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Unlocking the diversity in the Texas energy landscape;

The Power of The Aggregator with C&I In The Era of IRA

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Abstract

In August 2022, to achieve national climate goals, the Inflation Reduction Act (IRA) was signed into American law and has garnered global attention around the world. In U.S. history, it is the biggest investment legislation on climate change and transition to renewables (i.e., Distributed Energy Resources, DERs) which have accelerated expansion towards energy. Around $370 billion will be poured into the domestic market to expedite private investments in clean energy solutions.

This dissertation aims to identify **how Texas can pave the way for a transition toward a clean energy state by leveraging the IRA**. Texas is a state highly dependent on fossil fuels with the biggest production and consumption, simultaneously, it has the largest clean energy capacity based on a unique electricity market structure. Texas' continuous extreme weather disaster gives strong motivation and urgency for change and has the potential to accelerate the state's energy transition through its unique deregulated electricity market structure. Also, The C&I sector accounts for most of the electricity consumption in Texas, it has a high potential to offer larger investments, greater capacity, and the potential for creating innovative business models.

However, the market structure of Texas poses many challenges and barriers for aggregators, hindering wider adoption thus lessening the impact of these technologies, and creating limitations for aggregators. Therefore, this study highlights the **aggregator's importance in the C&I sector** playing a pivotal role as an intermediary between the market and end customers optimizing DERs and facilitating the implementation of Demand Response (DR) and Virtual Power Plant (VPP) methods in Texas. Moreover, this dissertation gives insight **by analyzing opportunities and potential business models to unlock the roles of aggregators,** furthermore, it emphasizes **the importance of encouraging C&I aggregator involvement in the wholesale electricity market in Texas**.

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List of Abbreviations

ADER	Aggregated Distributed Energy Resources
AI	Artificial Intelligence
AS	Ancillary Service
B2B	Business-to-Business
B2C	Business-to-Consumer
BESS	Battery Energy Storage System
BIL	Bipartisan Infrastructure Law
BMS	Battery Management System
BRP	Balance Responsible Parties
C&I	Commercial and Industrial
DER	Distributed Energy Resource
DR	Demand Response
DRPs	Demand Response Providers
DSM	Demand Side Management
DSO	Distribution system operator
EIA	Energy Information Administration
EMS	Energy Management System
EPA	U.S Environmental Protection Agency
ERCOT	Electric Reliability Council of Texas
ERS	Emergency Resource Service
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission
GHG	GreenHouseGas
GHGRP	GreenHouseGas Reporting Program
IEEE	Institute of Electrical and Electronics Engineers
IIJA	Infrastructure Investment and Jobs Act
IOU	Investor-Owned Utility
IRA	Inflation Reduction Act
ITC	Investment Tax Credit
LNG	Liquefied Natural Gas
LP	Load Participant
LSE	Load Serving Entity
OEM	Original Equipment Manufacture
OpenADR	Open Automated Demand Response
PCS	Power Conversion System
PMS	Power Management System
PTC	Production Tax Credit
PUCT	Public Utility Commission of Texas
QSE	Qualified Scheduling Entities
REP	Retail Service Provider
RMI	Rocky Mountain Institute
RMI	Rocky Mountain Institute
ROI	Return on Investment
RRS	Responsive Reserve Service
RPS	Renewables Portfolio Standard
SMB	Small Business Administration
TSO	Transmission System Operator
V2G	Vehicle to Grid
VPP	Virtual Power Plant

Introduction

The imperative to mitigate the worst impacts of climate change, triggered by the release of greenhouse gas emissions (GHG) from the burning of fossil fuels, has brought the global energy transition towards cleaner and more sustainable energy sources that is currently underway. The United States is the largest cumulative CO2 emission country[1] and the second-largest annual CO2 emission country after China. Thus, it has a significant responsibility to take actions for climate change historically and currently.

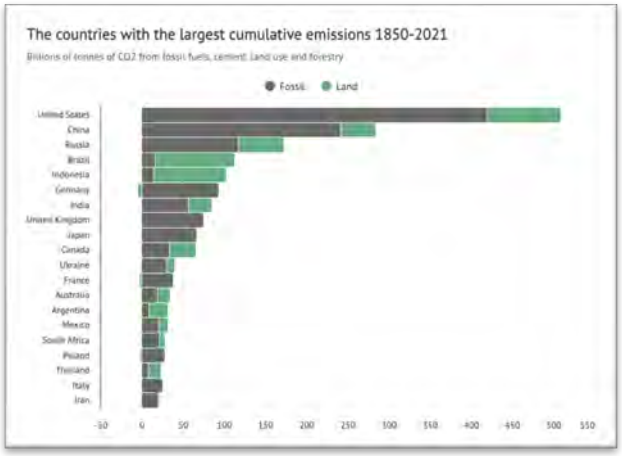


Figure 1. The Countries with Cumulative CO2 Emission (source : CarbonBrief)

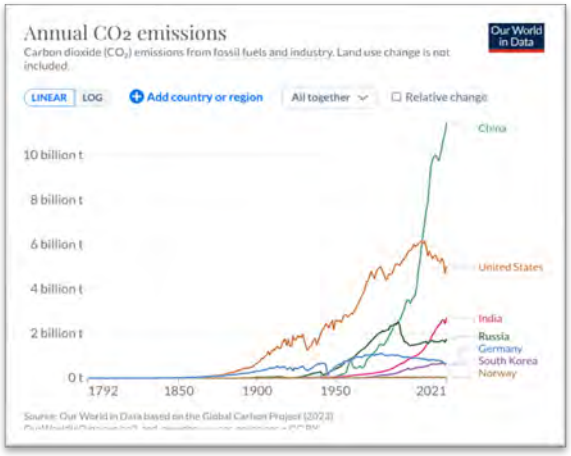


Figure 2. Annual CO2 emission by countries (source : Ourworldindata)

In recent years, the U.S has been taking a number of steps to address this issue, both domestically and internationally such as rejoining the Paris Agreement in 2021, establishing the National Climate Task Force[2], and setting an ambition to reduce greenhouse gas emissions by 50~52% from the 2005 level by 2030 through the Nationally Determined Contribution (NDC)[3]. Furthermore, In Figure 3, the *US long-term strategy* presents the representative pathway for Net-Zero Emissions by 2050 through the transformation in the energy sector in turn causing an energy transition, better energy efficiency, and decarbonizing electricity. In order to achieve a net-zero by 2050, the long-term strategy shows that the crucial pillar is to require the Federal Leadership to have a sustained and coordinated action spanning the investments and incentives for clean technologies in all sectors to support the deployment [4].

