressional districts (Brennan Center for Justice, 2019).

### 3.1.2 Commissions

Some states use different types of commissions in the redistricting process. While the commissions and their level of authority vary among states, legislators may still have a say in the process. Four states currently use advisory commissions to draw congressional districts. Advisory commissions have no authority to draw lines, but their guidance is supposed to influence the decisions made by the legislature. Members are to be independent of the legislature itself, so they provide objective and ethical perspectives to advise on the process. The government can decide to listen to or ignore the commission's suggestions completely. (Ruley, 2017).

True to their name, independent commissions consist of members who are in no way associated with the legislature. Some states mandate that members have a waiting period to run for office, if they wish, after serving on the commission (The Conference Board, 2018). Members are chosen by officials of the political parties in the state. Legislative commissions, on the other hand, consist of elected officials. For example, in Arkansas, members of the legislative commission are the governor, Secretary of State, and the Attorney General. In New Jersey, five members of each party serve on the commission (Levitt, 2010). While still separate from the legislature, the political views and ideologies of the members can still cloud their judgement, thus causing additional issues (Ruley, 2017).

Finally, there are backup commissions, which are used by three states for congressional districts and five states for state legislative plans. Backup commissions are a "failsafe" if the legislature does not reach an agreement. The backup commission may consist of the governor's plan, the plan of specific legislative actors, another elected or appointed official or a mixture. This commissions "serves as both an incentive for the legislature to reach a consensus and as a means of ensuring that the redistricting process does not end in gridlock" (Ruley, 2017).

### 3.1.3 Alternatives

There are additional possibilities and proposals as to who should be involved in drawing maps. Some include letting computers or algorithms draw lines, having citizen commissions where the members are selected by random, or even employing a commission of retired judges who are chosen randomly as well (Proposition 77: Redistricting Initiative Constitutional Amendment, 2005). It is essential that whatever way a state decides to redistrict, that it is done fairly and impartially to avoid bias or ill intent.

## 3.2 Types of Gerrymandering

### 3.2.1 Partisan Gerrymandering

Partisan gerrymandering occurs when one political party benefits by redistricting. Since lines need to be redrawn every 10 years, the party that has control over the legislature during this process will most likely create maps that will help them to remain in power. There are two ways in which partisan gerrymandering occurs. Cracking is when the votes of the opposing party are divided into districts to constitute a minority in each of them, making it impossible to win a majority. On the other hand, packing is when voters of the opposing party are concentrated in a few districts so that they win those but are unable to win overall (Royden, Li, & Rudensky, 2018). As the Brennan Center for Justice argues in their study of congressional elections from 2012-2016, partisan gerrymandering undermines the "one person, one vote" standard by promoting a political landscape that encourages election results that may not reflect a party's share of statewide voters (The Conference Board, 2018). The Brennan Center attributes a net gain of 16 Republican House seats between 2012-2016 to partisan gerrymandering (Royden & Li, 2017).

### 3.2.2 Bipartisan Gerrymandering

There may be situations where control of the state legislature is divided between parties, or the governor is of a different party than the legislature. When this occurs, members of the government have an incentive to work together to manipulate the election in their favour by reducing competition. Since incumbents were elected before, they try to maintain the same map while also swapping voters who are unlikely to vote for them with those likely to. Cracking and packing may also be used here, but they may not be as obvious (Royden et al., 2018).

### 3.2.3 Prison Gerrymandering

Prison gerrymandering is the result of mass incarceration and unfair census guidelines that disadvantage low-income minorities. The census determines updated population numbers, which are used for reapportionment. The census has a "usual residence rule" which states that people will be " [counted] at their usual residence, which is the place where they live and sleep most of the time" (United States Census Bureau, 2010). As such, prisoners are counted where they are incarcerated. Michael Skocpol argues in his Stanford Law Review note that the consequences of prison gerrymandering are threefold. First, the prisoners' home communities suffer since their democratic representation is eroded – the population may be much lower since prisoners are not being counted as living in their home. Next, prisoners are being used to inflate population numbers. Prisoners in many places cannot even vote, but they are being counted as equal constituents with those who can.

Lastly, Skocpol identifies distortive effects: "Mass incarceration results in districts where representatives tend to favor policies that favor even more mass incarceration" (Skocpol, 2017). A rule was enabled by the Census in 2010 to adjust for prison populations, but it was not used. Some argue that administrators at prisons will be burdened because they will need to collect more information from prisoners (Ebenstein, 2018). There has been no change in the way prisoners are counted for the upcoming 2020 census.

## 3.3 Identifying Gerrymandering

### 3.3.1 The Efficiency Gap

The efficiency gap was first introduced by Nicholas Stephanopoulos and Eric McGhee in their paper *Partisan Gerrymandering and the Efficiency Gap* as the difference between the parties' respective wasted votes in an election divided by the total number of votes cast. Votes are considered to be wasted if they were cast for the losing candidate or are additional votes cast for a winning candidate beyond the threshold needed to win. In other words, wasted votes are the sum of lost and surplus votes.

One of the benefits of the efficiency gap is that it can be determined for any district plan, no matter how gerrymandered the state as no additional information is needed besides the election results. An example of perfect partisan symmetry would have the same number of wasted votes, resulting in no efficiency gap.

Stephanopoulos and McGhee calculated the efficiency gap for state and congressional house plans between 1972 and 2012 and came up with interesting results. While they found that the majority of plans hovered around an efficiency gap of zero, recently, plans have been tilted in the pro-Republican direction. Also, they looked specifically at the efficiency gap of districts named in gerrymandering litigation. They found that they had a relatively small measure, indicating that according to the efficiency gap, these districts may not have been truly gerrymandered.

Potential limitations discussed regarding the efficiency gap include the instability of the metric over time, uncontested seats, and strange results that occur when a district is extremely partisan, which occurs when a party receives more than 75% of the vote across the state (Stephanopoulos & Mcghee, 2016).

### 3.3.2 Seats-to-votes curve

The seats-to-votes curve was pioneered by Gary King and Edward Tufte in the 1980s and revisited by Nicholas Goedert in 2014 in his analysis of the 2012 congressional elections. Gary King identified the pitfalls with previous attempts to measure unfair voting practices and created a formula to model historical share of votes won by a party based on that party's statewide vote share. King was able to measure partisan bias and democratic representation by fitting a curve to the relationship between a party's average share of the statewide vote and its share of seats in a statewide congressional delegation. Once an election happened, the actual seat share as compared to the expected seat share, and discrepancies may have been the result of gerrymandering (King & Browning, 1987).

Nicholas Goedert took King's model of expected responsiveness of seats and imputed a slope that is the average for all congressional elections since federal equal-population districts were implemented. Goedert found that in 2012, in every state where Republicans controlled redistricting, Democrats won fewer seats than expected based on historical patterns. In six cases, states underperformed by 20% or more. He concluded that Republicans cost Democrats nine seats as a result of the maps that they drew. Goedert recognized limitations to his model as it fails to account for incumbency playing a role in elections as well as unequal population distribution (Goedert, 2014).

### 3.3.3 Mean-median gap

First proposed by Michael McDonald and Robin Best in 2015, this metric focuses on the consequence of unequal voting rights as a result of gerrymandering. Simply, the symmetric vote bias is equal to the difference in the median district percent minus the mean district percent. This measure may be preferred compared to the seats-to-votes curve because it is an observed measure and more transparent. While the seats-to-votes curve is beneficial because it looks at historical data, it may be too complicated for the less-scientifically or data-inclined. The mean-median difference is one number with a straightforward interpretation.

# 4.0 ANALYSIS AND DISCUSSION

## 4.1 Why do redistricting and gerrymandering matter?

### 4.1.1 Politicians choose their voters

Politicians who control redistricting are given the power to decide who will be voting for them. In a bipartisan gerrymander, legislators try to draw districts to encompass those who will vote for them and replace those who will not. Due to the increased availability of information about voters and advancements in technology, politicians can precisely draw lines to maximize their chances of winning (The Conference Board, 2018). As such, the election becomes less about who can appeal to voters, who has the best policies, and who represents the majority of the people. A shift in voter ideology will most likely not be reflected in who wins the election because a party's share of voters in a state does not translate into legislative representation in gerrymandered districts.

### 4.1.2 Non-competitive elections

Incumbency reelection rate in 2018 in the House of Representatives was 91% (OpenSecrets.org, 2019), this is nothing new: An editorial 15 years ago argued that "both parties have succeeded in drawing district lines in ways that cement their current power by eliminating contested elections"("Elections with No Meaning," 2004). Still, if there is an expectation about who will win an election, people will be even less likely to vote. In the United States, voter turnout is already much lower compared to other established democracies. Belgium, Sweden, and Demark have turnout rates of well over 80% of registered voters (Desilver, 2018). The uncompetitive nature of elections means that citizens are not participating in the civic engagement process. The two main political parties are disincentivized to compromise, leading to distortion and the powerlessness of citizens' votes.

## 4.2 Other Potential Causes

Despite evidence to the contrary, some argue that gerrymandering is unintentional or the result of where people choose to live. Even with independent commissions or bipartisan efforts, gerrymandering may take place accidentally. For example, commissions sometimes are unaware of the demographic characteristics of an area to avoid racial gerrymandering. However, it could still take place unintentionally. Citizens of similar race, socioeconomic status, ideology, and lifestyles tend to live in common geographic areas. In major cities, the centre is usually dominated by Democrats, whereas Republicans cluster in suburban and rural communities (Chen & Rodden, 2013). These patterns of human geography, where one party's voters are more geographically clustered than another's, could also influence the outcomes of elections if district lines are drawn to preserve communities.

## 4.3 Suggestions for Reform

### 4.3.1 Independent commissions

Out of all of the ways possible to draw lines, independent commissions seem to be the most impartial. However, these commissions must have relevant characteristics to ensure autonomy and fairness. Commissions should be leaders in the process, be independent of the legislature, and have limits on how soon members can run for office after serving. They should have access to demographic information to avoid unintentional gerrymandering and guarantee compliance with the VRA. The process should be transparent to the public. Only the commissions should be responsible for drawing maps, and they should have nonpartisan staff and nonpartisan funding (The Conference Board, 2018; Zellner & Nierzwicki, 2014).

### 4.3.2 Prisoners

There must be new standards adopted by the Census Bureau and state governments to count prisoners in their home communities rather than as members of prison communities. Not doing so inflates the representation of mostly white, rural communities where prisons are located at the expense of minority communities due to the drastic racial disparities in who is incarcerated (Skocpol, 2017). Representational equality is a right that the Supreme Court agrees within their assertion of "one person, one vote," so prisoners should be able to share that right with their community. There needs to be more legislation around prison gerrymandering. Delaware, Maryland, New York, and California have already taken action to make changes (Prison Gerrymandering Project, 2018), and more states need to follow.

### 4.3.3 2020 Census

Since reapportionment is based on census numbers, the accuracy and integrity of the count are integral to the redistricting process. There are plans to offer online completion options to some citizens. Still, the high cost of this approach will leave the Census Bureau without adequate funding to certify high-quality data collection. This lack of money has meant that the Bureau has failed to complete preparation projects in anticipation of the 2020 count (The Conference Board, 2018). The proposal of a citizenship question to the census could mean a much lower response rate and thus an inaccurate count. Adequate leadership, funding, and appropriate questions that do not disadvantage specific populations are vital since the census is so essential to redistrict.

## 5.0 Conclusion

In recent years, the political climate seems to have become increasingly more divisive. The polarization of voters and legislatures is only exacerbated by the unequal division of votes to benefit the party in charge. Gerrymandering undermines the voting process, often at the expense of minority populations and other disadvantaged groups. Laws need to be created, using appropriate and proper methods, to directly address the abuse of power by the ruling political party to restore fairness to the election process. Without them, elected officials will not represent the majority or reflect potential changes in the ideological landscape of the constituents. It is up to political parties to work together to construct unbiased and equitable districts to ensure that voters can elect the candidate who will best represent them.

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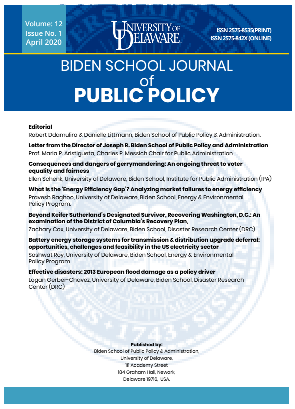
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# What is the 'Energy Efficiency Gap'? Analyzing market failures to energy efficiency

**PRAVESH RAGHOO,** University of Delaware, Biden School, Energy & Environmental Policy Program (ENEP)

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**ABSTRACT**

Energy efficiency is key to establishing a sustainable and clean environment for present and future generations. Without initiatives to develop energy efficiency, there are doubts that the path towards greater sustainability can ever be achieved. The literature on energy efficiency has long demonstrated the presence and persistence of an 'energy efficiency gap.' This paper examines the nature and size of this gap, identifies vital explanatory factors, and explores approaches by which to bridge the gap between potential and actual improvements in energy efficiency for sustainable development.

## 1.0 INTRODUCTION

Over the last several decades, a large body of literature seeking ways to alter energy consumption and production, and to improve energy efficiency and conservation approaches, has been developed. Research has been undertaken in nearly all sectors where energy is utilized, namely, in industrial facilities and manufacturing sectors (Abdelaziz et al., 2011; Rohdin & Thollander, 2006; Tanaka, 2011, Hasan et al., 2019), in the household sector (Chegut et al., 2016; Copiello, 2015; Thondhlana & Kua, 2016), and in building services (Abu Baker et al., 2015; Hou et al., 2016; Fossati et al., 2016; Tan et al., 2016) just to name a few.

Research has focused on countries from "developed" to developing, including Sweden, Vietnam, Indonesia, Brazil, the United States, China, Bangladesh, and others. This research is in an array of fields, ranging from technological aspects of energy production (Xu et al., 2016) to policy-based studies (Bird & Hernandez, 2012; Geller et al., 2006; Schleich, 2009; Viholainen et al., 2016), behavioural attitudes and consumer responses to energy efficiency policies (Ma et al., 2013; Lopes et al., 2012; Wijaya & Tezuka, 2013), and economic aspects of energy efficiency (Cantore et al., 2016; Linares & Labandeira, 2010; Gillingham et al., 2009; Jaffe et al., 2004).

Energy efficiency has gathered international interest as it can mitigate the effects of climate change and meet international obligations, to increase resilience against energy security issues, to improve industrial competitiveness and reduce production costs, and to reduce air pollution and improve human health, among other benefits at both micro and macroeconomic level (IEA, 2010).

Despite considerable research in the area of energy efficiency, it is noted that consumers and businesses do not always adopt cost-effective energy efficiency measures and technologies to the degree that is considered justified on a financial basis (Gerarden et al., 2015). This gap between consumer demand and the existing financial rationale exemplifies the existence of an 'energy efficiency gap' — the difference between actual use and optimal use of energy (Hirst & Brown, 1990; Jaffe & Stavins, 1994; Gerarden et al., 2015), this arises because of economic failures in the energy efficiency market (Allcott & Greenstone, 2012; DeCanio, 1998; Rohdin & Thollander, 2005; Sanstad & Howarth, 1994; Stadelmann, 2017).

This energy efficiency gap necessitates examination and assessment for accurate decision-making and the design of conducive energy policy interventions in the energy efficiency domain. Therefore, this article examines the origin and causes of the energy efficiency gap. The article reviews the literature to identify five energy efficiency market failures: (i) asymmetric information, (ii) split incentives and the principal-agent problem, (iii) externalities, (iv) poor regulatory policies, and (v) behavioural 'anomalies', which contribute to the energy efficiency gap. This article thus contributes to the ongoing debate on energy efficiency market failures. It provides a concise review to policymakers and other interested stakeholders an understanding of the complexity behind the 'energy efficiency gap.'

## 2.0 ENERGY EFFICIENCY MARKET FAILURES

The rich literature on energy efficiency depicts numerous barriers that are hindering energy efficiency measures. Market failures can be defined as any flaw that causes an economy to deliver an outcome other than the efficiency maximizing level, leading to a social welfare loss (Gruber, 2011, pp. 3). These are caused by violations of the assumptions made in neoclassical economic theory, which include asymmetric information, split incentives, negative externalities, and distortional regulatory policies (Brown, 2001; Jaffe & Stavins, 1994; Stadelmann, 2017). Neoclassical economic theory also assumes that consumers are rational individuals with stable preferences. However, the novel area of 'behavioural economics' research has identified inconsistencies in consumer behaviour that deviate from the utility–maximization model, forcing consumers to make some irrational decisions (Lopes et al., 2012). These behavioural 'anomalies' can also be regarded as a type of market failure. The literature also discusses 'market barriers', which are defined as any impediments that slow the rate of diffusion and adoption of energy efficiency measures and technologies, despite their cost-effectiveness (Brown, 2001; Jaffe & Stavins, 1994). However, 'market barriers' are likely to be derivatives or 'side-effects' of market failures as most originate from them. Market failures are discussed in the sub-sections below.

### 2.1. Market failure 1 – Asymmetric information

Suboptimal investment in energy efficiency occurs due to asymmetric or incomplete information or if obtaining information is too costly (Brown, 2001; Sanstad & Howarth, 1994). Since energy is consumed in terms of the services it offers and information about energy consumption is not readily available to consumers, it is difficult for them to obtain an estimation of their consumption and associated cost, this leads to energy efficiency getting little priority over investment or purchasing decisions (DeCanio, 1993; Trianni et al., 2013; Thollander et al., 2007). Asymmetric information also leads to uncertainties and increases the level of financial risk between stakeholders of any given transaction (Schleich & Gruber, 2008). For instance, a borrower seeking capital to make a high investment in an energy efficiency project can find his application rejected if the lender is not a risk-taker. For some efficiency technologies, in the industrial sector, in particular, the investment cost is high, this creates liquidity constraints and leads to difficulties in securing finances for energy efficiency projects.

There is evidence of asymmetrical information hindering development in energy efficiency. Ma et al. (2013) showed that citizens of Chongqing, China are willing to save energy provided that their level of comfort is not compromised and that their level of information and guidance on the subject is limited. Meyers (2018) revealed that in a situation where tenants lack information, and it becomes difficult for landlords to capitalize energy efficiency investment into higher rents, landlords underinvest in energy efficiency in the housing rental market in the U.S. Brown (2004) used the example of cases in which vehicles may have the same level of energy efficiency, however, the consumer is unable to identify which is more energy-efficient. There is also empirical evidence which shows that the lack of access to energy information on consumer products can lead to under-investment in energy efficiency (Ward et al., 2011; Allcott, 2011; Davis & Metcalf, 2015; Houde, 2018; Newell & Siikamäki, 2013; Cattaneo, 2019), this implies that consumers require complete information in order for them to decide on investing in energy efficiency. This failure of transparency makes consumers worse off because it causes them to bear higher energy bills and lose trust in energy efficiency endeavours.