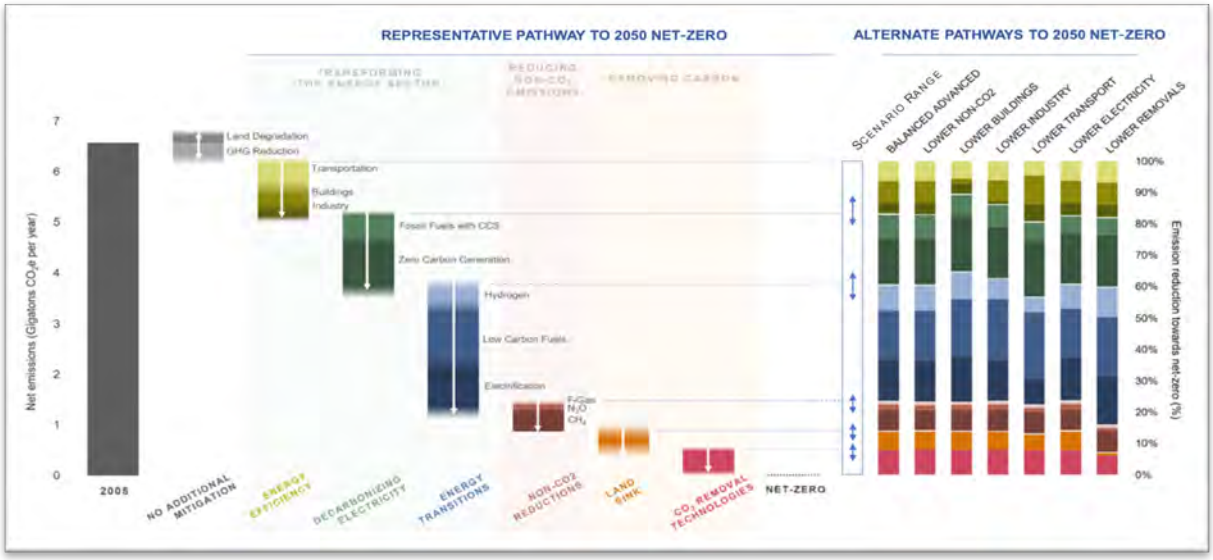


Figure 3. US long-term strategy for pathway to Net-Zero GHG by 2050

America's Flip-flopping on climate change, IRA

In efforts for the federal government to accomplish the goal, the United States has been accelerating their climate policy to focus on investments and incentives on the implementation of clean technologies. In November 2021, they legislated the Infrastructure Investment and Jobs Act (IIJA) also referred to as the Bipartisan Infrastructure Law (BIL) for investing in the nation's infrastructure and competitiveness[5]. The deal mainly focuses on rebuilding and upgrading infrastructures such as domestic roads, bridges, public transit system, airports and tackling the climate crisis. Especially, IIJA's investment in clean energy and climate resiliency which has been meaningful in upgrading the transmission, grid, and building resilient infrastructure for extreme weather events. For instance, while resolving geographic limits for Electric Vehicle (EV) expansion, it invests $7.5 billion to build an astonishing 500,000 EV chargers across the country and to replace school buses and ferries with clean and zero emission yellow school bus fleets and ferries made in America[6].

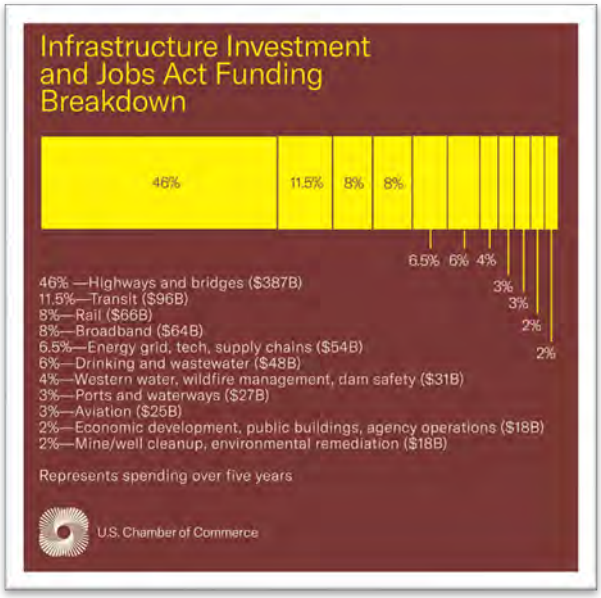


Figure 4. IIJA funding breakdown

However, IIJA's kryptonite in the climate change investment is that one-third of the funding investment is needed for physical highways and bridge projects that do not include renewable energy and follow no strict requirement to adhere to strong environmental standards as shown in Figure 4[7]. It was criticized to have potential new subsidies for fossil fuels, and it does not do enough to address the root causes of climate change[8].

In August 2022, The United States moved a significant step toward a clean energy transition when the Biden administration passed the Inflation Reduction Act which is the largest investment in the fight against climate change historically ever made[9]. It invests $369 billion through tax credits and grants to secure America's energy future and achieve the national climate goals in order to prevent a climate crisis. It will accelerate energy electrification and drive a decrease in price of renewable resources by increasing renewables investment, and at the same time also putting in place a tax penalty plan on methane emitters which will lead to a big impact on reducing GHG. As one of the climate change plans in IRA, it has a focus on building a clean energy economy[9] that will increase the use of renewable energy sources.

By 2030, the plan includes the installation of 950 million solar panels, 120,000 wind turbines, and 2,300 grid-scale battery plants, which will all contribute to the growth of distribution of energy resources (DERs[1])[11]. This investment for climate change will also accelerate investors' attention to cleaner projects and increase the American competitiveness of renewable-related projects in the world[12]. With these new clean resources increasing, the cost of energy production and renewable manufacturing is expected to decrease[13], making renewable energy more cost-competitive with traditional energy sources. This will facilitate the rise in the importance of energy resource aggregation to manage and expand energy resources. As a result, the IRA is poised to significantly boost the adoption of DER across the country, paving the way for a more sustainable and resilient energy future.

[1] [10] Distributed Energy Resources; such as fuel cells, PV, Wind and Energy storage technologies like batteries, EVs. It refers to electric power generation resources that are directly connected to medium voltage (MV) or low voltage (LV) distribution systems, rather than to the bulk power transmission systems. DER includes both generation units.

Why Texas?