A special form of asymmetric information that arises when one party involved in a transaction has a greater level of information than the other one is the adverse selection (Akerlof, 1970). Suppose a buyer is looking for an energy-efficient house. Given that the seller has more information than the buyer, he can flaunt the merits of appliances or weatherization in the house, making the buyer worse off if the house is not as energy efficient as desired by the buyer. A study by Hyland et al. (2013) shows that in Ireland, property buyers and tenants are willing to pay more for energy-efficient properties, this provides an incentive for realtors to increase the selling price or rent of such more energy-efficient properties. Empirical evidence of adverse selection has also been found by Qiu et al. (2017), where households having low energy consumption during peak hours voluntarily enroll for Time-of-Use pricing programs, this implies that utility companies might undergo a net loss in revenues, which will be passed onto consumers and subsequently undermine the progress for the whole program.

To overcome asymmetrical information problems, the simplest solution is to provide adequate information to consumers for them to make informed decisions concerning the purchase of energy-efficient goods or consumption of energy. The provision of information is expected to induce consumers to make more rational decisions and reduce transaction costs (Sanstad & Howarth, 1994), this can be done in many ways, namely through product labelling, feedback programs, or energy audits. Though there seems to be a consensus that all these policies are adequate, it is still debated how efficient these measures are in altering consumers' energy consumption patterns or the adoption of energy efficiency products. There is evidence that consumers tend to consider appliances' labelling when making purchasing decisions, though the influence of the energy efficiency factor is not clear yet (Cattaneo, 2019).

Newell & Siikamäki (2013) found that information on the physical energy consumption of an appliance guide purchasing decisions, even though financial information remains a higher priority. Ward et al. (2011) showed that consumers are willing to pay higher prices for ENERGY STAR products, but willingness to pay decreases with age and is different between genders. Murray and Mills (2011) found that willingness to pay for products is also different based on socioeconomic status and ethnicity. Countries like the United Kingdom, the United States, and Ireland have moved a step forward by establishing appropriate indices that show the energy efficiency attributes of a property. However, Carroll et al. (2016) found that the index is under-utilized by potential renters in Ireland.

Other studies have discussed the importance of feedback on energy consumption to inform consumers better, but results have been mixed (Fischer, 2008; Schleich et al., 2013; Allcott, 2014; Ayres et al., 2012). In Linz, Austria, Schleich et al. (2013) showed that feedback on electricity consumption had increased electricity savings by 4.5% and cost savings of some $30 (USD) annually. Ayres et al. (2012) showed that feedback reports to customers have led to a reduction of energy consumption by 2.1% in Sacramento, California, and 1.2% in Puget Sound, Washington. They also demonstrated that this decrease is sustained over months (12 months in Sacramento and seven months in Puget Sound). However, Allcott & Rodgers (2014) showed that while feedback reports spur energy conservation in the short-term, over time, customers get accustomed to receiving reports and eventually efforts to decrease energy consumption decay, this is not to say that the strategy of providing feedback forms to consumers is not working, but rather that a better formulation of this strategy is needed for it to provide long-term positive effects. On a short-term basis, this strategy seems to be providing positive results.

In the industrial and small to medium business sectors, some countries have implemented energy audit services, which act as decision-making support for firms to make more accurate decisions on their anticipated energy consumption. In response to economic incentives, such as a subsidy, firms are willing to participate in energy audits. The adoption of energy efficiency measures is dependent on several factors, cost implications being the first. Fleiter et al. (2012) showed that the German energy audit program has been very effective in reducing carbon dioxide ($CO_2$) emissions. Studies also show that energy efficiency measures in small and medium-sized companies also required low investment costs making them more cost-effective than business as usual (Fleiter et al. 2012).

In the case of the United States, Anderson & Newell (2004) showed that energy audits have led to the adoption of over 50% of energy efficiency measures proposed by the auditor in manufacturing plants. The adoption of these measures was also greatly influenced by low implementation costs, short payback period, and economic incentives (Anderson & Newell, 2004). A prior study by Harris et al. (2000) made similar observations that Australian firms are likely to participate in energy audits, but that there are hurdles, mostly financial when it comes to investment. Thollander et al. (2007) and more recently, Kalantzis & Revoltella (2019), found similar results in the cases of Sweden and Europe, respectively.

## 2.2. Market failure 2 – Split incentives and the PA problem

Split incentives are regarded as a market failure and originate from the Agency Theory, and a situation commonly referred to as the principal-agent (PA) problem (Eisenhardt, 1989; Hirst and Brown, 1990; Gillingham & Palmer, 2014). The PA problem is driven by incomplete and asymmetric information, as discussed above. Due to information asymmetry between a 'principal' and an 'agent,' the principal has to bear the cost of an investment they did not make, allowing the agent to trade energy efficiency to reduced capital costs.[1] A classic example of the PA problem is the landlord and tenant example, where a landlord seeks to minimize capital costs in the house put to rent, and subsequently underinvests in energy efficiency. As it usually is difficult for tenants to have this information, they

1 To note that the PA problem is different from the free rider problem. In a free rider problem, the individual making the investment enjoy the benefits compared to the PA problem who do not.

have to bear the energy costs in their monthly energy bill for an investment they did not make (Case II in Fig. 2). Hence, the Agency Theory posits that the divergence in the objective of the landlord (whose objective is to minimize cost) and that of the tenant (whose objective is to minimize energy consumption and associated costs), as well as the fact that the tenant cannot verify or follow the actions of the landlord, constitutes a PA problem.

This situation produces three possible relationships between the principal and the agent, as given in Fig. 2, where Cases II-IV represents such a PA problem. For an owner (see Case I), the principal and the agent are the same individual and therefore chooses energy efficiency and pays for energy bills eliminating all kinds of market failures (IEA, 2007). Case III is a situation in which the landlord does not pay the energy bill, and the onus of paying the energy bill lies on the tenant. In this situation, the tenant has no incentive to reduce energy consumption (usage problem) or to invest in energy efficiency. Case IV depicts a condition where the marginal cost of the individual renting the place is zero, this posits a 'moral hazard' problem where the energy bill of the tenant is passed on to the landlord, and the renter has no incentives to reduce energy consumption, as the landlord pays for their energy bills.

| | The individual owns the place | Individual rents the place |
|---|---|---|
| Individual pays for energy costs | Case I: No PA problem (Principal and Agent same entity) | Case II: Efficiency problem (Agent chooses technology and principal pays for energy costs) |
| The individual does not pay energy costs | Case III: Both efficiency and usage problem | Case IV: 'Moral Hazard' problem (Energy costs are passed to the agent tied in an agreement) |

***Table 1 – Possible relationships between principal and agent ('landlord-tenant' example) (Adapted from IEA, 2007)***

Studies have provided empirical evidence of the problem and magnitude of split incentives. Levinson & Niemann (2004) showed that tenants use more heating and turn down the thermostats less when they are away from their homes. Therefore they recommended energy costs to be included in rents as landlord-led energy efficiency measures yielding greater efficiency in housing units. Gillingham et al. (2012) found that when landlords pay energy bills in California, tenants do not adjust their temperature accordingly, resulting in a higher energy use per unit area (energy intensity) in their homes. Similar findings were previously made by Maruejols & Young (2011) in landlord-energy included Canadian multi-family dwellings, where the latter set temperatures significantly higher and do not adjust temperature settings when the house is unoccupied, confirming the split incentive problem. Melvin (2018) confirmed the split incentives problem and found that tenants use 3.9% more natural gas, 1.2% more electricity, 2.2% more propane/LP, and 2.6% more fuel oil when landlords pay the energy bill.

Some authors (Bird & Hernandez, 2012; Charlier, 2015) have suggested solutions to the split incentive problem. These include enforcing public policies, such as a well-defined contract between landlord and tenant, concierge services, and regulations between the 'principal' and the 'agent.' The overarching solution in this context is the implementation of green building codes and confirmation that all housing units conform to some form of energy efficiency measure. Leadership in Energy and Environmental Design (LEED) is a type of building code implemented in the U.S. housing market to curb the magnitude of the split incentive problem. The issue, however, is that green building codes apply only to new buildings and exclude existing ones (Bird & Hernandez, 2012). Concierge service is another welcomed initiative where policymakers provide an "all-in" transformation of homes. Examples include the Green London Concierge Service and the British Columbia Green Landlords project. Concierge service models include weatherization upgrades in homes and other services, such as the provision of soft loans, grants, education, and other degrees of oversight (Bird & Hernandez, 2012). The problem with these solutions is that they require political support as well as significant financial resources, which are both challenging to secure (Bird & Hernandez, 2012).

## 2.3. Market failure 3 – Externalities

What happens when the price of a good or service does not capture the total cost of production? Production and consumption of goods and services affect people that are not part of a transaction, and when these effects are large enough, they can be problematic, this is what economists call 'externalities.' Externalities can be both positive and negative.

An externality is a consequence of an activity that affects other parties without being reflected in market prices. The use of an energy-inefficient technology (termed as a *black* technology) can thus be considered as a *negative externality* due to the pollution it produces from the consumption of a relatively large amount of energy when low energy technology is an option. In this respect, a *green* technology that produces lesser pollution levels can be considered a *positive externality*. Energy markets do not address externalities and thus lead to market failure. The use of a vehicle powered by gasoline, therefore, produces a negative externality from the pollution it produces, which is not reflected in the selling price of the gasoline or vehicle (consumers get a private benefit). The monetary effects of the pollution are borne by society as a whole, who has not demanded to incur these costs (society incurs a social cost). A zero-emission vehicle, on the other hand, produces a positive externality.

Government intervention can correct negative externalities by offering financial incentives like tax credits, rebates, tax deductions, or grants and loans for energy efficiency programs or the purchase of energy efficiency equipment. An additional financial incentive is the levying of an energy tax on an energy-inefficient technology. The idea is to invest in *green* technology less costly than one in *black* technology. Financial incentives, in many cases, have been considered adequate, as they are transparent and promote behavioral change among consumers (Cattaneo, 2019). However, taxes or credits have also been criticized for two reasons.

Firstly, the impact of an energy tax is limited if the price elasticity of energy demand is small; this is the current situation, according to a meta-analysis by Labandeira et al. (2017). As price elasticities of a variety of energy sources are inelastic, consumers are less responsive to price changes and taxes imposed to decrease the use of these energy sources, and the energy services these sources provide become less effective. Secondly, financial policy instruments are associated with a rebound effect. This is a phenomenon that increases energy efficiency, but energy savings are less than expected (Gillingham et al., 2016). In the example of Gillingham et al. (2016): "Buy a fuel-efficient car, drive more." The fact that the car consumes less fuel per mile travelled means that one can drive more, ending up using the same amount, or more, of fuel. Energy efficiency programs have often been criticized because of the rebound effect when these programs 'backfire' and result in higher energy use.

There are four ways in which the rebound effect manifests itself in energy efficiency, which are summarized in Table 1. Some studies have detected the presence of some form of a rebound effect. Davis et al. (2014) detected rebound effects in Mexico's *Cash for Coolers* (C4C) program to substitute air conditioners and refrigerators against a payment incentive given by the government.

Davis et al. (2014) found that there is no visible decrease in energy use when consumers change their refrigerators for a more energy-efficient one against a payment they receive from the government. In the case of households which have replaced their air conditioners, they found that these households have increased their consumption of energy, rather than reduce their energy use, as initially expected. The rebound effect, in this case, has caused a net reduction of $CO_2$ at $500 a ton and was deemed too expensive (Davis et al., 2014). In other settings, the rebound effect was also detected Alberini et al. (2016), where incentive takers replaced their heat pump with that of a higher size one when providing a tax credit, leading to a net increase in usage of energy.

The rebound effect figured in the scientific literature for long, but there is still some research needed to understand the rebound effect fully. Sorrell et al. (2009) have tried to provide some empirical estimates of the rebound effect, but as they acknowledged, their results are indicative rather than accurate and consistent. Hence, internalizing externalities come up with another set of issues which have to be carefully addressed during policymaking. These issues, however, should not be a distraction in progress towards more energy efficiency but rather a source of more significant action for the sustainable development of the world (Gilingham et al., 2013).

| Types of a rebound effect | Description |
|---|---|
| 'Direct' rebound effect | 'Direct' rebound effect occurs when an increase in the price of an energy service leads to an increase in the demand of the said energy service when the contrary should normally be happening. |
| 'Indirect' rebound effect | 'Indirect' rebound effect occurs when the money saved from an efficient energy service is used to purchase another energy service that is energy-intensive in its manufacture or use. |
| 'Macroeconomic' effects | *Effect 1*: One type of macroeconomic effect can occur when energy efficiency development increases in one sector cause opportunities in another sector, which consumes more energy.<br>*Effect 2*: Another way, if energy efficiency leads to a drop in a fuel economy like the United States, then global oil prices may drop too, and people globally might be encouraged to drive more. |

***Table 2: Types of rebound effect (Adapted from Gillingham et al., 2013)***

## 2.4. Market failure 4 – Poor regulatory policies

Another market failure often cited within the literature, which is slowing down energy efficiency measures is distortionary regulatory policies (Brown, 2001). Any investment is motivated based on social and economic goals, and with above-discussed market failures, a certain degree of risk management. Comprehensive energy policies are essential to keep any growth in energy efficiency going. An absence of a proper regulatory system can impede such development. Berg (2015) identifies ten critical functions of regulators who are responsible for creating a survival climate for energy efficiency policy programs, which can be broadly classified into administrative functions, organizational tasks, and policy and decision-making tasks. Among, a policy-making task of a regulator is to design policies favouring investment in energy efficiency, but the literature suggests some policies which do not favour the same. Previous researchers (Gillingham et al., 2009; Golove & Eto, 1996) point out the structure of energy pricing might promote underinvest in energy efficiency rather than optimal investment. As electricity prices are mostly fixed based on average costs (regulated price) rather than marginal costs (market price), and as average costs are below marginal costs, underinvestment in energy efficiency is more likely. To correct for this mispricing in energy tariffs, policymakers came up with Time-Of-Use (TOU) and real-time pricing (RTP) schemes where consumers can adjust their energy consumption based on time of use. However, there are few empirical studies that prove that these schemes favor energy efficiency and conservation.

Poor regulatory policies also reflect the inability of regulators to develop human resources. Studies have often highlighted that there is a lack of capacity and knowledge base to implement or monitor energy efficiency management systems in industries (DOE, 2015; Palm & Thollander, 2010; Raghoo et al., 2017; Timilsina et al., 2016; Trianni et al., 2013). Brown (2001) attributes the lack of education and training of practitioners due to the public good nature of education. Deviating from the classic definition of the public good of non-excludability and non-rivalry, the question of who has the responsibility to educate and form energy efficiency experts often surfaces. Some firms hesitate to invest in providing training and equip employees with new skills, and there is no guarantee that employees will work for the company till the time the company gets an adequate return on the investment made on the employee. There seem to be expectations that they mostly overlook training and education on energy efficiency to come from regulators. The question of who is going to provide training remains unresolved.

## 2.5. Market failure – Behavioral 'anomalies' and cognitive barriers

As mentioned above, the economic concept of utility-maximization assumes that consumers behave rationally; however, there are shreds of evidence that consumers do not behave rationally even though complete information is available (Lopes et al., 2012). From the literature, four market failures that arise because of individual preferences and behavior with regards to energy efficiency programs or investment decisions — in the energy efficiency jargon, behavioral 'anomalies' — can be identified. These are (a) time discounting, (b) positive illusions, (c) egocentrism, and (d) irrational behavior (Lopes et al., 2012; Stadelmann, 2017; Bazerman, 2009; Cattaneo, 2019).

### 2.5.1 Time discounting

Research has shown that we tend to put more emphasis on a high discounting rate and tend to overweight short-term considerations. For example, we would prefer to get $10,000 now, instead of $12,000 after a year — even though, if we wait for a year we will get more money. Still, human decision-making processes will favor more the money we will get in the present over the added benefits we might get in the future. This, in behavioral economics, is called being present bias. Time discounting reflects the level of impatience that we have as an individual and has been regarded as a cognitive barrier in adopting energy efficiency practices.

We tend to devalue future rewards for present gains. In the context of energy efficiency, since we have a high hyperbolic discounting rate, we are expected to be less willing to carry out energy-saving investments because we have little consideration of the benefits we might get from energy savings in the future. Fuerst & Singh (2018) show that in Delhi (India), individuals who are more patient and less present-bias are more likely to purchase energy efficiency appliances. Among other findings, Bradford et al. (2014) show that the more patient and less present biased individuals are more likely to use less air conditioning in the summer. It is not only as individuals that we tend to discount the future but also as an organization too. For example, Bazerman (2009) cites the case of construction works in a university where the organization has emphasized the reduction of current costs over the long-term costs of running the building, hence neglecting any investment in energy efficiency if that means higher costs.

The reasons behind the attitude that we, as humans, tend to discount the future because we are uncertain what the prospects of future cost savings are, or what are the risks associated with technical performance. Thus, people who are reluctant to take risks (risk-averse people) are less likely to adopt energy efficiency appliances, or retrofit their houses or choose hybrid cars, as some studies have revealed, as they are not sure what are the cost savings are and whether these savings justify present investments in energy efficiency. As Bazerman (2009) explains that we tend to 'over discount' the future when it comes to passing the costs to future generations, as we 'view them as vague groups of people living in a distant time.' Passing the costs to future generations is considered as being a low-stakes gamble which people prefer. This also explains why projects and policies on climate change mitigation are faced with much debate because some people think that it is not worth it to invest now for benefits that this generation will never get. As Bazerman (2009) said in his paper that, "overweighting the present can be viewed not as a foolish but also immoral as it robs the future generation of opportunities and resources" — a severe consequence of a high time discounting preference.

### 2.5.2 Positive illusions

People having 'positive illusions' tend to have a reverse effect when it comes to making decisions, especially in the context of energy efficiency. During the oil embargo, when oil prices hit $4 a gallon mark, it would be logical for consumers to reduce their automobile use. Still, people did not modify their consumption and were struck by the embargo. One reason that Bazerman (2009) advances for this occurrence is that we tend to have positive illusions about the future. Having positive illusions have benefits such as in improving self-esteem, increasing commitment to action, coping diversity, and persistence to face different tasks, but having positive illusions also reduces our quality to make conducive decisions and have a role in preventing us from acting on time (Bazerman, 2006). We tend to believe that the future will be better, and the problems that we face now will fade away soon. Researchers have found that this collective mindset of ours forces us to believe that the effects on climate change will be less significant than the scientific community perceives them to be. This compels us to take little action when it comes to climate change mitigation or adopting energy efficiency initiatives when, in a positive spirit, this way of thinking forces us to believe that we will be fine in the future, where the contrary might happen as with this belief we are not taking actions towards the safeguard of the environment and towards limiting climate change.

### 2.5.3 Egocentrism

According to Bazerman (2006, 2009), egocentrism is our tendency to make self-serving judgements regarding allocations of blame and credit, a phenomenon that in turn leads to differing assessments of what a fair solution to a problem would be. Bazerman exemplifies the egocentrism concept with the failure of the Kyoto Agreement. The Kyoto Protocol which was enforced in 2005 got mostly negative reviews because India and China which were the biggest carbon emitters (36% of the total global carbon dioxide) were excluded from the Kyoto Agreement under the principle of 'common but differentiated responsibilities,' and this was unacceptable by the United States which emitted 15% of carbon dioxide at the time. For then-President George W. Bush, enforcing the Kyoto Protocol meant that he has to launch the necessary mechanisms to decrease carbon emissions which might undermine growth for the United States, while the biggest polluters were exempted from the Agreement, but they will also get the benefits despite doing little to cater for their pollution level. Eventually, as the egocentric behaviour of the United States leads to nothing more than an unfair solution, we have seen that the United States withdrew too from the Agreement to join the two other polluters. These three accounted for almost 51% of carbon dioxide emissions that were left out without regulations. The central tenet of reducing carbon emissions was then on over hundreds of countries which contributed less than 50% of carbon dioxide; most of them contributed less than 1% of carbon dioxide to the global total.

For social scientists, the United States is looking at its benefits first and then to the benefits that a particular policy or program can impart to others. Psychologists will frame the failure of the Kyoto Protocol on the issue of egocentrism. Economists like Cattaneo (2019) will more likely frame this question as a 'free-rider' problem. For President Bush, the United States endorsing the Kyoto Protocol and working towards achieving its goals meant that China and India — which have no obligation to reduce greenhouse gases — will tend to 'free ride,' that is they will reap the benefits of the reduction of carbon dioxide which entirely come from the efforts done by the United States and other countries with targets, without any investment done by them.

The problem of egocentrism is exacerbated by the lack of conclusive scientific and technological information about a particular policy, and eventually reinforces the PA problem between a landlord and a tenant, highlighted earlier. A landlord will not invest in energy-efficient appliances in the house if energy bills are paid by the tenants as he will not reap the benefits of such investment — it is not in his/her self-serving interests to invest in energy-efficient appliances as he/she can use this investment on other projects where he/she gets a more direct return. This is another barrier to the adoption of energy efficiency in households.

### 2.5.4 Irrational behavior

The idea of rational behavior is rooted in different areas of study, including economics and sociology. Economics theories typically assume that individuals are rational decision-makers, working to obtain what is most beneficial to them with minimum investment. For instance, the economic theory posits that if the price of gasoline increases, the demand for gasoline will decrease; this assumes that humans are rational thinkers. However, when the price of gasoline increases that does not necessarily mean that people are going to reduce their consumption of gasoline — it might be that the person has a habit to drive his car and does not want to change or he is simply happy to drive, despite any increase in oil prices. These outlying events are not captured by neoclassical economics and tend to compromise the design of energy policies as well as its efficacy of policies.

More recent research on this topic tends to consider these behavioral irrationalities of people and how, outside of rational economic thinking, people make key decisions. With regards to energy efficiency issues, there are three general considerations, including (a) reference dependence, (b) rational inattention, and (c) bounded rationality (Cattaneo, 2019; Stadelmann, 2017), these are discussed below;

***(a) Reference dependence (or loss aversion)***

The fields of cognitive psychology and decision theory have well established the claim that consumers are more loss averse than gain averse, that is consumers tend to weigh losses more heavily than gains of equal magnitude and this has contributed significantly towards increasing the energy efficiency gap (Greene, 2011; Stadelmann, 2017). In the household sector for example, since there are uncertainties in future energy costs between an efficient and an inefficient appliance (depending on how the appliance is used or changes in energy prices, etc.), there is a probability that an efficient appliance can prove to be non-profitable in the long-term in retrospect (Greene, 2011; Stadelmann, 2017), this eventually leads to some households not investing in energy-efficient appliances and can have an overarching impact when it comes to other sectors.

### *(b) Rational inattention*

The idea of rational inattention most probably stems from the fact that we tend to rank the criteria which we depend on to make a purchase. Additionally, since energy is not visible, and the direct costs with its usage are not always known to the consumer, the energy consumption of an appliance is often overlooked. Studies have shown that energy requirements such as their electrical consumption and associated energy costs of an appliance do not figure among the top criteria that we consider to make a purchase which explains rational inattention. Allcott (2011) found that vehicle buyers do not consider fuel costs when buying a vehicle. It should also be pointed out that neglecting energy consumption of an appliance can be out of choice, or because of 'bounded rationality' (discussed hereunder). Rational inattention increases the energy efficiency gap, and the causes can be numerous such as buyers not knowing the importance of considering energy costs of an appliance or their willingness to ignore energy consumption indicators and focus on other decision criteria like brand, price of the appliance, etc.

### *(c) Bounded rationality*

When we do not have all the information available to us at the time to make a decision, we tend to depend on heuristics; that is, we tend to make decisions based on the information we have in hand and face cognitive constraints and limitations in doing so. This concept is known as bounded rationality. Since people do not have the full information on the energy consumption of an appliance, they are bound to undervalue energy and make purchases based on the information they have, this also explains why energy usage of an appliance does not figure among the top criteria of a purchase because, in the absence of details on the energy consumption of an appliance, we will depend on 'shortcuts' to make a decision. Lacetera et al. (2012) and Turrentine & Kurani (2007) have both found evidence that individuals resort to bounded rationality when deciding on the car market (but they did not find evidence that heuristics favor non-energy efficient cars).

## 3. CONCLUSION

To rectify market failures, government intervention is required. Government work by passing policies. And to pass policies, a comprehensive understanding of the problem is mandatory. In this paper, a thorough understanding of the energy efficiency gap -- and market failures underpinning the persistence of this gap -- is presented. Five market failures were recognized as follows: (a) asymmetric information, (b) split-incentives, (c) negative production externalities, (d) distortionary regulatory policies, and (e) behavioral 'anomalies'. Issues of externalities can be solved by taxing companies that consume an excessive amount of energy, but the government has to be careful not to affect some sectors and discourage investment disproportionately. Proper classification of each sector has to be done — into small, medium, energy-intensive, and proper tax rates establish for each. Similar, public policies, as mentioned hitherto can solve the split-incentive problem and issues with asymmetric information. However, for the behavioral 'anomalies' observed, more research has to be done to unveil and predict ways people make decisions so as energy efficiency products can be better accepted in households. The paper attempts to describe the problem and to brings out the situation that there is no silver bullet to solve the problem. Research is still underway to solve these problems and reduce the energy efficiency gap. This paper has provided several key insights into the issues associated with the energy efficiency gap. The onus for the solutions now lies with policymakers and scientists to experiment and resolve them, in the quest to maintain a livable world for future generations.

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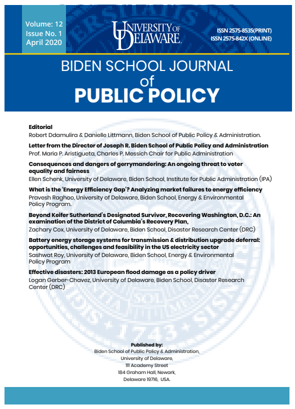


# Beyond Keifer Sutherland's Designated Survivor, Recovering Washington, D.C.: An Examination of the District of Columbia's Recovery Plan

**ZACHARY COX**, University of Delaware, Biden School, Disaster Research Center (DRC)

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**ABSTRACT**

The popular imagination, as exhibited by the television show Designated Survivor, constructs disaster recovery as a process performed by omnipotent government agents who guide action in ways that are comprehensive, fair, and efficient. However, as the National Disaster Recovery Plan and the District of Columbia Recovery Plan demonstrate, there is little understanding of the processes required to recover from a disaster. This paper examines the Plan for the District of Columbia's Economic Recovery from disaster and proposes recommendations that could more easily streamline the planning and recovery of disaster in Washington, DC.

## 1.0 INTRODUCTION

Kiefer Sutherland stars as Tom Kirkman, an on-the-outs cabinet member in the Department of Housing and Urban Development who is thrust into a high-stakes world of political intrigue when, as the "Designated Survivor," he is the only member of the government to survive catastrophe in Washington, DC. Indeed, a disaster affecting the seat of the federal government of the United States of America makes for good television. However, if we move beyond power-playing politicians, sex scandals and every other form of drama imaginable, recovery managers must ask: how would the District of Columbia's business and economic recovery from disaster be operationalized, and based on the literature, would the District's current documentation be sufficient to meet its stated goals?

This paper reviews FEMA's National Disaster Recovery Framework (2011), which frames disaster recovery in the United States as "providing guidance that enables an effective recovery." Similarly, this paper will interrogate the District Recovery Plan (Homeland Security and Emergency Management Agency, 2014) which seeks to "assist the government, non-governmental organizations and the private sector to more efficiently and effectively organize and operate recovery efforts from events that have impacts on the physical, social, emotional, economic and natural environments."

This paper first introduces the business and economic recovery sections of each recovery plan in broad strokes before discussing the academic literature to recommend improvements. Beyond the content of each document, this paper suggests that innovative advanced technologies like web-based tools and blockchain are required to prepare for a recovery that includes many stakeholders successfully.

## 2.0 FEMA'S NATIONAL DISASTER RECOVERY FRAMEWORK AND DC'S RECOVERY PLAN

Washington, DC's Recovery Plan, like many in the United States, builds on FEMA's National Disaster Recovery Framework (NDRF). Created to describe what recovery management processes could look like for recovery managers, the NDRF provides definition to different recovery support functions, maps local resources to their counterparts at other levels of government, and notes items that might enable the most effective recovery in a specific domain, business recovery for instance. Although never going so far as becoming a static template of fill-in-the-blanks, each recovery support function has a few pages detailing the overall mission statement, why each component is essential, things to do in the preparedness phase, and items to keep in mind during recovery. Often brief in detail, this may be attributed to the fact that as a new concept, the components of an effective recovery plan are not well understood (Berke et al., 2014). This paper does not try to hold the NDRF and other documents based on it in contempt, but rather to see them as works in progress which will improve over time with the end goal of addressing the root causes of a disaster.

By definition, disasters overwhelm local resources (Drabek, 1986). Perhaps knowing this, the authors of Washington, DC's Recovery Plan (2014) have built on the recovery support functions by including a selection of front matter to help give the unfamiliar recovery manager dropped into this high-priority geography with a little background of a fighting chance. This preamble details the city's key stakeholders, processes for document approvals during regular times, and the hazards facing the District of Columbia. Interestingly, the Plan designates flooding as the most significant hazard, with the Potomac river causing some anxiety. Ironically, the "Human/Adversarial Hazards" section features very little detail, despite American Airlines Flight 77 crashing into the Pentagon on 9/11 and Washington DC being defined in the Plan itself as a potential target for action against the United States - the central plot point of Designated Survivor.

Much time is spent discussing the sort of recovery-focused work that can begin during the mitigation and preparedness phases, but there is little by way of risk analysis or appropriate interventions. Even something as simple as a decision tree (Kirkwood, 2002) with probabilities and consequence values would allow for recovery managers to begin predicting costs and focus their efforts on the most significant opportunities. Furthermore, the analysis does not need to begin with expensive, difficult, or time-consuming data collection: that can come later. Instead, following Hillier & Liberman's (2001) example, a Monte Carlo simulation using ball-park estimates constructed in a tool as simple as Microsoft Excel could be enough to understand the probabilities of different hazards occurring. Work could then begin on protecting the social features most likely to fail during a disaster, with a foundation that is more comprehensive than the qualitative perceptions of planning officials that are currently listed.

Understanding where things are likely to fail will allow for complete planning, and therefore a quicker recovery. The Washington, DC Recovery Plan (2014) itself notes this on page 16 by saying that there is a need to "balance quick and prompt recovery actions with the need to elicit active community engagement in the recovery process." Achieving this balance is a significant first step, for as Johnson and Hayashi (2012) note, recovery is time-dependent, and some solutions will only be applicable for a short period. However, the current explanation works only as a first step, since there is no action plan to discuss how to achieve this balance outside of a brief mention in FEMA's companion webinar, IS-2900 A: National Disaster Recovery Framework Overview (2018), which spends 30 seconds discussing the pace of recovery after Hurricane Ike in 2008.

## 3.0 ECONOMIC RECOVERY

FEMA (2011) seeks to integrate the expertise of the Federal Government with local businesses to help sustain and rebuild the economic opportunities that are key to a recovered community. At the same time, the government has historically done a poor job of keeping businesses afloat after a disaster (Corey & Deitch, 2011). Accordingly, the economic recovery support function suggests that some few-strings-attached seed money be made available to energize disaster-struck locales. Further, it singles out pre-disaster planning and mitigation as essential to an effective recovery, including the suggestion that local businesses be invited to exercises that allow them to prepare for a disaster, participate in planning and be ready to recover, though no specific resources are detailed. The coordinating agency that is assigned to oversee these activities is the Department of Commerce who is supported by FEMA, the Department of Labour, the Small Business Administration, Department of the Treasury, and Department of Agriculture.

Washington, DC breaks out six objective categories and sorts them based on time, either intermediate or long term. These objectives include: "buildings and other facilities," "employees and personnel," "supporting infrastructure," "consumers and other clientele services," "supplies and inventory," and "governance." Shorter-term, intermediate objectives include "completing damage assessments," "assisting employers in locating and contacting employees," and making sure that infrastructure services are running to an acceptable degree. In the long term, these objectives become "repair or replace facilities," "assist employers in recruiting and retaining employees," and to keep making sure that there is enough supporting infrastructure to meet their needs.

Many of these objectives sound reasonable. With that said, even the simple and 'easy' tasks must be developed beyond the one-sentence descriptions they are given in these plans. For instance, what does it mean to make sure that there is enough staff? On the surface, the question sounds needlessly academic and arcane, maybe a little silly, since obviously, the Plan says that recovery managers should make sure that there are enough people to do work. Scratch below the surface, however, and the idea of actually having people to do work begs nuanced questions. What was the size of the business pre-disaster? Large firms and government agencies in the Washington, DC metro area may be able to absorb the shock of having a few people unavailable by shifting the workaround among the remaining employees, but such a strategy might be impossible for smaller organizations (Tierney, 2007). Further, many small businesses are owner-operated (Tierney, 2007) and, therefore, may not have employees available. In these cases, the characteristics of the owner must be taken into account, especially their ethnicity and gender. The research on how much of an impact the features of owner ethnicity and owner gender have on business success is mixed with Webb et al. (2002) finding little significance, while more recent studies by Sydnor (2017) did find statistical differences. Likely, the success or failure of women-owned or minority-owned small businesses in the aftermath of disaster comes down to the local culture, and it is, therefore, crucial for Washington, DC emergency planners to understand these features and plan for them.

## 4.0 PROPOSED INNOVATION

Even without a much-needed further alignment with the literature surrounding economic and business recoveries, there is much content in FEMA's National Disaster Recovery Framework, and it would be easy for the documents based on their templates to become unwieldy behemoths full of words that are incapable of providing results when they are needed. Accordingly, to operationalize concepts that could be obscured in the frantic pace of disaster recovery, web-based tools that allow multiple entities to interact and share data in an accessible format is critical. The groundwork on these tools has already been set with innovations like www.trackyourrecovery.org by Horney et al. (2018), which allows users to input disaster recovery progress data and represents the much more connected future of disaster recovery. Paired with other new technologies like blockchain that protect information by storing it in a series of other information, thereby making unauthorized edits or fraud impossible (Gupta, 2018), and the emergency management teams from government agencies, the private sector, and non-profit sector become able to interact in ways that would not have been otherwise possible. Incorporating modern technology is not a 'nice to have' kind of item; it is essential.

Things can quickly become unwieldy in the Washington, DC context, where the recovery plan includes 60 government departments, 29 non-governmental departments, 11 federal agencies, and eight regional organizations. These are in addition to an untold number of private sector businesses that have been identified as playing either a primary or supporting role in tasks ranging from health and human services to critical infrastructure (Homeland Security and Federal Emergency Management Agency, 2014). In reality, it is unfeasible to expect, at current levels of funding and interest, that the emergency management team who staff the District of Columbia's emergency management office can check in with the, for instance, Office of Cable Television to make sure that they can perform their critical infrastructure systems recovery tasks as defined in the document's Recovery Support Function Annex.

## 5.0 STRENGTHS OF THE CURRENT RECOVERY PLAN AND FUTURE RESEARCH

It would be unfair to characterize the District of Columbia Recovery Plan or the National Disaster Recovery Framework as all bad, and that is not the goal of this paper. Indeed, there is work to be done, but this is an excellent first step. Just in dealing with business recovery, let alone the other seven sections, recovery planners in Washington have begun to peer into the Zone of Uncertainty (Smith & Birkland, 2012) from the perspective of practitioners. A valuable exercise, if currently light on details. Future revisions of these documents should move beyond the emergency manager's office and seek to understand the unique features of the Washington, DC metro area to tailor recommendations and provide specific supports (Smith et al., 2018). As part of this, the National Disaster Recovery Framework should be expanded beyond its current scale as a simple document to be an entire program. The Emergency Management Institute's three hour IS-2900.A: National Disaster Recovery Framework Overview could be part of this vision if it were expanded. As well, the inclusion of effective recovery plans from other districts that have had to use them, if those exist, would further aid in the quest for understanding and allow practitioners to understand better the direction they should be taking.

## 6.0 CONCLUSION

It is not just the President (or their Designated Survivor) who need to be kept in mind when planning for disaster recovery in Washington, DC. Businesses and other economic organizations, such as federal government agencies, need a technically innovative approach that uses modern tools to help them prepare, then one day, recover from a disaster. More than simple one-sentence pieces of guidance, this support should be critical and thought-provoking, encouraging planners to ask more profound questions about the nature of organizations in their District. The District Recovery Plan is a significant first step to understanding how organizations in Smith & Birkland's (2012) Zone of Uncertainty might interact with recovery, but as the field of recovery management develops, these ideas should become more nuanced and comprehensive.

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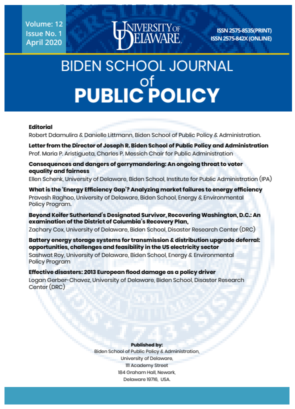


# Battery Energy Storage Systems for Transmission & Distribution Upgrade Deferral: Opportunities, Challenges and Feasibility in the US Electricity Sector

**SASHWAT ROY,** University of Delaware, Biden School, Energy & Environmental Policy Program

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## ABSTRACT

**ABSTRACT**

Battery Energy Storage Systems (BESS) are emerging technologies which are opening new opportunities that improve and reduce the costs of electricity. However, exactly where the storage is deployed (generation, transmission or customer) on the electricity system can have an immense impact on the value created by BESS technologies. In this study, we highlight the value created by BESS when installed downstream from a nearly overloaded node at the distribution level by deferring investment in capital-intensive feeder upgrades. The study also examines regulatory policy initiatives in "storage as a transmission asset" and provides recommendations based on the understanding of the regulatory treatment of energy storage to ensure increased deployment of these systems as transmission assets.