Texas is an interesting case study for examining the impact of the Inflation Reduction Act (IRA) on the energy sector due to its unique energy landscape which contains its own power grid (ERCOT). Unfortunately, even though they will be one of the biggest beneficiary states of the IRA stimulus[14], new challenges and battles will arise[15] and Texas will need to face them to achieve its ultimate goal. Texas has a deregulated electricity market and is isolated from other states. Its unique structure allows for a competitive marketplace among the ERCOT region, where consumers can choose their electricity provider and developers can easily build and operate new renewable energy projects. However, it also led the lack of prevent solution for extreme weather event like Winter Uri in 2021[16], [17]. Nevertheless, this structure has resulted in Texas already having a large and diverse mix of energy resources and an open electricity market structure that promotes competition and innovation.

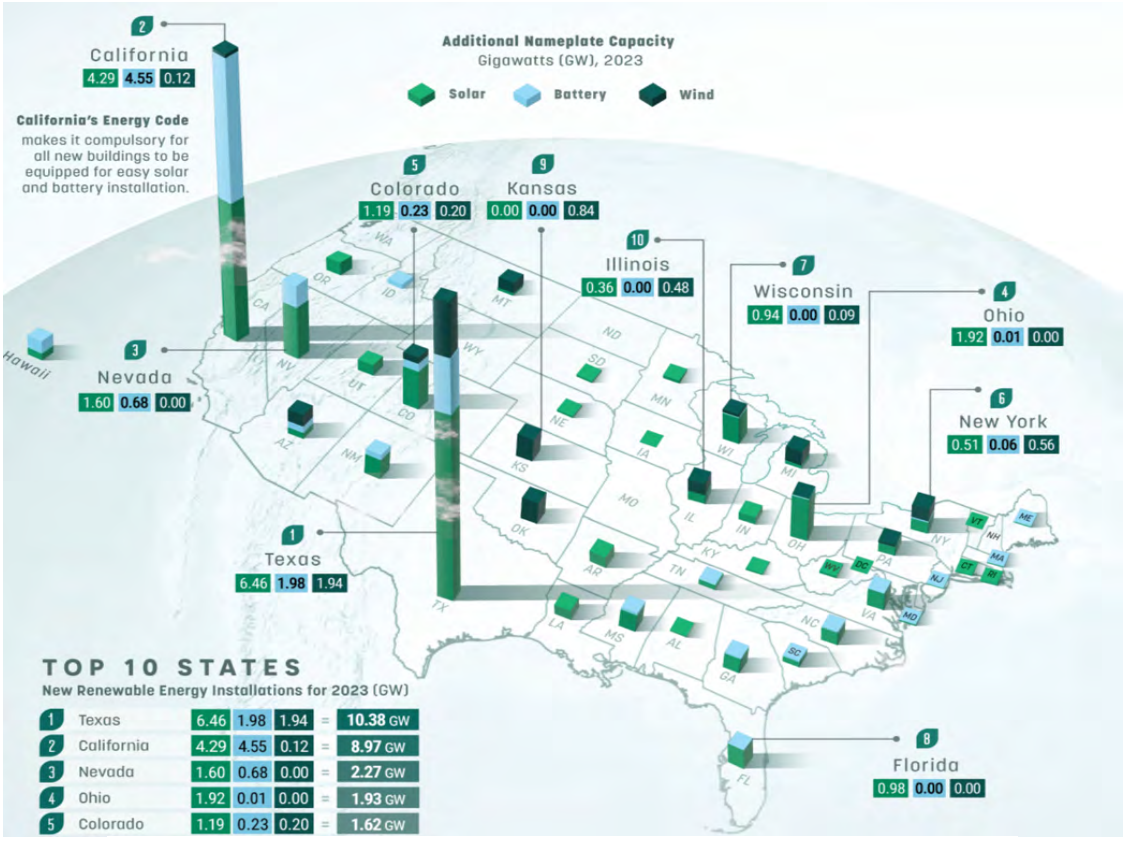


Figure 5. Planned U.S. renewable energy and battery storage installations by state for 2023. (Source:Visualcapitalis.com, EIA data)

As a result in Figure 5 shown, Texas has long been a leader in the development of renewable energy sources [18], particularly wind energy. It puts the state in a strong position to adapt to new regulation for energy transition and the increasing use of distributed energy resources

(DERs) that will be brought on by the investments made. Furthermore, the state has a thriving energy industry, with leading companies possessing unparalleled technical expertise and experience in clean energy technology, which is one of IRA's vital funding sectors.