***Keywords:*** *Transmission & distribution, Battery energy storage systems, distribution feeder, load-carrying capability, storage as a transmission asset, load curve, benefit-cost analysis, upgrade deferral.*

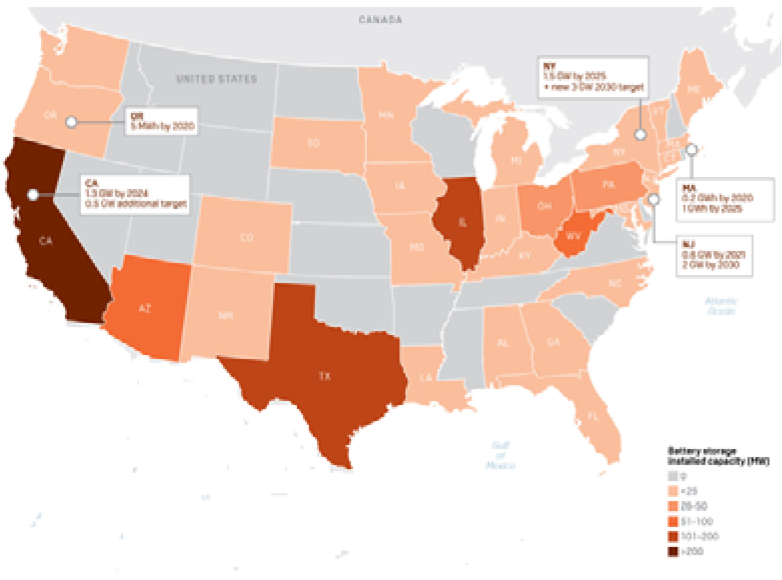
# 1.0 BACKGROUND

Energy storage has often been called the 'holy grail' for a clean energy future because it has the potential to play a pivotal role in the electricity system, especially as the grid ages and new infrastructure is required to maintain reliability. As the falling component and installed costs are leading to favorable economics, policies and market regulations have lagged due to lack of knowledge on the sweeping value streams of energy storage in the current electric grid. The role that energy storage can play in the ever-increasing share of renewables in the fuel mix for the electricity sector is also important to understand.

The electric sector is seeing numerous changes, including the growing adoption of electric transportation and the ever-increasing amount of renewable energy penetrating the grid. These changes will provide many benefits, such as the ability to respond to green public policy goals, increased "diversity of generation options, and increased consumer choice, but these changes will also present several distinct challenges that energy storage can help to alleviate such as (1) increasing consumer demand for reliable, affordable, renewable power options; (2) speed of investment and deployment of variable generation; (3) ancillary services needs resulting from the fact that distributed energy resources (such as storage) create bidirectional power flow that taxes distribution systems which are reliant upon voltage regulation and protection schemes; (4) "limited transmission capacity which can force resources to be curtailed during their time of peak production, while the expansion of new transmission capacity poses regulatory and environmental challenges."

The ability of energy storage systems to inherently act like a "sponge," i.e., absorb energy during excess and discharge energy to the grid when the demand is high, is of paramount importance in today's grid. Although conventional energy storage systems like pumped hydro (potential energy to electrical energy), have been around for a few generations, battery-based energy storage systems (BESS) are gaining popularity due to their increased efficiency, modularity as well as higher charge density, all characteristics which are suited towards the modern grid. A variety of market reports have emerged hailing grid-scale BESS as the "the next big asset" in the present energy system with annual growth projections of over 10% with a market valuation of $21.6B in 2018, a number which will grow much higher in the coming years (Adroit, 2019). The U.S. has the world's largest battery storage market, with 61.8 megawatts of power capacity installed in the second quarter of 2018 with a market growth rate of 60% year to year (Utility Dive, 2019). The U.S. is one of the largest markets in the adoption of battery storage technology at a commercial scale. Currently, 36 states in the U.S. have a combined operational capacity of 1.6 GW of battery storage resources.

***Figure 1: Operational Battery Storage Projects and State Energy Storage Mandates in the US, March 2019***



***Source: DOE Global Storage Database, S&P Global Platts Analytics (March 2019)***

The Federal Energy Regulatory Commission (FERC) defines energy storage as a "resource capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid (FERC, 2019). This definition is intended to cover electric storage resources capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid, regardless of their storage medium (e.g., batteries, flywheels, compressed air, and pumped hydro). In 2018, FERC finalized two landmark regulations paving the way for the deployment of storage resources in the future. FERC Order 845 proposed reforms to the generator interconnection procedures and agreements to explicitly account for storage resources (like BESS).

FERC Order 841 mandates ISO/RTOs to revise their tariff to facilitate the participation of storage resources in capacity, energy, and ancillary services markets. Transmission entities have filed their comments/ compliance plans to these regulations. Recently, ISOs/RTOs such as CAISO (California Independent System Operator) and MISO (Midwestern Independent System Operator) have started deliberations regarding the treatment of "storage as transmission asset" (SATA), which would enable utilities to recover investment costs through transmission rate recovery (TRR). The policy development proceedings are still underway as of June 2019 in CAISO. Based on their location of the application, BESS can be classified into behind-the-meter, which usually entails residential or commercial systems and front-of-the meter which are systems owned and operated by the utilities and independent power producers on the generation, transmission and distribution side of the grid.

In this research, the focus would be on front-of-meter grid-scale (or utility-scale) BESS particularly targeted towards deferring transmission and distribution investments, which can occur due to load growth in a region leading to transmission congestion and rise in electricity prices. The aim would be to evaluate whether grid-scale BESS can allow utilities to defer capital-intensive transmission and distribution upgrades by installing these systems downstream from the transmission/distribution substation. In this evaluation, it would be essential to cover the characteristics that BESS requires, as well as the opportunities and challenges that it can encounter in this nascent application field. Transmission and distribution upgrades (poles, wires, equipment) have been contentious in the recent past due to high-cost outlay, environmental concerns and high probability of stranded assets which lead to a rise in the actual cost of electricity to the consumers in the service area since the upgrades are added to the rate base leading to an increase in the transmission charge.

## 1.2 Introduction

With increasing emphasis on reducing global carbon emissions and promoting universal energy access (SE4All, 2017), and long-term concerns over fuel price volatility and energy security (Yergin, 2016), renewable energy technologies, with rapidly declining costs (Kost et al., 2011; Breyer et al.,2013), are becoming an increasingly important part of the future energy system (Jacobson et al., 2009). However, integrating high shares of variable renewable energy sources into power systems can prove to be a challenge (Peters et al.,2011). Out of the several available flexibility measures, energy storage technologies are particularly promising response options because of their unique ability to decouple power generation and load over time. Battery energy storage systems or BESS have emerged as frontrunners to provide a multitude of opportunities for utilities and IPPs to generate revenue through market applications such as energy arbitrage, capacity firming, frequency regulation, etcetera. The development of transmission infrastructure is increasingly facing challenges involving "who pays for" and "who owns" new transmission capacity in part due to the high capital cost, and difficulties in siting transmission infrastructure due to environmental impacts, costs, and aesthetic concerns (Bhatnagar & Loose, 2012). The ability of BESS to provide a secondary source of electrical energy during times of peak overload in a transmission/distribution line or substation has recently been a topic for research, although the commercial viability is still up for debate.

This research tries to understand the techno-economic viability of Battery Energy Storage Systems (or BESS) by asking three pertinent questions:

1. ***What are the general indicators for the viability of BESS as a Transmission & Distribution (T&D) Asset? In other words, why do we need BESS in the T&D sector?***
2. ***Can BESS technology be techno-economically viable in deferring capital investments in the T&D sector, i.e., do the economic benefits outweigh the costs when installing & operating BESS as a transmission asset and a transmission + market asset?***
3. ***What are the underlying opportunities and challenges for this technology in the T&D system in the future?***

Recent efforts have focused on implementing BESS to serve the load growth in an area where upgrading the transmission & distribution (T&D) infrastructure is difficult due to terrain and other physical conditions. Arizona Public Service (APS) recently purchased a 2 MW/8 MWh Li-ion BESS as an alternative to the traditional approach of upgrading 20 miles of 21-kilovolt cables that service the town of Punkin, AZ (Utility Dive, 2018 (a)). The upgrade required construction through hilly and mountainous terrain, with considerable expense and local disruption, which was avoided with the use of BESS, which would provide the town with peak electricity during the days in which the line was forecasted to be overloaded. Another example, in 2017, a utility that serves customers in Massachusetts announced plans to install a 6 MW energy storage system with an 8-hour duration alongside a new diesel generator on Nantucket Island to provide backup power and postpone the need to construct a costly submarine transmission cable to bring electricity from the mainland to meet anticipated growth in electricity demand (Rusco, 2018).

Another factor that has generated interest is the ability of BESS to avoid stranded assets. System planners must contend with the possibility of stranded T&D assets for infrastructure built in the context of reliability for load growth that never materialized. In South Carolina, ratepayers were saddled with a $9B bill after two nuclear reactors were abandoned due to cost overruns and lower than expected electricity demand[2]. Recently energy storage has also been debated in regulatory circles as either a generating asset, transmission asset or both. In November 2018, Generators NRG Energy, NextEra Energy Resources and Vistra Energy filed comments with the Public Utility Commission of Texas (PUCT) last week arguing that transmission and distribution (T&D) utilities cannot legally own battery storage under existing state rules (Utility Dive, 2018 (b)). It has thus become an important issue to define ownership rights around battery storage, which can act both as generation and load on the power grid.

The basic premise for utilizing BESS for the T&D upgrade deferral is fairly straightforward. The utility or the regional planning authority would forecast the peak load periods or days during which the line/substation is overloaded, i.e., exceeds the power handling capacity (in MVA or MW) based on historical load profiles and an annual growth rate. This study is usually conducted in the yearly or 10-year local capacity requirement studies conducted in the transmission planning process. As the demand profile approaches the PHC, congestion in the system increases, as a result of which LMP prices rise. The function of BESS would be to have enough power or energy during these times to serve the load downstream from the transmission/distribution substation. The complexity arrives in the financial valuation of these benefits and costs for the utility and the ratepayers. The literature on BESS application for T&D deferral is scarce and portrays differing values of deferral, making it

2

certain that the value is location dependent. Also, there is a significant gap in literature attributing the benefits of lower-cost transmission upgrades using preferred resources such as BESS for the ratepayers.

Balducci et al. (2018) evaluated the benefits of deferring investment in a substation located on Bainbridge Island, Washington, by nine years, estimating the deferral value at $162/kW-year. Eyer and Corey (2004) determined the cost of transmission and distribution (T&D) upgrade deferral combined by estimating the cost of the T&D upgrade to be deferred based on $/kW to be added or the T&D marginal cost (Balducci et al.,2015). The value of cost deferral can be significant due to the nature of utility cost accounting. For example, if an energy storage system could be used to shave local load peaks resulting in deferral of a $10 million substation for five years, the benefit would be $3.2 million if the cost of capital to the utility minus inflation was 8% (Balducci et al.,2018). Another study estimated transmission upgrade deferral benefits at $36/kW-year based on average annual transmission cost for every unit of reduced peak demand. This estimate is consistent with the average annual transmission cost per kW of summer coincident peak load in ERCOT. On distribution upgrade deferral, it was noted that distribution system costs are driven by non-coincident, local peak loads with deferral value estimated at $14/kW-year (Schmitt & Sanford, 2018). In this study, the primary metric used has been chosen to ensure a holistic value estimate considering both utility and ratepayer benefits. This would be discussed later in the case study section.

## 2.0 NEED FOR BESS FOR TRANSMISSION & DISTRIBUTION DEFERRAL

Battery-based energy storage systems or BESS can become an alternative to building new lines and power plants and help increase the throughput of electricity in existing lines by reducing congestion and unhelpful electric effects, such as voltage issues, thermal overloads, or providing reactive power to the grid. BESS can be positioned downstream from the transmission constraint and charged when the demand for electricity is low (i.e., off-peak or nighttime) and discharge during peak hours. By bringing storage closer to the load, it may also help alleviate high line-congestion and line-loss rates that occur during times of peak demand, this reduces the need for new transmission projects and extends the life of the existing system. It allows grid planners to become more reactive and reduces uncertainty during transmission planning by allowing them to address peaks on a shorter future horizon. But this argument may not hold for locations where the load growth rate is higher than average or where building transmission infrastructure is necessary for reliability and resiliency concerns. Thus, utilities must analyze each situation on a case to case basis when approaching the idea of implementing BESS before undertaking transmission and distribution (T&D) upgrades. The key factors to consider are briefly examined below:

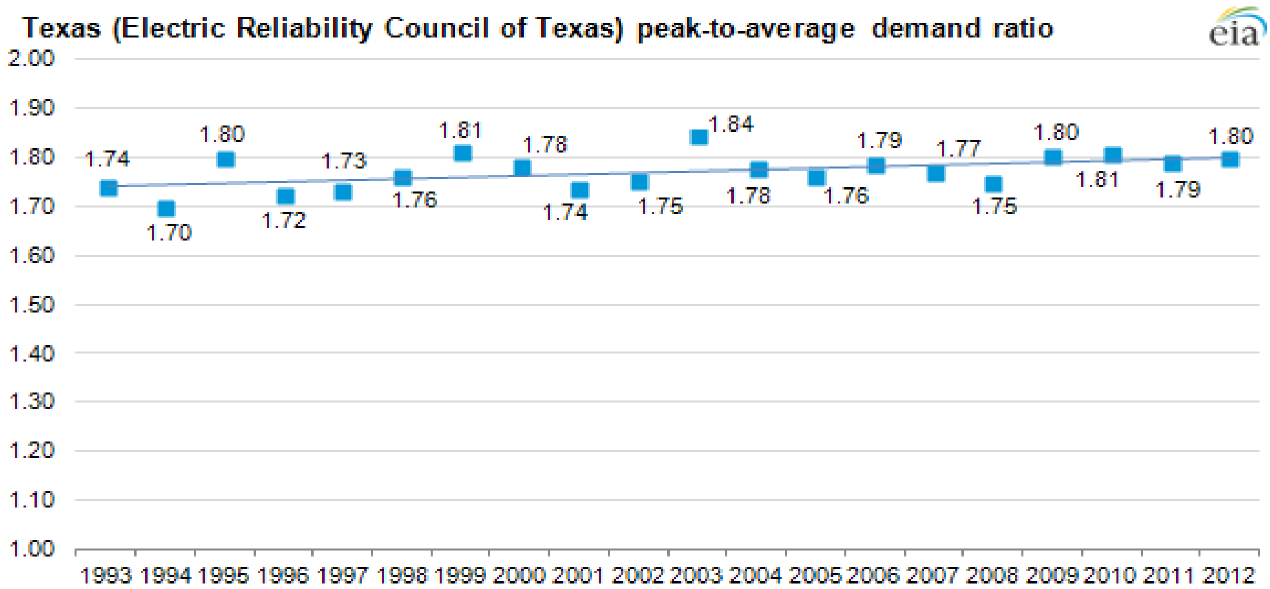
### 2.1 High cost and lead times of T&D investment:

BESS offers a lower-cost alternative to expensive transmission & distribution upgrades. Infrastructure projects are also prone to cost overruns, environmental concerns, and sometimes public outcry due to right-of-way regulations, this leads to long lead times for approval, construction, and project delivery. All of these constraints could be easily bypassed using energy storage resources, which are much easier to install and operate downstream from a transmission or distribution substation. According to a Department of Energy (DOE) report published in 2015, a typical transmission line could cost upwards of $1.5M/mile, which is much higher compared to storage alternatives of a similar capacity.

## 2.2 High peak-to-average demand ratio:

The peak-to-average demand ratio is the ratio of the peak demand to the average demand for a service territory/region. It is a ratio that measures how much higher hourly peak demand is than average hourly demand. A high peak-to-average demand ratio means a large fluctuation in daily electricity demand. A higher ratio also translates into decreasing average utilization levels for generators in a region. Thus, electric systems must maintain sufficient capacity to meet expected peak loads plus a reserve margin. In the US, the peak-to-average demand ratio is increasing (see Figure below) especially in the New England whereas Texas has a flatter curve although it is increasing which is troublesome but offers an opportunity for modular BESS to be operated (discharged) to cover the peak demand periods instead of upgrading the T&D infrastructure just to meet the peak load periods.

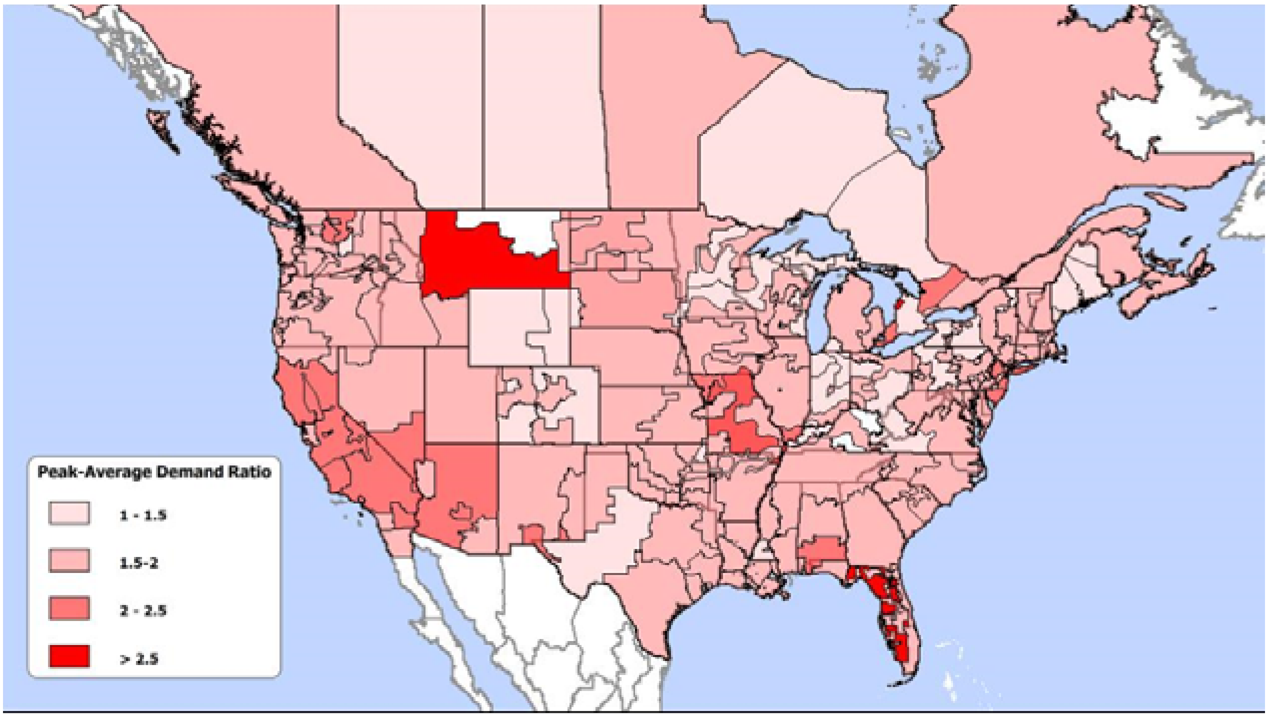
***Figure 2. Electric Reliability Council of Texas peak-to-average demand ratio:***




*Source: EIA 2014*

From the figure above, it is clear that the peak-average demand ratio has remained around the same level in Texas. However, the higher value of the ratio signifies peak demand exceeds the average demand significantly during peak demand days.

*Figure 3. Peak to average demand ratio for transmission zones across the US*




Source: ICF, ABB Velocity Suite 2019

The figure above shows the high potential viability of BESS in regions such as California, Arizona, Florida, New Jersey, Montana and New England region.

## 2.3 Slow peak demand growth (rate):

In general, it is more beneficial to defer upgrades using modular resources at hot spots where peak demand is growing slower than it is to defer upgrades of T&D equipment serving the demand that is growing rapidly (specifically, inherent demand growth, not including block load additions such as new commercial facilities and residential development). There are two basic reasons for this. First, if the probability based on historic load analysis portrays that the demand growth will be slow, it usually indicates the need for a relatively small amount of storage resources to defer an upgrade, in a given year. Secondly, since relatively small amounts of storage resources are needed – in a given year –storage resources may be economically viable for more years of deferral if demand growth is low.

## 2.4 Uncertainty about the timing and likelihood of block load additions:

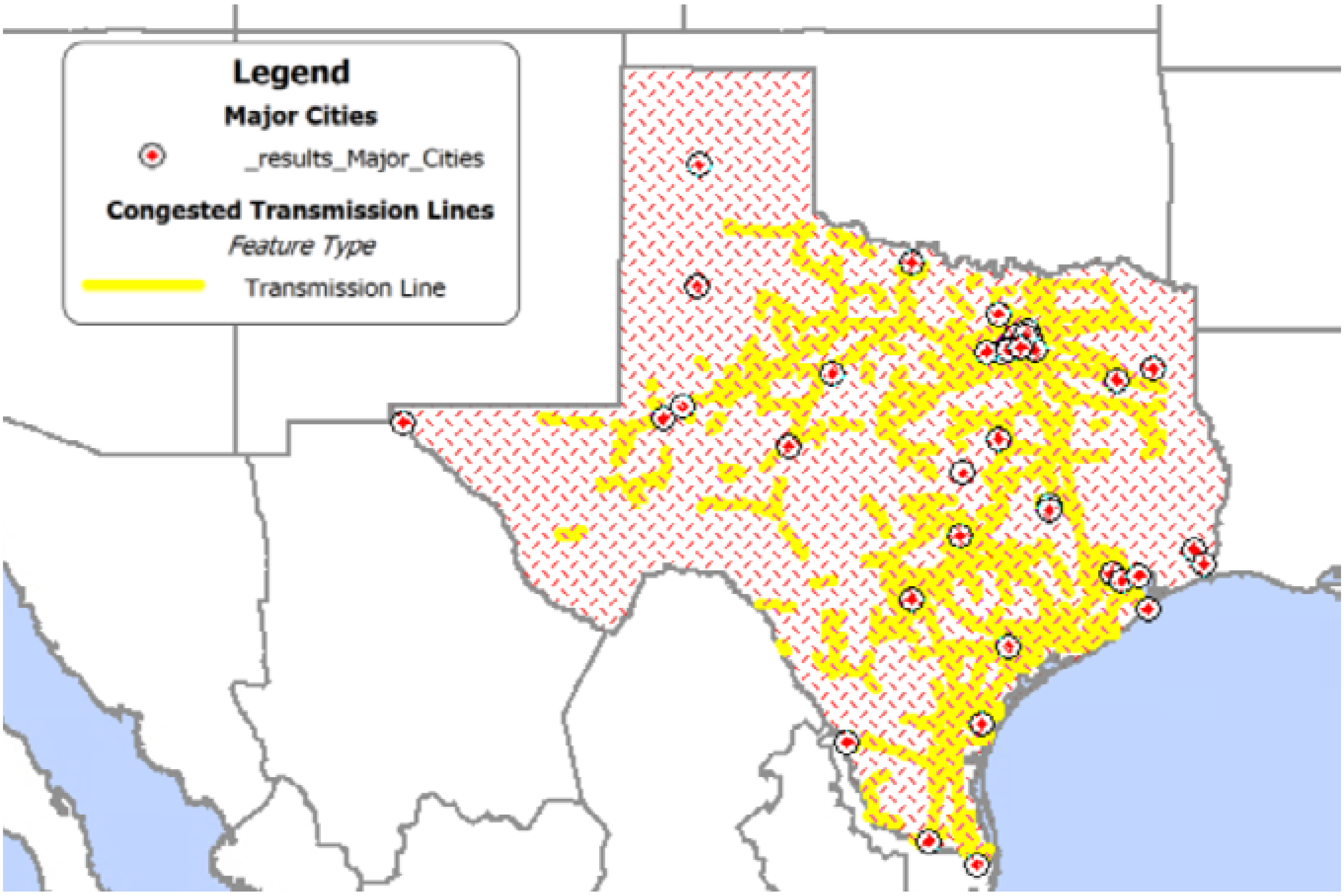
BESS and other DERs may be attractive alternatives when there is uncertainty about the magnitude and timing of block load additions that would cause an overload. Block load additions are usually related to commercial or residential development or the expansion of existing industrial facilities in a service territory/area. A recent example of uncertain load characteristics in a local service area has been the growth of oil & gas related drilling activities in the ERCOT region (Texas), especially in the Panhandle and West Texas region. The dependence of oil & gas industry electricity usage on the commodity prices of oil also plays a role in shaping the load curve for these regions, which may see spikes during high prices of oil and lower demands when oil prices are low.

## 3.0 T&D UPGRADE DEFERRAL: A CASE STUDY IN ERCOT SERVICE TERRITORY

ERCOT (Electricity Reliability Council of Texas) region has shown a higher demand growth than many other organized markets with a 2.2%/year growth rate compared to US average 1.3%/year from 2000 to 2017 (ICF, 2019). The peak demand in this region is projected to grow at 1.8%/year and total demand at 2.4%/year according to recent market studies. ERCOT is seeing an increase in the amount of energy storage resources being developed for a variety of grid and customer applications in the ERCOT region. As of 2019, 89 MW of utility-scale battery resources, which are a type of energy storage, are registered, and approximately 2,300 MW of new battery capacity was under consideration for the ERCOT region. The recent increase in battery interconnection requests may be due to declining battery technology costs and the availability of Investment Tax Credits for qualifying energy storage systems (ERCOT, 2018).

Many of the battery projects under development are being co-located with solar facilities since batteries can be deployed when solar power is unavailable or at lower output levels to better match load ramps. Batteries also can effectively store wind power that is produced during off-peak hours. A major share of existing battery resources is currently used for Ancillary Services (operating reserves that are procured to respond to variability in load and generation output), which usually means smaller battery systems with short duration discharge capacity (of 30 min – 1 hour). Since FERC Order 841, which encourages greater participation of battery or in general, storage resources in the energy, capacity and ancillary markets does not fall within the purview of T&D deferral, and this value stream has been slow to emerge.

***Figure 4. Congested transmission lines in Texas and their proximity to major cities/load centers.***



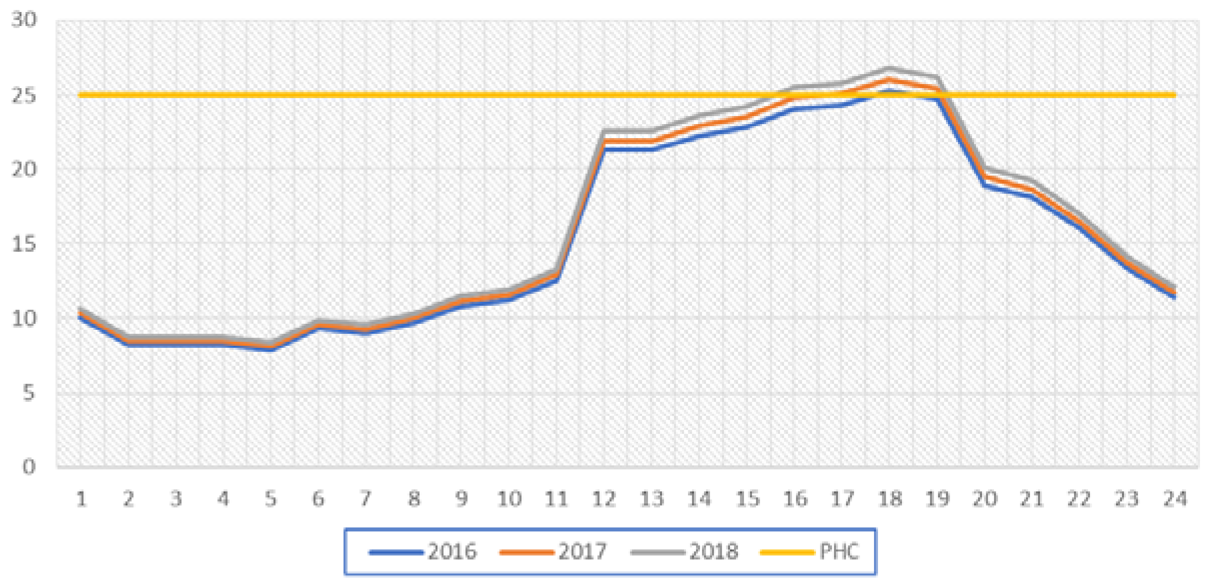

*Source: Ventyx, ABB.*

StorageVET (Storage Value Estimation Tool) is a techno-economic model for the analysis of energy storage technologies and some types of aggregations of storage technologies with other energy resources such as wind or photovoltaic technologies. The tool can be used as a standalone model or integrated with other power system models. The fundamental use of StorageVET is to support the understanding of energy storage project economics and operations. The tool is adaptable to many settings, including policy or regulatory analysis, commercial decisions (by a range of actors), infrastructure planning and research (EPRI, 2018). For evaluation of the financial benefits of deferral to the utility and ratepayers, several cost tests portray the effectiveness of the investment into capital-intensive projects similar to benefit-cost analysis ratios. Each test answers a different question in terms of who and how the investment will assist. A table showing the different tests and their respective purposes and values are shown below:

For this case study, a benefit-cost ratio (BCR) test would be most appropriate since the investment into a deferred investment would affect both the utility and ratepayers. A novel concept, i.e., considering "Storage as a transmission asset" (SATA), allows utilities to recover their investment through cost-based revenue recovery by adding the project to their rate-base, which can eventually show up on a customer bill as an extra charge for transmission. The benefit-cost ratio consists of benefits produced by the investment (here avoided cost of T&D investment and market revenues), and the total costs of the BESS include installed, fixed and variable costs, including federal tax incentives. BCR expressed as a net greater than one (1), means that the investment will have a positive impact on the utility's resource acquisitions. Measures and programs that have a BCR less than one (1) are sometimes adopted because they have value for other reasons such as equity, emergency measures, etcetera. Some residential and low-income programs are examples of programs that may not pass the BCR test but are still implemented.

The logic for assessing different battery power and energy capacities stems from the observation that different utilities would have different expectations on upgrade investment deferral. This depends on the risk-averse nature of the utility, meaning a more risk-averse utility would like to defer for a lower number of years and invest in T&D upgrades more quickly to meet the projected demand growth reliably. The battery charge/discharge durations considered in the study are 4 hours and 5-hours due to larger capacity requirements for the ERCOT region due to higher than average load, although this depends on local requirements. The projected load growth rate is representative of the ERCOT region, which is undergoing rapid growth (2-3% growth per year). A higher battery size has been assumed to be selected for a higher projected load growth due to the requirement of more energy capacity.

***Figure 5. Load growth for the 69-kV test feeder during a typical peak demand day with a 3% projected load growth:***



The Figure above demonstrates how the load growth for the 69-kV test feeder during a typical peak demand day with a 3% projected load growth rate. This shows how the load exceeds the load-carrying capability or power handling capability (25 MW) of the distribution feeder post-2016.

## 4.0 RESEARCH DESIGN & METHODOLOGY

The methodology for this case study is focused on providing T&D deferral, although it has been shown in pilot studies that value-stacking with deferral as the primary use-case is possible. The most practical values available to be used with T&D deferral according to the knowledge of battery operation and market dynamics are real-time energy arbitrage and voltage support, this is discussed in the later sections in more detail. The study is based on the evaluation of different scenarios of battery sizes (power and energy capacity) to defer T&D upgrades by:

1. Analyzing the load profile and power handling capability of a distribution feeder and identifying the peak demand days.
2. Initiating battery storage dispatch algorithm to charge during off-peak hours and discharge during on-peak hours (peak demand) when the demand > PHC of the line/substation.
3. Calculation of number of years that BESS can successfully defer upgrade investments and the benefit-cost ratio by assessing the net present values of "avoided cost" of traditional transmission upgrades and installed cost of BESS from recent DOE and industry reports.
4. Calculation of the number of years that BESS can successfully defer upgrade investments and benefit-cost ratios of BESS operation as both a "transmission" and "market" asset.

It is important to note that if the rated power and energy of the input storage system is larger than the estimated daily minimum to meet the deferral, then the upgrade can be deferred for the year. If partial deferral occurs, then the model outputs the number of hours that overload could not be avoided. A growth rate is applied to the deferral load profile (load profile from the feeder) to estimate the number of years of successful years that asset upgrades can be deferred. This process repeats until the rated power and energy is lower than the estimated minimum. The corresponding year is recorded as the first year of failed deferral. For solving mixed linear programming (MLP) optimization problem before the first year of failed deferral, the following constraints are added to make sure the storage keeps the net power at the overloaded asset within bounds:

(1) $$\max import_{deferral} \geq load - battery\ charge + battery\ discharge$$

(2) $$\max export_{deferral} \geq load + battery\ charge - battery\ discharge$$

Here 'battery charge' and 'battery discharge' are optimization variables in the StorageVET Python environment.

For battery optimization under hybrid operation as a transmission and market asset, StorageVET allows the selection of multiple grid services, although the code was modified to only operate on the real-time markets with priority to T&D deferral. The algorithm for energy arbitrage, i.e., buy low and sell high, was utilized for these months, and the profit was calculated as the difference of discharge revenue and charging cost by utilizing historical ERCOT West prices. The model is robust to identify peak overload scenarios in a week-ahead timeframe and limits arbitrage to accommodate discharge during overload periods. Battery replacement costs are not included in the analysis to avoid complexity but will play a role when considering hybrid operation due to increased battery cycling-related degradation.

In typical radial distribution systems, the power is delivered from the substation to the end-users through dedicated feeders. Each feeder has a recommended apparent power limitation. This limit is defined mainly by the feeder conductor size and allowable sag. A feeder upgrade is required when the demand exceeds feeder capacity, or the sagging of overhead conductors reduces the clearance below the minimum required value (Zhang et al.,2016). A different upgrade situation would be caused by the feeder load exceeding the transformer kVA rating. A BESS could also potentially permit transformer upgrade deferral. Feeder upgrade planning is driven by projections of the magnitude and duration of peak loads, which typically follow daily, weekly, and seasonal patterns, as shown in Figure 6 below.

## 4.1 Model Assumptions and Limitations:

1. Batteries are assumed to last till the entire duration of deferral for transmission cases while a single replacement is considered for 'transmission + market' (T+M) operation. Also, it is assumed that T&D upgrades will inevitably have to be implemented after '$t_p$' years of deferral to ensure long-term reliability.

2. The load growth rate for a scenario is applied to all the subsequent years and is not variable for a scenario. In the real world, the load growth understandably would change each year due to block load additions and other reasons.

3. Battery charging costs are assumed to be negligible in the "transmission" case since the batteries are only being utilized for fewer than 100 hours for the entire year and these costs can be recovered through a rate recovery arrangement.

4. The discount rate and loan repayment periods are representative of actual industry metrics but are subject to change on a case-case basis.

5. A successful deferral year does not consist of even a single hour of line overload.

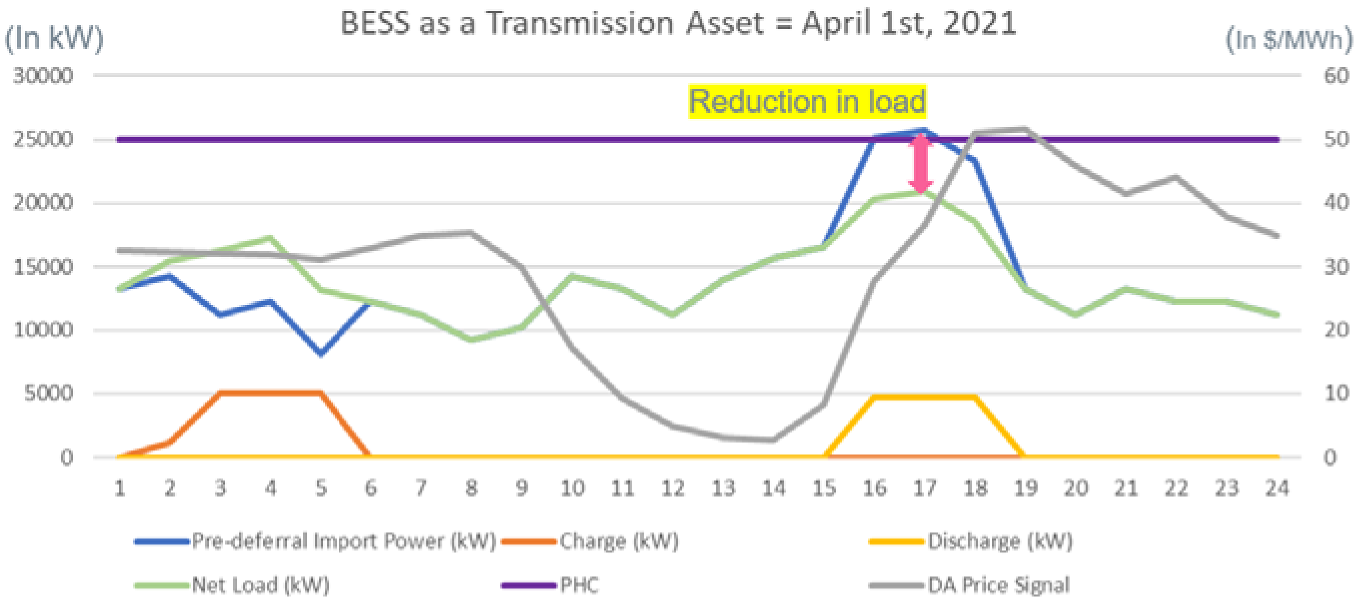
6. The incremental monthly benefits of the first year of failed deferral are not accounted for in the calculations of the economic benefits. Only the benefits accrued till the whole last year of successful deferral are being considered.