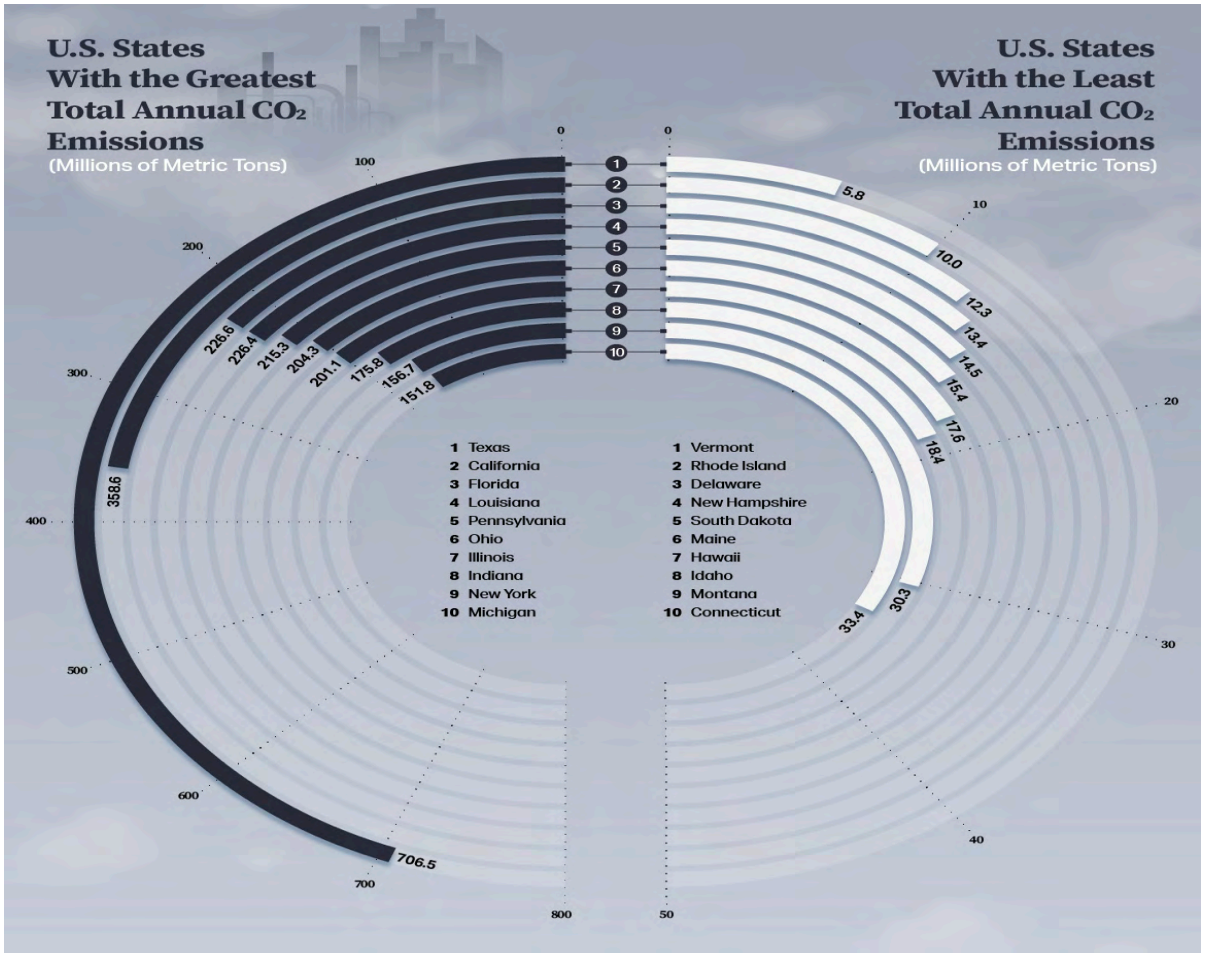


Figure 6. Texas is the greatest total Annual CO2 emission (Source: SolarPower.guide)

All that said, however, Texas is the largest gas-producing and consuming state as well as the largest emitter of GHG in the United States, making it heavily dependent on fossil fuels as shown in Figure 6[19]. The majority of Texas' GHG emissions come from the energy sector, particularly from electricity generation and oil and gas production. According to the Texas Commission on Environmental Quality, the electricity generation sector accounted for 33% of Texas' GHG emissions in 2019, while the oil and gas sector accounted for 53%. As a result, the state is increasingly vulnerable to the impacts of climate change, such as extreme weather events that disrupt energy infrastructure and threaten public safety[20]. The IRA's focus on reducing greenhouse gas emissions and accelerating the transition to renewable energy **could benefit Texas by incentivizing the state to further develop its DER market**

and invest in clean energy technologies, but it also could be a stick for the biggest industry in Texas as the IRA could pose challenges to Texas's traditional fossil fuel industries. On the other hand, with all the new clean energy tech, Texas still struggles to keep up with the demand causing it to be on a crutch named fossil fuels[21]. Furthermore, Texas's unique market structure has been struggling in driving a transformative shift toward an innovative market to make a reliable grid[22]. As IRA leads the bottom-up approach by increasing DERs which is pushing to restructure to accept DERs into the grid. It's at a critical point for Texas to break where they've been independent for a long time and have to respond quickly.

Why C&I sector?

The commercial and industrial (C&I) sector is a crucial player in Texas's energy landscape as it accounts for most of the electricity consumption in the state. According to the U.S. Energy Information Administration (EIA), Texas is the largest energy-consuming state in the country, and its C&I sector accounted for about 60% of Texas' total energy consumption in 2018 [23].

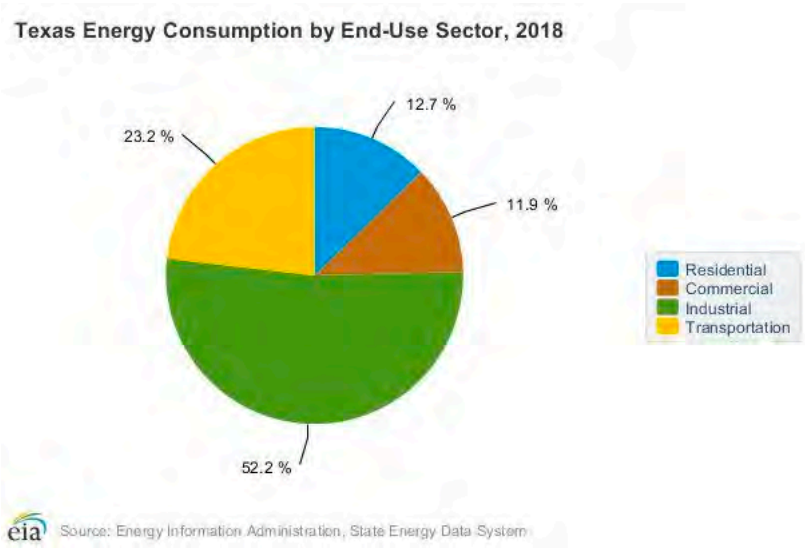


Figure 7. Texas Energy Consumption by End-Use Sector, 2018

Especially, the implementation of the IRA has played a significant role in driving investments in renewable energy within the commercial and industrial (C&I) sector. Given the pressing energy situation in Texas, **the C&I sector holds immense potential in fostering the installation of large-capacity clean energy sources[24].** With its substantial

share of electricity consumption in the state, the C&I sector can make a substantial impact on transitioning Texas towards a cleaner and more sustainable energy future. The urgency of the situation calls for accelerated efforts in harnessing the C&I sector's capacity and influence to promote the widespread adoption of renewable energy technologies and drive the necessary transformation of Texas' energy landscape.

How do C&I Sector Aggregators create changes?

One of the most important roles needing to be filled in the C&I sector are C&I aggregators [25], who act as intermediaries between energy consumers and DER providers, have emerged as a promising solution for managing and optimizing the use of DERs in the C&I sector.