7. The BESS optimization model for operation in the day-ahead/real-time market has perfect week-ahead foresight of the market prices and daily load curves.

## 5.0 ANALYSIS & RESULTS

A preliminary analysis of electric load data for the 25 MW distribution feeder showed that the overload period was usually occurring for the 3-hour period during peak demand days. To alleviate this overload period, battery discharge durations of 4 hours are considered in this case study. Three sizes of BESS: 3 MW/12 MWh, 5 MW/20MWh, and 7 MW/28 MWh were considered with three different load growth scenarios of 1%, 2%, and 3% in the region which are representative of ERCOT load growth possibilities. On simulating this battery model on StorageVET, the output values are the hourly battery dispatch of the last year of successful deferral as well as the first year of failed deferral based on the energy capacity of the BESS.

***Figure 6. Battery charging, discharge and load reduction for the test 5 MW/20 MWh BESS for a forecasted overload day in 2021 operating in pure transmission mode.***




The output, i.e., last year of "complete" successful deferral is the input into a techno-economic model developed in MS Excel which accounts for BESS installed costs, feeder upgrade costs and representative discount and loan repayment rates to evaluate the net present values of investment for both the options which is eventually utilized to evaluate the benefit-cost ratio of the investment deferral.

### 5.1 Benefit-Cost Ratio Calculation Methodology:

The benefits of distribution-system-connected energy storage are typically measured concerning the value obtained by the utility owner and operator (Kleinberg et al.,2014). This can be expressed in terms of the value of the "avoided cost" of feeder/substation equipment upgrade and market revenues, if any. The capital cost for a BESS can be divided into two main parts. The first one is the cost of the power conditioning system and its auxiliaries denoted as the "power" component with unit price in Million $/MW. The other one is the "energy" component, representing the cost of the actual storage components with unit price in M$/MWh. The total installed cost of the battery is the summation of power and energy components. To calculate the overall cost of operation of BESS over the deferred year, annual operating expenses (in $/year), which consists of the fixed and variable O&M costs are added to the installed costs.

The cost components and respective values of Li-ion battery systems have been obtained from NREL's 2018 PV-BESS cost benchmarks (Fu et al.,2018). The capital cost for the feeder upgrade is a function of the upgraded feeder length. It can be calculated as the product of upgraded feeder length (in miles) and price of feeder upgrade (in \$/mile). The case study assumes the upgrade of a 69-kV overhead line to an underground feeder line. Brown (2009) estimated that undergrounding local overhead distribution lines would cost ~\$1 million per mile, but to account for labor and other administrative expenses, \$1.50 million per mile is assumed to be a reasonable estimate. For comparison, the minimum replacement costs for existing overhead distribution lines ranged from \$86,700 to \$126,900/mile, with maximum replacement costs ranging from \$903,000 to \$1,000,000 (Larson et al.,2016). The respective cost values were inputted to the benefit-cost model developed to calculate the benefit-cost ratios for different scenarios of BESS deployment.

The method to determine the techno-economic benefit-cost ratio of feeder upgrade deferral is to compare the net present values (Zhang et al., 2016) of the following at the year t till the last year of successful deferral at year $t_p$:

The construction of an additional feeder at the future time $t_f$ when the load grows beyond the original feeder capacity limitation ($PV_{feeder}$) plus any market revenues obtained from BESS operation in the day-ahead or real-time market ($PV_M$).

The installation ($PV_B$) and total operational cost of a BESS ($PV_{BOC}$) at the time $t_p$ plus the deferred time $t'_f$ years of new feeder construction at a future time a year following $t_p$ at a discount rate 'd' (typically 7-8%).

(3) $$BCR_{t=t_p} = \frac{PV_{feeder} + PV_M}{PV_B + PV_{BOC} + \frac{PV_{feeder}}{(1+d)^{t_p}}}$$

***Table 1: Last year of successful deferral and benefit-cost ratios for multiple test scenarios assuming BESS only as a "transmission asset."***

| Scenario | BESS Specification<br>Power & Energy Capacity | Load Growth Rate % | Last Year of Successful Deferral (Base Year – 2018) | Benefit-Cost Ratio based on NPV Analysis (at $t_p$) | Benefit (\$/kWh) |
|---|---|---|---|---|---|
| S1 | 3 MW, 12 MWh | 1% | 2026 | 1.44 | \$493/kWh |
| S2 | 3 MW, 12 MWh | 2% | 2021 | 1.15 | \$212/kWh |
| S3 | 3 MW, 12 MWh | 3% | 2020 | 1.08 | \$128/kWh |
| S4 | 5 MW, 20 MWh | 1% | 2027 | 1.34 | \$247/kWh |
| S5 | 5 MW, 20 MWh | 2% | 2023 | 1.12 | \$63/kWh |
| S6 | 5 MW, 20 MWh | 3% | 2022 | 1.01 | \$17/kWh |
| S7 | 7 MW, 28 MWh | 1% | 2039 | 1.28 | \$152/kWh |
| S8 | 7 MW, 28 MWh | 2% | 2024 | 1.10 | \$89/kWh |
| S9 | 7 MW, 28 MWh | 3% | 2023 | 0.91 | -\$32/kWh |

Table 2: Last year of successful deferral and benefit-cost ratios for multiple test scenarios assuming BESS as a "transmission asset" with operation in the real-time energy market.

| Scenario | BESS Specification<br>Power and Energy Capacity | Load Growth Rate % | Last Year of Successful Deferral (Base Year – 2018) | Benefit-Cost Ratio based on NPV Analysis (last year of successful deferral) | Benefit-Cost Ratio for "T+M" Operation |
|---|---|---|---|---|---|
| S1 | 3 MW, 12 MWh | 1% | 2026 | 1.44 | 2.31 |
| S2 | 3 MW, 12 MWh | 2% | 2021 | 1.15 | 1.85 |
| S3 | 3 MW, 12 MWh | 3% | 2020 | 1.08 | 1.44 |
| S4 | 5 MW, 20 MWh | 1% | 2027 | 1.45 | 2.95 |
| S5 | 5 MW, 20 MWh | 2% | 2023 | 1.12 | 2.01 |
| S6 | 5 MW, 20 MWh | 3% | 2022 | 1.01 | 1.97 |
| S7 | 7 MW, 28 MWh | 1% | 2039 | 1.28 | 4.7 |
| S8 | 7 MW, 28 MWh | 2% | 2024 | 1.10 | 3.1 |
| S9 | 7 MW, 28 MWh | 3% | 2023 | 0.89 | 2.95 |

Based on the analysis shown in Tables 1 and 2 above, there is a clear tradeoff between the years of required deferral and economic viability of BESS, i.e., benefit-cost ratios. If opting under pure "transmission" operation, a higher benefit-cost ratio does not necessarily signify a more economical alternative since the number of deferred years may be lower, which may be against the utility's planning objectives for the service area. Battery capital costs and feeder upgrade costs are significant drivers in assessing deferral benefits. As BESS costs reduce further due to technological advancements and economies of scale, the analysis results may change moving towards more favorable economics for larger sized BESS configurations. Increasing BESS capacity leads to more years of deferral. However, higher capital costs offset the deferral benefits leading to lowering BC ratios for a considerable number of years before reaching breakeven compared to smaller sized BESS. Another insight obtained from this study is that under low load growth, it is much more economically viable to go for a smaller sized BESS (as shown in Fig) to ensure the capital costs do not exceed deferral benefits over the deferral period.

Even under a high load growth scenario, it is more economically viable to implement a lower sized BESS considering eventual feeder construction after '$t_p$' years. When load growth is minimal, hybrid-operation as a transmission and market asset is more profitable for larger-sized battery configurations because storage operation as a transmission complements operation in the real-time energy market leading to significant revenues. The revenues are even higher if the price volatility in the energy market is high, but battery replacement costs must be accounted for due to more frequent battery cycling under arbitrage operation.

When load growth increases over 2%, it is more prudent to have dedicated BESS to ensure transmission assets do not interfere with battery charge-discharge cycles and to limit battery degradation. Hybrid operation as a market asset (day-ahead or real-time) adds revenue leading to a substantial increase in benefit-cost ratios, which are possible for the future if sufficient battery optimization techniques are formulated. It is also necessary to implement relevant market mechanisms to notify storage operators for SATA or Market operation on a day-ahead basis such that battery charge-discharge cycles are not affected in hybrid operations leading to overload or loss of revenues. This may be in the form of a load-based notification test pursued by CAISO. It has been discussed in the later sections.

## 5.2 Opportunities and Challenges

Apart from the traditional usage of batteries to store off-peak energy and discharge during peak demand times, i.e., energy arbitrage or time-shifting, there are several other opportunities for BESS to be employed for key grid applications. Although the value of these services may not be quantified completely in the present market and regulatory structure, these benefits offer utilities a cost-effective solution to a variety of grid issues ranging from high capital costs to congestion. Three major opportunities have been mentioned below:

### 5.2.1 Modularity

A significant advantage of BESS as a transmission asset is its modularity and transportability. A potential business model that a utility or transmission operator can consider is transferring BESS physically to different areas for upgrade deferral or any other ancillary purposes inside its service territory area where issues such as peak load growth, low power quality or reactive power injection can be treated. Grid battery systems are extremely modular. Cells are assembled into *modules,* and then the modules are mounted into cabinet *racks* (mostly 19-inch), and racks are installed into a standard-sized *container* (mostly 40 feet long) (Hesse et al.,2017). A typical container usually stores 1-5 MWh of energy. A large battery plant is essentially a bunch of containers synchronizing to provide energy and capacity services. This modularity is not only good for BESS customization, but also the control and maintenance down to the single-cell level. It also buys significant time for the utilities to assess the demand profile of a service territory for a future line or substation upgrades.

### 5.2.2 Value Stacking with Complementary Services

As of now, batteries utilized as transmission assets are not allowed to operate in the wholesale market due to the current regulatory structure of ISO/RTOs. Some transmission operators such as CAISO and MISO have initiated proceedings to formulate rules regarding the hybrid operation of storage for transmission and market purposes. An important aspect of considering value-stacking for BESS with the primary use of peak-shaving which can defer upgrade investments in existing lines, feeders or substations is the “compatibility” of the secondary use-case with the primary use case.

### 5.2.3 Integration with PV

Integrating BESS with on-site PV can provide additional flexibility and revenue streams for a utility deferring T&D upgrade. The dispatch algorithm for the PV-BESS can be adjusted to include PV generation during daylight hours or can be adjusted to store PV-based energy in the storage to dispatch during peak demand hours finally. Eq (1) and (2) can be changed as:

(4) $\max import_{deferral} \geq load - battery\ charge + battery\ discharge - PV generation$

(5) $\max export_{deferral} \geq load + \ battery\ charge - battery\ discharge - PV generation$

Although the added cost of PV may prove to be a deterrent initially, PV combined with storage is eligible for tax deduction under US’ Business Investment Tax Credit or commonly known as ITC which reduces 30% of the capital cost of the combined system in the form of a tax deduction for the utility or tax equity investor. Currently, projects which would start construction before December 31st, 2020, are eligible for a 30% deduction, which will eventually be faded to 22% after 2022. An important caveat here is that to become eligible for the tax credit under this law, and the BESS must be charged entirely from the PV system attached to it, or else the 30% credit drops down to the % of energy charged using solar energy. Also, the charging cost reduces when PV is supplying energy to the BESS. To potentially utilize hybrid systems for T&D deferral, additional studies need to be conducted to analyze the resource potential and variability of solar energy in the region to ascertain whether it would be technologically viable or not. In areas where peak demand periods coincide or succeed hours with high solar output potential, hybrid systems may offer an attractive opportunity to reduce charging costs from the grid as well as defer capital investments on upgrading T&D infrastructure such as feeders, transformers etcetera.

Energy storage systems have the potential to disrupt the electric grid as we know it for years to come due to its expanding growth, falling costs, and awareness among policymakers and industries. To achieve that, the storage ecosystem needs to be aware of some key challenges which can decelerate the phenomenal growth it has seen over the last decade. These barriers and challenges have been mentioned below.

## 5.3 Irregular Demand Forecasts

A major challenge for utilities investing in storage systems for T&D deferral would be to assess the demand forecast for upcoming years to design and dispatch the battery system accordingly. Across the US, electricity demand has slowed in some places (PJM) and exploded in other areas (ERCOT) due to a variety of reasons such as increasing demand response measures and rapid residential and industrial growth. The role of emerging technologies like energy efficiency, industrial demand response, and explosive growth of the EV industry will create problems for utilities to predict load across their service territories due to the intermittent nature of the demand. Utilities had struggled with flat demand for the last decade, but analysis by the National Renewable Energy Laboratory (NREL) predicts steady growth across the next three decades, largely driven by the adoption of electric vehicles. Although a challenge, the flexible nature of BESS will eventually help the electric grid in providing energy during peak demand times when other supply options can't be ramped up. For this to happen, better algorithms and optimization models need to be developed to keep the technical characteristics of the battery and the grid in mind to adjust for uncertain situations.

## 5.4 Uncertain electricity market design and regulatory framework

One of the major barriers present in the US markets is the classification of electrical energy storage systems as a "generation asset" by federal authorities. Energy storage resources are technically capable of providing services in each of the functional classifications of generation, transmission and distribution (T&D) of electricity. Although recent FERC rulings (FERC Order. 841) have allowed ISO/RTOs to formulate regulations on allowing energy storage to participate in the energy and ancillary markets effectively, there still remains concerns on the T&D side due to lack of federal guidance on how to deploy storage as transmission asset (FERC Order 1000). Regulatory restrictions, along with accounting practices and requirements and the lack of clarity and transparency in these practices and requirements, effectively prevent a utility or developer from obtaining revenue with a resource providing service under multiple classifications. These issues are particularly prevalent in ISO/RTO regions in the US since, in non-ISO/RTO, a vertically integrated utility can recover the costs and profit by delving into all the value streams possible in each functional classification.

## 5.5 Material and Operational Safety

Although the adoption of storage has been increasing, safety codes and standards for storage are still under development, and questions have been raised about safety risks and how to mitigate those risks, according to a recent government study (Rusco, 2018). Efforts are underway to ensure that safety codes and standards address energy storage systems, but these types of standards tend to lag behind the development of storage technologies.

In addition, concerns about the operational safety of large storage systems as a fire hazard can be a barrier to their deployment in urban areas or proximity to other grid resources such as substations, and local entities such as city EHS and fire departments may not allow the deployment of storage on certain sites. This happens when an electrical short develops inside the cell, causing a thermal runaway rendering the external protection ineffective in nullifying this threat. For the lithium-ion battery runaway, it is caused by the exothermic reactions between the electrolyte, anode and cathode, with the temperature and pressure increasing in the battery, the battery ruptures (Wang et al.,2012). Since 2012, there have been three instances of fire explosions involving BESS, most recently in APS' 2 MW facility outside Phoenix, AZ.

A major issue brought to the fore from these experiences is that local jurisdictions and emergency responders, along with storage system installers, insurers, and others may not have a complete understanding of the hazards associated with storage and best approaches to addressing these hazards, such as the appropriate fire protection measures. Besides, local entities' review of energy storage systems, for example, can add additional time to the permitting process, given that these entities may not be familiar with storage systems and potential safety concerns. Although stricter standards are required for battery packs to lower the risk associated with electric short-circuiting, another important aspect is research on effective ways to educate firefighters to douse battery fires efficiently.

## 6.0 CONCLUSION & POLICY IMPLICATIONS

The strongest impacts on deferral benefits are the capital costs of the storage battery and the feeder upgrade, followed by other factors like the rate of load growth/increase and loan durations for BESS and feeder. Larger BESS sizes lead to more deferred years, but since capital costs of BESS are high, this leads to lower benefit-cost ratios and longer payback periods when storage is operated only as a transmission asset. It is also important to understand that factors such as utility objectives specified in the IRPs or transmission plans dominate the decision-making process to decide whether to invest in upgrades or not. So, if a utility is more inclined to defer for a larger period, then storage configuration can be optimized accordingly. In terms of techno-economic viability and long-term needs, it is better to utilize a smaller sized BESS, especially under low growth scenarios, as shown by the analysis results. Although utilities are allowed to recover costs from rate recovery, it is prudent to consider that utilizing storage would improve their financial situation. On the other hand, larger battery sizes are significantly more profitable when storage acts as both a transmission and market asset due to market revenues, but the charging/discharging cycles need to be optimized carefully so as not to hinder with the primary value-stream of application, in this case, i.e., transmission asset to reduce overload periods. The recent regulatory implications discussed below offer a solution for storage to act as both a transmission and market asset, which would propel utilities/ transmission operators to implement larger battery sizes.

Energy storage is often presented as a solution to the challenges utilities face in trying to promote clean energy resources, which reduce the effects of global warming and climate change. The U.S. Energy Storage Monitor Q4 2018 estimates that installations totalled 338 megawatts in 2018, and will grow to 3.9 gigawatts by 2023, much of it front-of-the-meter utility-scale projects. Despite this growth, most utility-scale battery installations are occurring in vertically integrated utility service areas outside of the organized power markets serving two-thirds of all U.S. electricity consumers. Storage can indeed encourage the penetration of intermittent and variable renewable energy resources through its time-shifting characteristics. A corollary to the assumption that storage is necessary for the integration of clean energy resources is that storage would also lead to a reduction of greenhouse gas emissions because it can store the excess energy generated at times of low market demand and inject it to the grid at a later time, reducing the need for generation from fossil-fuel-powered bulk system generators (Condon et al., 2018).

Other than FERC activities described in the previous sections, to date, federal policies involving energy storage have been limited, and most policy actions involving energy storage have been at the state level. State-level policy actions include setting procurement mandates, establishing incentives, and requiring incorporation of storage into long-term planning mechanisms such as integrated resource plans (IRPs) that demonstrate each utility's ability to meet long-term demand projections using a combination of generation, transmission, and energy efficiency investments, while minimizing costs (US EIA, 2018)**.** Recent policy discourse on integrating energy storage resources to the electric grid has revolved around regulatory hurdles inhibiting its deployment in multiple organized markets across the US. Even in vertically integrated markets, storage has been stifled due to the inability of the utilities to define storage value, particularly questions like "how to ask for storage in RFPs?". As shown through this study, positive benefit-cost ratios and investment deferral has the potential for utilities to save money and increase expenditure in the proliferation of renewable energy systems.