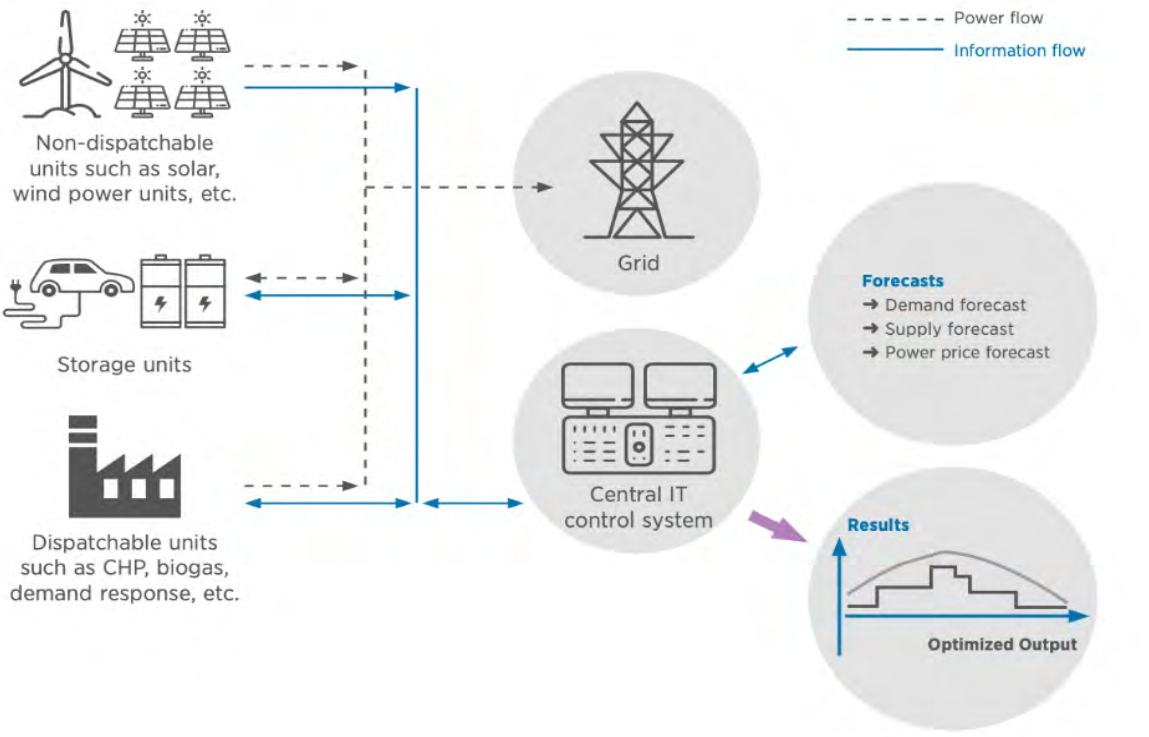


Figure 8. Overview of an aggregator's information(data) flows, IRENA

By aggregating multiple DERs, C&I aggregators can provide more reliable and cost-effective energy services to their customers while also maximizing the value of DERs for the grid[26]. The emergence of C&I aggregators and their role in managing and optimizing distributed

energy resources (DERs) within the C&I sector has led to the implementation of a Virtual Power Plant (VPP) scheme in Texas[27].

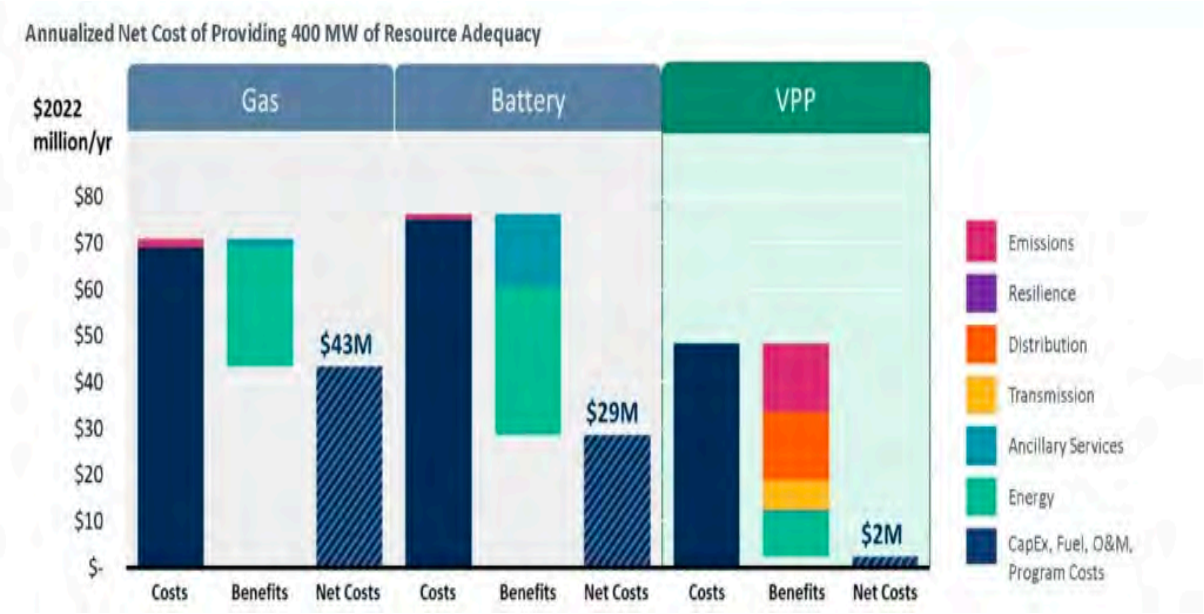


Figure 9. VPP could provide the same resource adequacy at a significant cost discount relative to the alternatives (Source: Brattle Group, 2023)

By leveraging the flexibility and diversity of DERs through the VPP scheme, Texas has the potential to bolster its resilience, mitigate grid disruptions by extreme weather, and ensure a more reliable and efficient energy system, ultimately benefiting both C&I customers and the overall grid stability[28], [29]. However, with the vague aggregator definition and "glass wall" making it harder to participate in the wholesale market and has slowed expansion of its market potential. The potential of C&I aggregators to reach the United States' long-term strategy and prevent extreme weather events in Texas is becoming more and more significant, nevertheless, little attention is paid to the potential of the C&I sector's contribution to the energy transition by aggregators.

This thesis endeavors to investigate the influence of the Infrastructure Reduction Act (IRA) on the role of Commercial and Industrial (C&I) aggregators in Texas and to unlock the diversity of Texas landscape. It analyzes the challenges and opportunities to provide insight for the necessary restructuring of the Electric Reliability Council of Texas (ERCOT) to fully capitalize on the opportunities presented by the IRA. Chapter 1 will conduct an analysis of Texas's energy system, examining the benefits and challenges associated with the IRA's implementation in the state's energy sector.

In Chapter 2, it aims at the understanding of the Texas market structure, examines the reason why expansion of aggregators has been slowed, and its challenges. Furthermore, through an understanding of the C&I aggregators' characters and business model in Texas, utilizing stakeholder mapping to identify gaps and explore potential restructuring opportunities that enable ERCOT in order to optimize the incentives provided by the IRA. Additionally, it analyzes recent projects in the USA, potential partnerships, businesses, and brings up interviews with aggregators' companies that will provide firsthand insights into the practical impact of the IRA.

Chapter 3 will present conclusive opportunities for the next path in Texas to foster their energy security while influencing positive impact economically, politically, and environmentally. This research aims to provide valuable insights to policymakers, industry stakeholders, and investors involved in the Texas energy market.

Chapter 1. Texas Energy System and IRA: Legacies, Changes.

In the historical context of the Texas energy system, fossil fuels have traditionally held a dominant position until the mid-20th century. Especially, the subsequent discovery of shale oil and gas reserves [30], which christened the “America's Shale revolution [31]," triggered a substantial surge in production, solidifying natural gas as a primary energy source and further entrenching the state's path dependence on fossil fuels. It led Texas to the greatest growth state in the USA [32], consequently, Texas has a robust infrastructure, political clout, and intricate economic interconnections with the fossil fuel industry that have fortified this path dependency.

However, recent extreme weather events like the Winter Storm Uri in 2021 have prompted a reevaluation of Texas' energy system and the need to break away from fossil fuel dependency [33]. As a wings and a player, America's historically significant investment on climate change 'IRA (Infrastructure Reduction Act)[9]' legislation accelerate it. To understand **how Texas fossil fuel dependence embedded deeply** and **what will be the key to break out the dependency**, in this chapter examine Texas history and electricity market, and the impact of IRA in Texas.

Texas Energy System.

The energy system of Texas has a rich history that can be traced back to the early 19th century when fossil fuels began to play a significant role in the United States. In Figure 10 shows, the 1850s is when coal began to be used as a fuel source for steam engines [34]. Coal became dominant in the late 19th century, followed by petroleum and natural gas consumption in the mid-20th century [35].

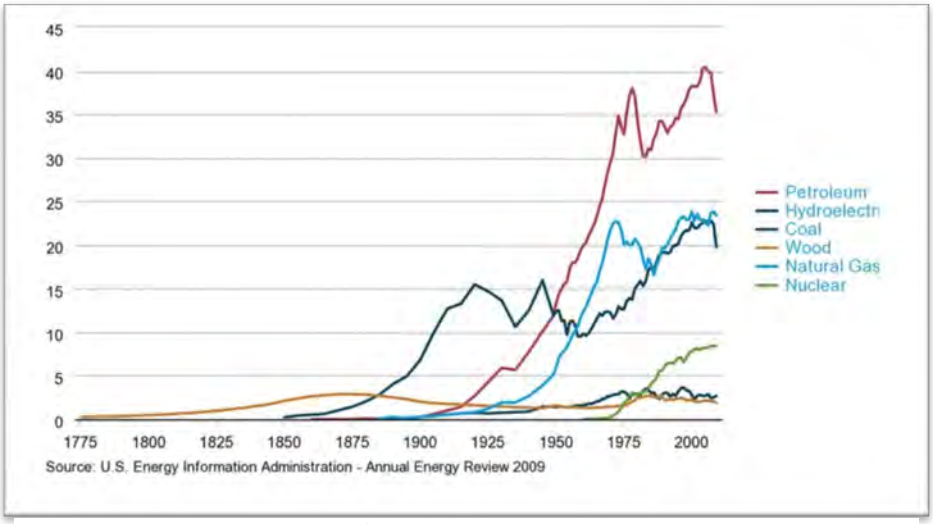


Figure 10. The U.S. History of energy consumption, 1775-2009 (quadrillion Btu)

However, with the discovery of shale oil and gas reserves in Texas and other states, the consumption and production of fossil fuels have experienced a tremendous rise in the early 21st century [32]. As depicted in Figure 11 and 12, since the shale revolution, natural gas production and consumption have surpassed the demand and capacity for coal, establishing it as a major energy source that continues to dominate till present in the USA. This trend can infer a potential continuation, where natural gas and crude oil increase while coal production/consumption decreases. Notably, while the production of natural gas is increasing the consumption is decreasing. It indicates that the United States of America is either exporting at an increasing rate or it is building up its energy security [36], [37].

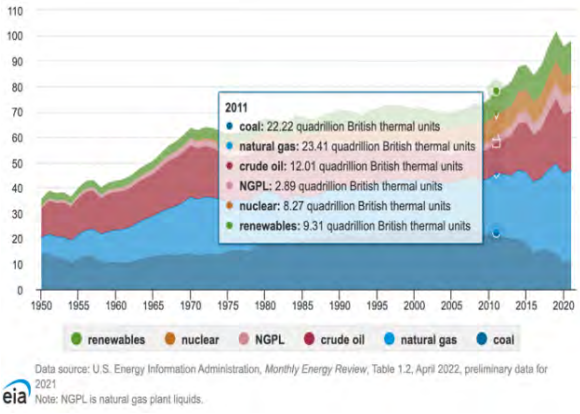


Figure 11. Primary energy production by major source in the USA, 1950~2021 (quadrillion Btu)

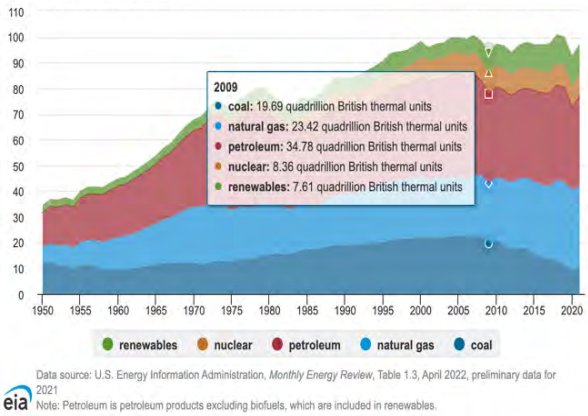


Figure 12. Primary energy consumption by major source in the USA, 1950~2021 (quadrillion Btu)

Furthermore, as seen in Figure 13 [38], Texas fills a vital role in the United States production. Texas now is producing 41% of all the crude oil in the United States, which is twice the share it had in 2009. Also, between 2009 and 2019, the United States saw a 76% increase in marketed production of natural gas, with **Texas accounting for one-fourth of capacity in the USA**.

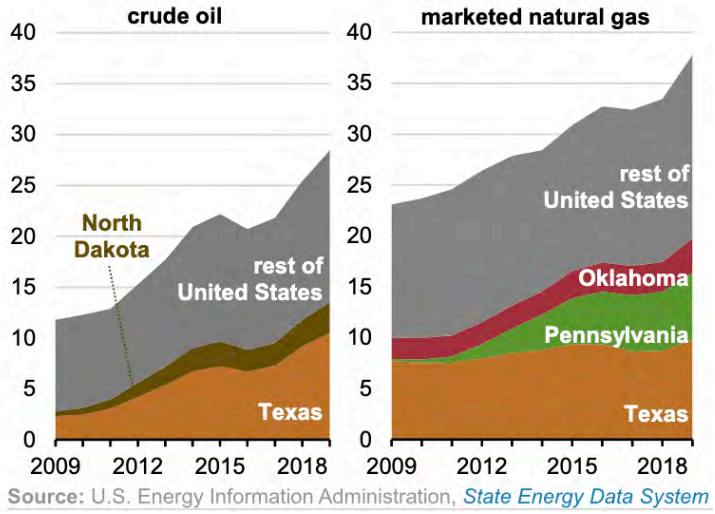


Figure 13. Energy production by source, select U.S. states (2009-2019, quadrillion British thermal units)

Texas Oil and Gas Industry Where and How It Started.