The real challenge lies in formulating an effective structural framework to integrate multiple services for BESS and streamline the cost allocation process, This may involve allowing BESS to be classified as a generator, load as well as a transmission asset. The need of the hour is a separate classification scheme for energy storage assets to value all these services fairly and reasonably. SATA with market operation can provide a huge boost to utility revenues and save billions of dollars in the avoided cost of upgrade investment if and only if RTO/ISOs come up with structural changes to their market operations. CAISO has taken progressive steps in this regard by initiating a scheme for SATA to recover costs and operate in the real-time and day-ahead market through policy proceedings for developing rules and regulations for SATA operation. MISO also opened proceedings for considering storage as a transmission asset in 2018, although it has made little headway in formulating actionable steps due to push back from state legislators. Federal and state policymakers must understand the benefits to the utilities as well as ratepayers that can be accrued from utilizing energy storage options and take concerted action towards formulating policies supporting their deployment rather than looking at obsolete options for transmission and distribution investments.

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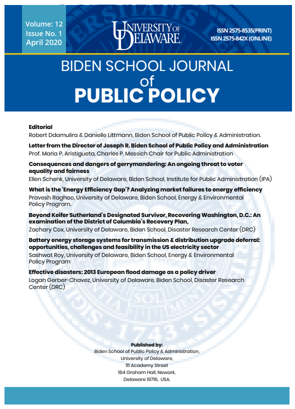


# Effective disasters: 2013 European flood damage as a policy driver

**LOGAN GERBER-CHAVEZ**, University of Delaware, Biden School, Disaster Research Center (DRC).

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## ABSTRACT

Disasters are the most tangible representation of climate change in our time. For policymakers, the easiest way to engage their constituents on new public policy is to relate it to a specific need. Natural disasters are an easily visible reference to remind people of a very pressing need for new disaster policy. Are frequent references to disasters then a motivation for policy change? If yes, do policy changes coincide with the degree of disaster damage? To compare policy responses to disasters it requires holding the magnitude of a disaster as a constant so as to compare the difference in policy action in relation to the same disaster. This assessment compares policy responses by nine (9) European countries (including; Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Serbia, Slovakia) affected by the 2013 flood of the Danube, Elbe, and Rhine rivers. Life years are implemented to compare the disaster impacts across multiple situations (Noy, 2015). The expectation was that the country most impacted would have the most incentive and therefore apply the most elaborate disaster policy in response.

***Keywords:*** *Keywords: Disaster; Policy; Flood; Europe; Policy Change; Policy Drivers; Life years.*

# 1. INTRODUCTION

Studies of policy change in the United States show disasters as focusing events in terms of new policy adoption (Birkland, 2004; Birkland, 2006). The question is whether this stands internationally and whether there is a threshold for how severe a disaster has to be before disaster policy is altered to incorporate lessons learned. The hypothesis is that a country that is more severely impacted by an accident would have more incentive and therefore pass changes to disaster policy following a significant event.

To look at this situation, in particular, a single disaster was required that was considered to be major climatologically, affecting multiple countries, and also not too recent to allow time. For policy changes, but not too long ago as to no longer be relevant. From these criteria, the Danube/Rhine/Elbe Rivers flood of 2013 was the best fit with the most data available. This disaster is considered the 7th most severe flood in the world from 1900-2016 in measurements of economic damage and largely impacted nine countries over one month (EM-DAT, 2017). This case also provides the exciting aspect of having eight of the nine involved countries being a part of the broader European Union community, with one completing the joining process within a month of the flood (CIA, 2017).

A comparison technique to include impacts from disaster across income levels was used to most accurately show non-monetary damages for each country equally. This measure of Life years (Noy, 2015) is based on the World Health Organization's Disability Adjusted Life Years to measure all damage in terms of human life instead of casualties or economic loss, which can both depend on individual qualities of the country (Noy, 2015). In countries with high incomes and high living standards, there is more expensive infrastructure, and even a little damage can cost a lot more than a levelled city in a country with fewer economic resources. Countries with high population densities will be more affected by a disaster in any given area but by raw numbers. There are other ways to measure disaster damage, for example, by the number of households or amount of agricultural damage, but all of these have a bias for different situations. Here, Life years are used to incorporate multiple types of disaster damage and reduce bias between countries at separate income or population levels (Noy, 2015).

National disaster policy has a long history of case studies observing action following a single disaster. The government is about to take responsibility for work when pushed by the public, but that only happens after the event, not proactively in any case (Birkland, 2004). Failure of the Tous dam in Spain in 1982 prompted a change from a focus on post-disaster aid and small-scale flood controls to mitigation techniques and improved preparedness (Serra-Llobet, 2013). Italian landslides have the same indicators as disasters that open policy windows, but these particular disasters have been noted not to necessarily cause policy change as standalone events (Scolobig, 2014). These are examples of an individual nation's response to a single event with limited comparative value to other situations.

## 1.1 Disaster Overview

While inland flooding is one of the most common natural disasters, the meteorological conditions of the 2013 European flood were rare but very similar to the significant 2002 and 2005 floods in the same region (Grams, 2014; Breinl, 2015). The flood occurred from May 28 to June 18th with the effects of lingering floodwaters lasting much longer, in some cases years (EM-DAT, 2017; Liska, 2014). The weeks before the flood was already cold and wet, saturating the ground. Fresh air was trapped over the Alps, and warmer air was stalled north, causing three consecutive cyclones moving westward and created a northerly flow against the west-east mountains, which created orographic enhancement of an already massive precipitation event. This 'warm conveyor belt' process in that direction is an infrequent situation but has "high potential for triggering very severe heavy precipitation events" (Grams, 2014).

Significant floods have become more frequent in the Danube River Basin over time (Bloschl, 2013). Significant flood event records go back to the 1700s, but the more recent events were in 1954, 2002, and 2005 (Bloschl, 2013). Many of the areas affected by the 2013 flood are the same that were hit by the 2002 flood which is known to have already instigated policy changes (JBA, 2014; Bloschl, 2013). In some areas, flood protection methods had been implemented following the flood of 2002. These avoided some of the damages in 2013 that would have occurred without those preventative measures. Most of those measures were in terms of natural levees rather than citizen education and preparedness (JBA, 2014; Bloschl, 2013). Damage evaluations of the entire flood showed the effects of the 2013 wave in Austria, Czech Republic, and Germany, at the same magnitude level of previous significant floods in 1954 and 2002, even after the implemented risk management programs over time (Fewtrell, 2013). For comparison at earlier waves, Passau, Germany, experienced flood levels similar to the highest recorded flood ever from 1501 (Bloschl, 2013). The flood magnitude was measured in different locations as anywhere between a 50-year flood to a 1000-year wave (ZIC, 2014).

## 1.2 Geographic Context

The geography of Austria is mostly mountains with the Danube flowing through. The majority of the population lives in the North eastern region of the country, because of poor soils and steep slopes most elsewhere (CIA, 2017). The Danube basin covers 96% of Austria, save a tiny portion of the western mountains; Austria covers 10% of the entire Danube basin (Gascoigne, 2009). Austria does receive high rainfall amounts in the Alpine mountainous regions, but much lower precipitation rates are recorded in the Northeast (ICPDR, 2006a). The Danube is used for hydroelectric power, amounting to 33% of Austria's total electricity, and is widely used for transportation of goods and drinking water.

The Danube River Basin covers almost half of the country and has 46% of the Bulgarian population residing within the basin (Gascoigne, 2009; ICPDR, 2017). The river also has regularly flooded; with virtually all of the open valley being used for urban infrastructure or agriculture. There is minimal water storage capacity surrounding the river (ICPDR, 2006a).

Most of the population of Croatia live in the northern half of the country with a quarter in the capital of Zagreb and the surrounding area (CIA, 2017). The Danube river makes up the far easternmost boundary between Croatia and Serbia as it flows southward from Hungary. The Danube basin covers 63% of Croatia, most of the northern and central portion, and 69% of the population (Gascoigne, 2009). The Danube is a major transportation route for international trade in Croatia and provides most of the drinking water for the country. Croatia does have generally more full preserved floodplains than most of their neighbours, but 15% of the mainland is still at regular risk for flooding (ICPDR, 2010).

The Elbe River Basin covers most of the country, and the Elbe itself goes through the capital city of Prague. Most of the previous flood policy has been centred on the Morava River after severe flood events in 1997 and 2002 (ICPDR, 2007a).

The southern German border is made by the Rhine River and the southern portion of the country, including Bavaria, has the Danube running through it (ICPDR, 2007b). The Danube River Basin only covers 17% of Germany, but Germany has the third-largest population residing in the Danube River Basin at 9.4 million people, behind only Romania and Hungary (Gascoigne, 2009). Flooding is the most common natural hazard for which Germany has to plan. With this substantial flood risk, Germany has taken many steps to develop flood prediction technologies and flood control measures (ICPDR, 2007b; CIA, 2017).

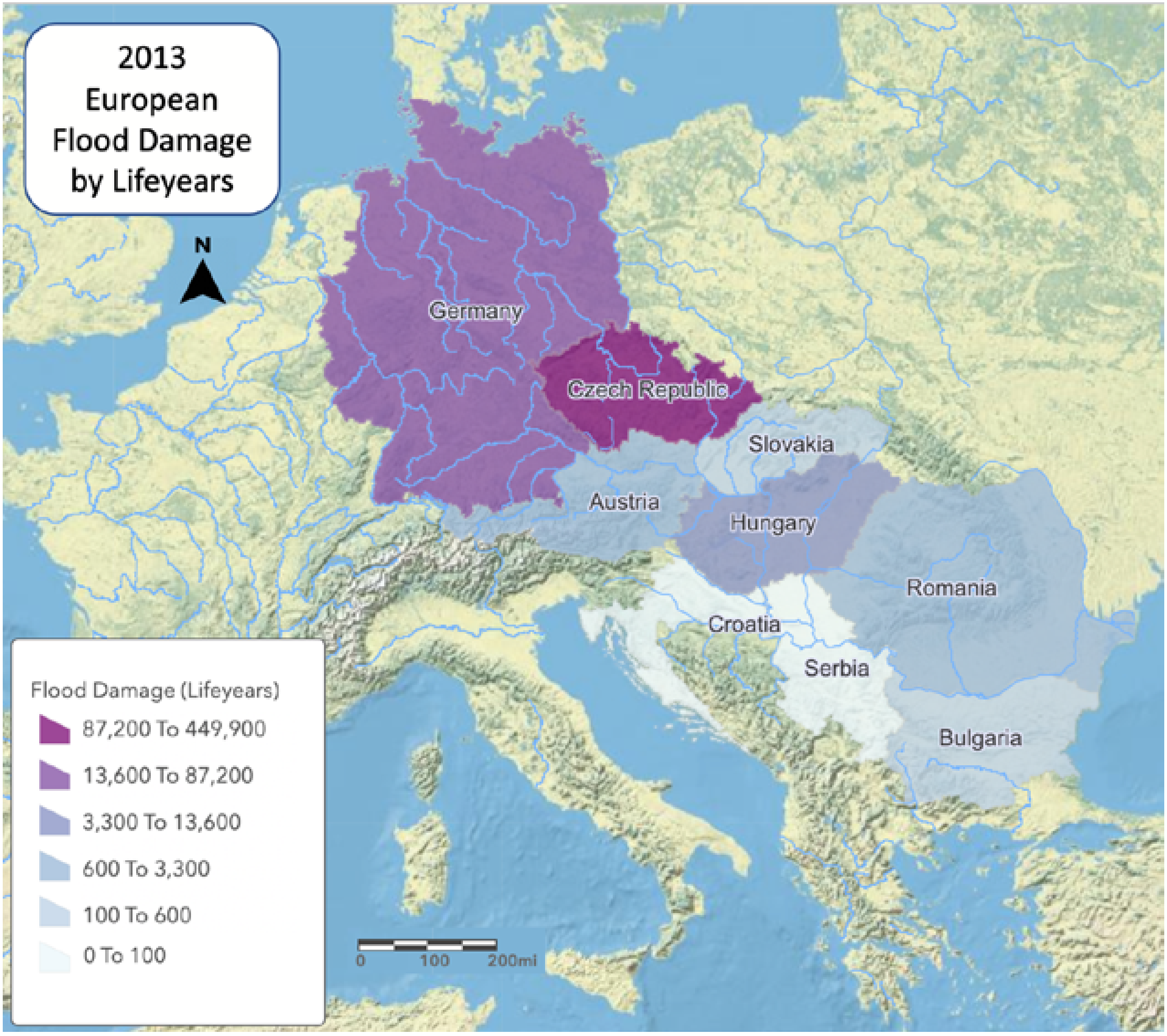
Hungary's entire population, 10.1 million people live in the Danube River Basin and the capital city of Budapest is directly on the Danube itself (ICPDR, 2006b). The Danube River Basin covers the entire country and Hungary contains the second-highest percentage of the total area of the basin for a single country at 11.6% (Gascoigne, 2009). A quarter of Hungary's population lives in a floodplain, along with a third of the rail system. Floods in Hungary have been known to last anywhere from hours to months. Because of this threat, they have developed flood protection systems consisting of emergency lowland flood reservoirs (ICPDR, 2006b).

The Danube River forms the southern boundary with Serbia and Bulgaria, and the river basin covers 97% of Romania, with 21.7 million Romanians residing within the pool (Gascoigne, 2009). Romania's water resources are generally limited, so they have taken great care to prepare for flood events both structurally and non-structurally with reservoir systems and reforestation programs as well as flood zone maps, education, and warning systems and public encouragement for flood insurance programs (ICPDR, 2006c).

The Danube River makes up the northern-most boundary between Serbia and Romania. Ten percent (10%) of the Danube River Basin is in Serbia and covers 92% of the country (Gascoigne, 2009). Serbia should have a lot of incentive to develop extensive water, and flood policies as 90% of its available water come from outside the country (ICPDR, 2006d). In northern Serbia, there are many levels, and in central Serbia, every major city lies in a flood plain. Serbia is prone to flash floods on smaller rivers and floods on significant rivers are common; yet, their flood protection policy is almost non-existent (ICPDR, 2006d).

Slovakia sits on the watershed divide between the Black Sea and the Baltic Sea and hosts parts of five different sub-basins of the Danube River (ICPDR, 2007c). Only 6% of the Danube River Basin is in Slovakia, but it covers 96% of the country and 5.2 million residents (Gascoigne, 2009). Slovakia experienced flooding often, but it is usually a result of snowmelt and occasionally summer precipitation. The cities are mostly already outfitted for flood protection along the major rivers (ICPDR, 2007c).

*Figure 1. Map of Study Area Indicating Damage*




## 1.3 Political Context

Germany is one of the most influential countries in all of Europe with the largest economy and largest population, besides Russia (CIA, 2017). Germany was one of the six original members of the EU and the Eurozone. Austria joined the EU in 1995 and has a fairly strong economy tied very closely to Germany. The Czech Republic, or Czechia, and Slovakia peacefully separated in 1993, and both joined the EU in 2004 (CIA, 2017). Bulgaria joined the EU in 2007, and as a former communist country still has one of the lowest per-capita incomes of EU members (CIA, 2017; World Bank, 2017). Romania was a communist nation until 1996 and also joined the EU in 2007 (CIA, 2017). Croatia joined the EU in 2013, and while it is the one of the wealthiest of the former Yugoslav Republics, for the countries affected by the 2013 flood, it is ranked 6th of 9, with a GDP higher only than Bulgaria, Romania, and Serbia (World Bank, 2017). Croatia was in an unusual situation during the flood as they were about to officially join the EU as of July 1, 2013, just after the flood. Therefore, they did not have any of the policy frameworks from the EU in place but were eligible to ask for EU aid after the flood. Serbia is the only country included in this study that is not a current member of the EU. With its turbulent past and ongoing negotiations about the independence of Kosovo, there is a goal for entry into the EU by 2025. Still, not much progress has been made since accession talks began in 2014 (CIA, 2017).

It is important to mention the government structures of each nation because the democratic nature and differences in form can influence whether the policy represents citizens' interests following the flooding event. The political structure of many of these countries is similar, most of which is a parliamentary republic with a civil law system in place. This goes for Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Serbia, and Slovakia (CIA, 2017). Romania is the only country in the study area with a slightly different government structure as a semi-presidential republic with a civil law system. In the Romanian executive branch of government, the President is directly elected by absolute majority, and a Prime Minister, appointed by the President with the consent of the Parliament. In Austria, Bulgaria, Croatia, Serbia, and Slovakia, the head of state is elected directly. In Germany and Hungary, the head of state is elected indirectly by the Federal Assembly by a simple majority and 2/3 majority respectively. The Czech Republic's head of state is now elected directly, but before the 2014 change in government, they were elected by the parliament.

The Czech Republic had a change of government in 2013-2014 and made it hard to look at small policy changes in the context of a huge structural shift. The new government of the Czech Republic that came into place in 2014 has been working on basic reforms to reduce corruption and maintain the economic strength of the country. Still, because of this turnover in the middle of the policy analysis time frame, there was a lack of data for any policy changes regarding disasters. It is unknown whether this is because of an actual lack of change or because action from the previous government was truncated.

The structure of the legislative branch is similar but varied in each of the countries involved. Each is either a bicameral or unicameral legislature with many different ways of electing their legislators. The legislative branch of Austria is a bicameral Federal Assembly consisting of the Bundesrat, appointed by each of the nine state parliaments, and Nationalrat, directly elected by proportional representation vote (CIA, 2017). The legislative branch has a unicameral Hrvatski Sabor with a variety of voting techniques, depending on the seat, from proportional representation to a simple majority by minority populations (CIA, 2017). The legislative branch of the Czech Republic has a bicameral Parliament with a Senate and Chamber of Deputies, or Poslanecka Snemovna, both directly elected for 6- and 4-year terms, respectively (CIA, 2017). The legislative branch is a bicameral Parliament consisting of the Federal Council or Bundesrat, appointed by state governments, and Bundestag, half elected by proportional representation and half elected by a simple majority (CIA, 2017). The legislative branch in Hungary is a unicameral National Assembly, about half directly elected by a simple majority and the other half elected by proportional representation along party lines (CIA, 2017). The Romanian legislative branch is a bicameral Parliament with a Sénat and Chamber of Deputies, both of which are elected by proportional representation via a party list (CIA, 2017). The Serbian legislative branch is a unicameral National Assembly with members serving in a single nationwide constituency and is elected by proportional representation by party affiliation (CIA, 2017). The Slovakian legislative branch is a unicameral National Council or Narodna Rada, elected for a nation-wide constituency by proportional representation (CIA, 2017). Bulgaria's legislative branch is a unicameral National Assembly, directly elected by proportional vote (CIA, 2017). This is represented in summary in Table 2.

There is an index of government corruption known as the Corruption Perception Index that measures "their perceived levels of public sector corruption" (CPI, 2017). In terms of reliability of representation, each country involved in the study ranks between 41-57 on the CPI, on a scale from 0-100 with 0 being highly corrupt. Germany and Austria are the only countries outside that range at 81 and 75, respectively (CPI, 2017). From this, we can gather that there is almost an equal comparison value between all the subjects, excluding Germany and Austria, which were already exceptional in their post-flood policy actions.