In 1894, The first major discovery of oil was in Corsicana-Navarro County, Texas [39]. This initial success paved the way for further advancements in the state's oil and gas sector. This discovery had led to the remarkable event that took place on January 1901, when an astonishing flow of thousands of barrels worth of oil was found at Spindletop, near Beaumont which shown in Figure 14[40]. The massive influx of oil wealth led to rapid industrialization and urbanization across the state, attracting entrepreneurs, workers, and investors from all over. The discovery's impact became what was needed to see the area truly flourish[41]. Along the Gulf Coast, Texas became home to large-scale oil refining and petrochemical manufacturing plants, generating employment opportunities and promoting economic expansion. Furthermore, around the same period as the discovery of oil, natural gas was also discovered in the early 1900s[42].

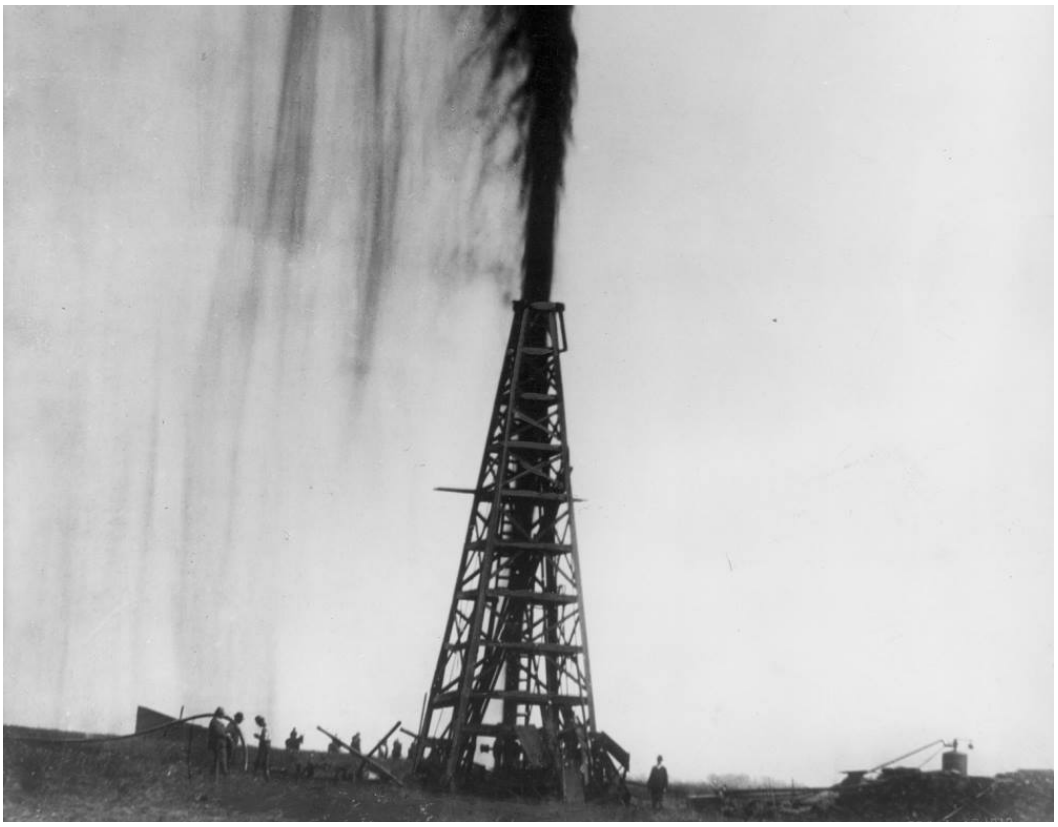


Figure 14. The Lucas Gusher of Spindletop Hill in Beaumont, Texas, "blowing thousand barrels of oil in the air in 1901." (University of Texas Arlington Libraries)

In the mid-20th century, Texas experienced a surge in industrialization, as shown in Figure 15[43], leading to the installation of extensive pipelines and processing facilities to extract and transport fuel throughout the state and beyond[44]. This period also saw a remarkable increase in consumer demand for natural gas, resulting in the installation of about half of the existing mainline natural gas transmission network and a significant portion of the local distribution network in the 1950s and 1960s[43]. Texas had so much oil and gas capacity that if Texas were a country, it will be the fourth largest oil-producing country surpassing Mexico and Canada[45]. The Texas oil and gas production boom propelled it to become the largest producer of natural gas between states in the United States. This transformation not only had an impact on the state's economy but also contributed significantly to the state's Gross Domestic Product (GDP)[46]. During the early 1980s, as oil and gas became a main pillar of the Texas economy, it had a direct contribution of over 15% towards the GDP of the United States[30].