# 2. DATA AND METHODS

## 2.1 Life years

### 2.1.1 Life years Data

Evaluations of the 2013 flood came from several sources, each having varying numbers and no consensus on the actual results. Some sources even claimed different countries were impacted, also though they were not and vice versa. Data from multiple reports and databases were combined to get the most thorough picture of the flood impact. Switzerland, for example, was included in one flood report as being affected by the flood. Still, because there were no reports of damage or any details at all from that source or any other, Switzerland was not included in the analysis.

Noy's Life years measurement requires data for deaths, injuries, those made homeless, those affected, economic damage, recovery time, and per capita GDP (Noy, 2015; EM-DAT, 2017; Liska, 2014; ZIC, 2014; Monguzzi, 2013; World Bank, 2017; UN, 2015; UN, 2017; BLS, 2017; EUROPA, 2017; Pa, 2013). In the original model, precise data about each death and injury was used to determine exactly how many potential years were lost for each person killed (Noy, 2015). In this case, that level of specificity in data was not available, so an average age per country, based on the closest demographic information, was used instead (World Bank, 2017).

### 2.1.2 Life years Methodology

To determine Life years, a modified version of Noy's model was used to incorporate the function of a non-monetary measurement of disaster impact with only estimated and debated data available. The Life years formula is shown as Equations 1 through 6, incorporating the World Health Organization's disability-adjusted life year (DALY) and quality-adjusted life-year (QALY) as well as Noy's formulas. Noy's formula uses metrics for casualties (mortality), injured, affected, homelessness, and economic damage but the equation was made for the most detailed of disaster damage reports to which we did not have access in this case. An example of the calculations performed to obtain Life years is shown in Equation 7, for the case of Austria.

A compilation of the data used in this formula for each country is included in Table 1. There is no single damage report for this flood to give a number for each category in each country. Each source for damage and persons affected in the 2013 flood was slightly different depending on their measurement methods. Table 1 shows the averaged number for each country across the sources (BLS, 2017; EM-DAT, 2017; EUROPA, 2017; Fewtrell, 2013; Liska, 2014; Monguzzi, 2013; Pa, 2013; UN, 2015; UN, 2017; World Bank, 2017; ZIC, 2014).

**Equation 1. Life years**

$$\text{Lifeyears} = L\left(M, A^{death}, A^{exp}\right) + I(N) + F(N) + H(N) + DAM(Y, INC)$$

**Equation 2. Mortality (L)**

$$\text{Where } L\left(M, A^{death}, A^{exp}\right) = \sum_{m=1}^{M} \left(92 - A^{death}\right)$$

M = number of deaths recorded

$A^{exp}$= 92, WHO measure of uniform life expectancy

$A^{death}$= age of death in each case, without that degree of detail we use the average age of citizens at the time of disaster

**Equation 3. Injured (I)**

$$\text{Where } I(N) = \alpha TN$$

α= for wounded and affected, 0.054, welfare reduction weight WHO DALY for "generic, uncomplicated disease; the anxiety of diagnosis."

T= time to return to normality for injured it is the length of injury which can be estimated by severity

N= number of wounded persons recorded

**Equation 4. Affected (F)**

$$\text{Where } F(N) = TN$$

T= time to return to normality

for affected, it is the length of time it took the country to recover (usually

in years)

N= number of affected persons recorded

**Equation 5. Homelessness (H)**

$$\text{Where } H(N) = \beta N$$

β= for homeless, 0.117, WHO QALY

N= number of homeless persons recorded

**Equation 6. Economic Damages (DAM)**

$$\text{Where } DAM(Y, INC) = \frac{(1-c)Y}{INC}$$

c= 0.75, acknowledging that we spend most of our time on non-work activities

Y= damage estimates

INC=per capita income at the time of disaster

**Equation 7. Example Life years Calculation of 2013 Flood in Austria**

$$\text{Lifeyears} = \sum_{m=1}^{4.75} (92 - 41.42) + (0.054 * 0) + (0.5 * 200) + (0.117 * 500) + \frac{(1-0.75)616298774.33}{53965.43}$$

***Table 1. Flood Impact Data Averaged Across Sources***

| Country | Death | Injury | Homeless | Affected | Damage | Recovery Time | Average Age | Per Capita GDP | Lifeyears |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | USD (2018) | Fraction of a Year | | USD (2018) | |
| Austria | 4.75 | - | 500.00 | 200.00 | 616,298,774.33 | 0.50 | 41.42 | 53,965.43 | 3,253.81 |
| Bulgaria | - | - | - | 248.40 | 1,839,661.58 | 0.33 | 41.87 | 8,166.05 | 139.12 |
| Croatia | - | - | - | - | 141,512.43 | 0.33 | 41.66 | 14,443.52 | 2.45 |
| Czech Republic | 11.00 | - | 12,666.67 | 882,266.67 | 566,644,314.46 | 0.50 | 42.17 | 21,190.64 | 449,848.54 |
| Germany | 4.00 | - | 7,350.00 | 29,425.00 | 5,401,713,901.63 | 2.00 | 47.46 | 49,508.89 | 87,164.59 |
| Hungary | - | - | - | 48,565.00 | 82,077,209.01 | 0.25 | 42.02 | 14,542.44 | 13,552.24 |
| Romania | 4.00 | - | - | 1,468.80 | 65,237,229.92 | 0.42 | 42.16 | 10,198.72 | 2,410.51 |
| Serbia | - | - | - | - | 396,234.80 | 0.08 | 36.82 | 6,760.47 | 14.65 |
| Slovakia | 0.50 | 1.00 | 245.00 | 892.00 | 17,173,948.42 | 0.33 | 37.31 | 19,355.88 | 575.18 |

## 2.2 Policy Change Analysis

### 2.2.1 Policy Change Data

Policies were obtained from each country’s government websites, records, and various reports on the subject. Because of limitations in English content, only systems on the national level are included on a more broad scale, and local flood policies are mentioned anecdotally. Information about government structure and transparency came from country profile reports and international public databases (CIA, 2017; CPI, 2017). Most of the policy information was derived from public records from the civil law systems, from UN reports of disaster risk program progress, or requests for aid, where the countries themselves are self-reporting their policies and policy goals as well as the circumstances around them. While these reports could be considered biased because they are self-reported, for our purposes, they were deemed reliable. It is in each country’s best interest to be the most thorough as far as current policy but to also not exaggerate as the UN could quickly check on any reported claims.

### 2.2.2 Policy Change Methodology

Disaster policy changes were difficult to identify in some cases and therefore, were only compared for countries with policy information available to the public. Each country’s policy changes were considered in context with previous policies that were already in place. As well as their government structure and general relationships with their citizens, i.e. are they known to be more representative of public concerns or more separated by corruption or dictatorship. These policy changes are described qualitatively in terms of the content of the change because they are specific to disaster policy and account for adjustments and expansions of very specific policies.

## 3. RESULTS

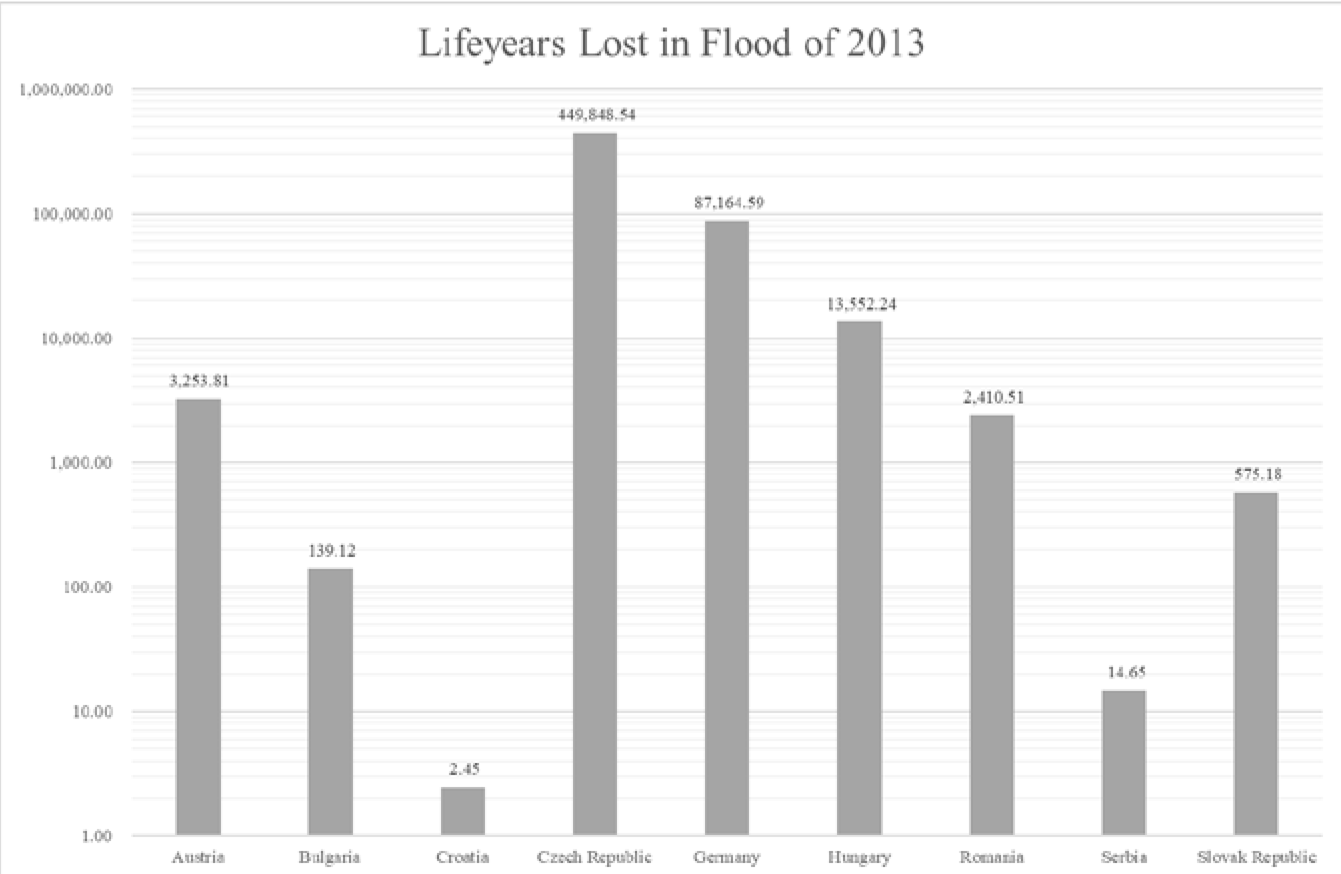
*Table 2. Life years and Policy Change Results with Brief Country Profile Ordered By Damage*

| Country | Population (2013) | EU | Government Type | Flood Damage (Life years) | Policy Change |
|---|---|---|---|---|---|
| Czech Republic | 10,514,272 | Since 2004 | parliamentary republic with a civil law system (enacted in 2014) – bicameral legislature Senate and Chamber of Deputies, or Poslanecka Snemovna (elected by party-list proportional representation) | 449,849 | **Change in government mid-study period |
| Germany | 80,645,605 | Original Member | parliamentary republic with a civil law system – bicameral legislature Bundesrat (appointed by state governments) and Bundestag, (half elected by proportional representation and half elected by simple majority) | 87,165 | A national and international agreement with Austria |
| Hungary | 9,893,082 | Since 2004 | parliamentary republic with a civil legal system - unicameral National Assembly (half directly elected by a simple majority and the other half elected by party-list proportional representation) | 13,552 | National policy change |
| Austria | 8,479,823 | Since 1995 | parliamentary republic with a civil law system – bicameral legislature Bundesrat (appointed by nine state parliaments) and Nationalrat (directly elected by proportional representation vote) | 3,254 | National (procedural) and International agreement with Germany |
| Romania | 19,983,693 | Since 2007 | a semi-presidential republic with a civil law system – bicameral Parliament with a Senat and Chamber of Deputies (elected by party-list proportional representation) | 2,411 | **Not enough public policy information to make conclusions |
| Slovakia | 5,413,393 | Since 2004 | parliamentary republic with a civil law system – unicameral National Council Narodna Rada (elected for a nation-wide constituency by proportional representation) | 575 | A national and international agreement with Ukraine |
| Bulgaria | 7,265,115 | Since 2007 | parliamentary republic and a civil law system – unicameral legislature (directly elected by proportional vote) | 139 | No |

| | | | | | |
|---|---|---|---|---|---|
| Serbia | 7,186,862 | NO | parliamentary republic with a civil law system – unicameral National Assembly (elected by party-list proportional representation) | 15 | No (National policy change after 2014 flood with much larger impact) |
| Croatia | 4,255,689 | Since July 2013 (1-month post-flood) | parliamentary republic with a civil law system – unicameral legislature Hrvatski Sabor (elected by a variety of voting methods depending on the seat) | 2 | No (National policy change after 2014 flood with much larger impact) |

***Figure 2. Total Lifeyears Lost***

Graphical representation of Table 2 on a logarithmic scale.




Life years measurements, shown in Table 2 and graphically in Figures 1 and 2, indicate the most affected country was the Czech Republic by a large margin. Next was Germany, followed by Hungary, Austria, Romania, Slovakia, Bulgaria, Serbia, and last Croatia.

The Czech Republic, which was the most impacted, did not have much information available regarding any disaster policy, so no conclusions were able to be made about an evaluation of policy changes. A few actions were mentioned in press conferences from the new Czechia government, but none of the statements related to these policies mentioned the 2013 floods specifically. The Czechia government did say the 2002 wave in one instance (Brabec, 2015; Sequensová, 2014).

Germany experienced the major flood of the Elbe River in 2002 and made changes that were adopted in 2005 to improve flood control and define 100-year flood plains (Mrzyglocki, 2015). The full implementation of 100-year flood plain maps was to be done by 2012 and have flood risk management plans done by 2015. The policy also established legal responsibilities for each level of government in flood prevention, warning, and recovery, and funding for research was planned to develop a common strategy for adaptation to climate change. Even with the previous policy changes from floods in the past, Germany did have an acknowledgement of lessons learned from the 2013 flood in their national plan in 2015 when they observed that social media played a role in informing those affected and allowing more efficient distribution of volunteers and first responders (Mrzyglocki, 2015). The goal of the plan was to use this observation to ensure the communication is accurate and efficiently managed.

Hungary faced immense damage across the country from the flood. They publically acknowledge that despite the high economic loss and many people affected, there were no casualties in Hungary. They attributed this to its "prevention and resilience measures" (Bakondi, 2015). To deal with the high number of people affected by damages, the government instituted a new way to compensate for disaster damages following the flood (Bakondi, 2015).

Austria's reaction post-flood in terms of disaster policy was to alter its budget to speed previously docketed flood protection plans. While this is a reaction and is a policy change, it is not a change to include new content (Pichler, 2016). Romania lacked in public information at all and no conclusion was made as to their policy response post-flood.

Slovakia already had some flood protection policies in place before the flood, namely a partnership with Ukraine for an early warning system across both of their at-risk populations (Burian, 2015). Post-flood Slovakia has moved to create more mitigation and protection plans instead of just warnings (Burian, 2015). Bulgaria had virtually no policy change shown. Even in public statements on risk reduction, they made no mention of past disasters or any reason to make disaster policy changes in the future. Serbia and Croatia didn't have any attributable policy change either but did in later flood events as will be discussed later.

Observations of regional and international cooperation were also found following the floods. In 2014, the state of Bavaria in Germany and the state of Upper Austria in Austria signed agreements on joint flood research and cross-border flood protection measures. They stated the motivation being the effects of the floods of the Oder river in 1990 and the Elbe river in 2002 and 2013 (Mrzyglocki, 2015).

## 4. DISCUSSION/CONCLUSION

The results show, as far as the available data, that the countries with the most progress in policy following the 2013 floods were Germany and Hungary. Also, supporting the hypothesis, Austria and Slovakia lost more Life years concerning some of their flood-affected neighbours, and in turn, had changed to their disaster policy following the flood. This supports the hypothesis that countries respond to non-monetary damages with policy change.

For each country, there is a very different background of policy pre-2013, many have been influenced by previous floods, but not always in the same ways or to the same degree. There was a major flood of the Elbe River in 2002 and another flood of Danube in 2005. Climatologically, floods have been increasing over time with three new records set since 2002 (Gascoigne, 2009).

The least impacted countries: Bulgaria, Croatia, and Serbia, had virtually no policy change in response to the flood. For Bulgaria, the Bulgarian corruption perception score is 43, the second-lowest in the study region (CPI, 2017). This indicates that the government is not known to be connected with the citizens' interests, so policies may not be expected to follow logically after a disaster as those with less corruption would. In the case of Serbia and Croatia, especially, this was not just a function of an unconnected government because both had a legitimate response to a larger flood the year after (EM-DAT, 2017; Holcinger, 2015; Blagojevic, 2017). In Croatia, they had a devastating flood in 2014 that is mentioned in subsequent policy numerous times while the 2013 flood was not mentioned. Even in the 2014 flood, the statements made in government reports offer only vague objectives, for example,

*"Recent events in Croatia (2014 floods in Slavonia) will result in many lessons learnt that should be supplemented by lessons learned from future cooperation and exercises and implemented into legislation and practice to economize resources and avoid duplications and lack of coordination of activities in all phases of disaster management." (*Holcinger, 2015:44)

The Croatian flood of 2014 in Slavonia, based on a non-exhaustive search for damage statistics, would be estimated at 151,906.02 Life years lost, which would put that flood at about the same level as the magnitude Hungary experienced in the 2013 flood (EM-DAT, 2017). It makes more sense in that context why the government would be much more inclined to make policy changes as a result of that flood rather than the one in this natural experiment. Serbia was much the same case; they were severely affected by the same May 2014 flood that Croatia experienced, and they made substantial changes to flood policy following that flood rather than the locally less intense flood of 2013. Following the 2014 flood, Serbia requested aid from the European Union, World Bank, and the United Nations to establish flood protection. A disaster risk reduction program, a post-disaster reconstruction law, and, after recovering, even became a donor to the Global Facility for Disaster Reduction and Recovery to help pay it forward for the aid they received (Blagojevic, 2017).

No conclusions were made about Romania or the Czech Republic because of a lack of information. While the Czech Republic did not seem to have any policy changes concerning the flood, it is still unknown if this is because there was no reaction or if it was a function of their government structure change in 2014 and lack of public record.

A specific threshold for policy change could not be distinguished without more comprehensive data. This analysis opens many new avenues into efficiency evaluations of post-flood policies and the evolution of national disaster risk reduction plans. Toward this goal, though, the Croatian and Serbian response to this flood in comparison to their more intense flood the next year shows the relationship between disaster magnitude and policy change does exist in at least one case (Holcinger, 2015; Blagojevic, 2017).

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