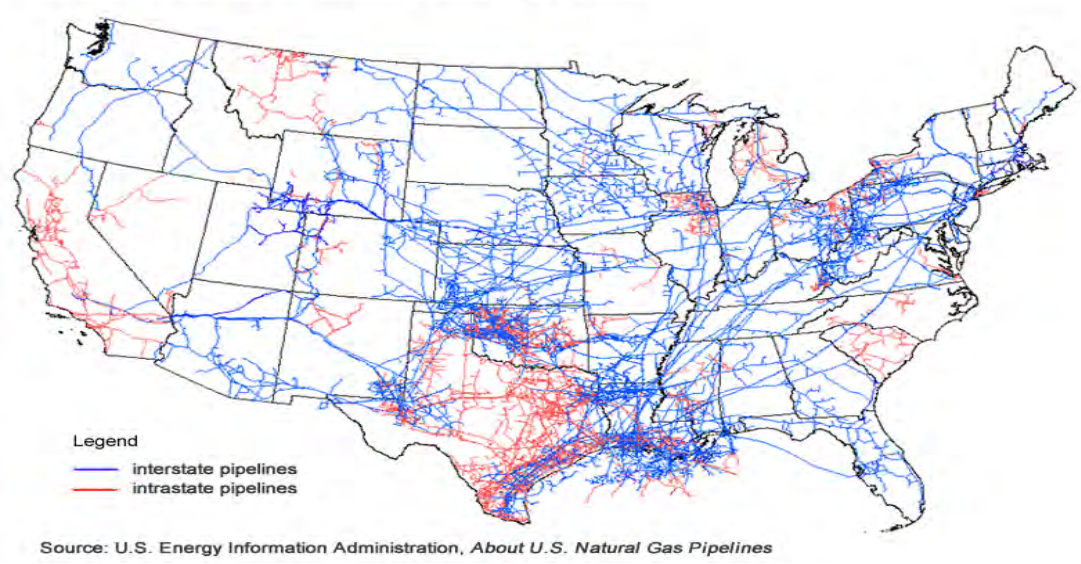


Figure 15. Map of U.S. interstate and intrastate natural gas pipelines

In 1981, Texas experienced a severe setback due to a national recession triggered by the collapse of oil prices in 1986. As the state's economy was heavily reliant on the oil and gas industry, Texas faced significant challenges during this period. The repercussions were substantial, with approximately one-third of oil and gas employment lost between 1982 and 1994, highlighting the heavy dependence on the fossil fuel sector and the profound impact of the economic downturn on Texas [47]. Moreover, to make matters worse, the oil and gas industry in Texas faced a decline as the discovery of new oil reserves became scarce, and the production of the largest oil fields gradually diminished. In response to these challenges, the industry increasingly turned to stripper wells, which have limited oil output but higher costs, making it harder to compete with global counterparts. Nevertheless, Texas persisted to navigate the evolving landscape of the oil and gas industry, seeking ways to adapt and remain competitive.

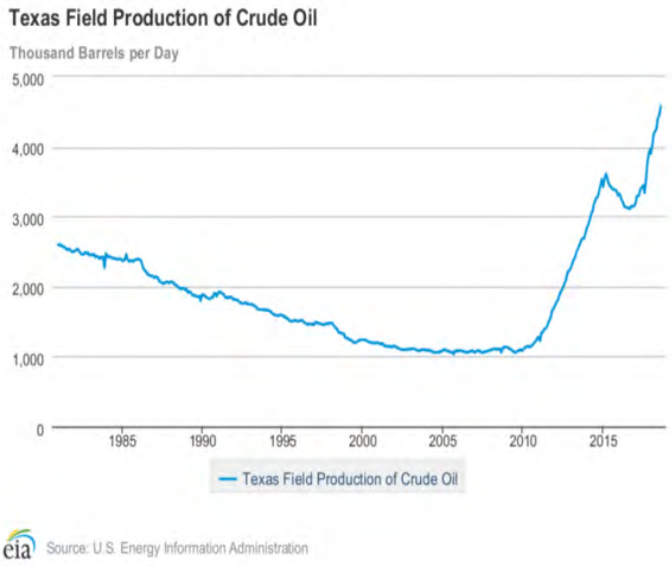


Figure 16. Texas field production of Crude Oil (1980~2020)

Silver Lining – Shale Revolution

One of the ways to get oil was horizontal drilling and hydraulic fracturing which had been combined in Texas during the late 1980s and early 1990s in wells in the Barnett Shale. The use of high-volume hydraulic fracturing—colloquially known as "fracking"—was used in Texas to open up previously inaccessible natural gas reservoirs. The development of hydraulic fracturing (fracking) and horizontal drilling technologies played a pivotal role in unlocking the potential of Texas shale oil and gas. The success of initial shale gas wells in Texas led to a surge in exploration and production activity throughout the state as Figure 17 illustrates that the technique had been used in a considerable number of U.S. states, spanning from New York to California[48].

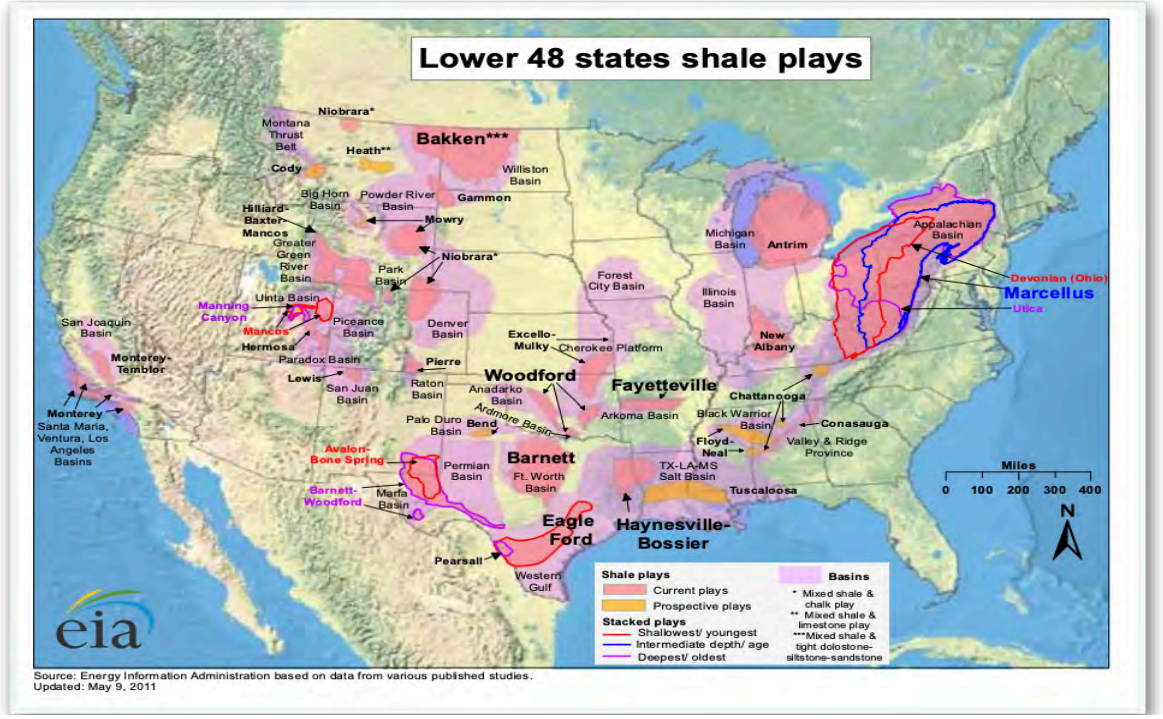


Figure 17. Shale Gas and Oil Place in the United States

The early 2000s shale oil and gas boom in Texas marked a turning point in the Texas energy landscape causing the state to emerge as a leader in shale gas production. It led to revitalizing the state's economy, creating jobs, attracting investments, and generating substantial revenue. Through Figure 18[2], the Shale Revolution led Texas to have the highest rates of employment growth and simultaneously the highest shares of oil and gas industry employment in the

[2] Note: 2006–2012 yearly employment growth rates; U.S. average annual employment growth of -0.05.
Sources: Author calculations; data from U.S. Bureau of Labor Statistics; U.S. Energy Information Administration.

United States with the largest production increase from shale. Also, it contributed significantly to the USA becoming one of the biggest exporters of liquefied natural gas today hereby, Texas's economy and the USA's energy security had led their dependence embedded deeply on fossil fuels[30].

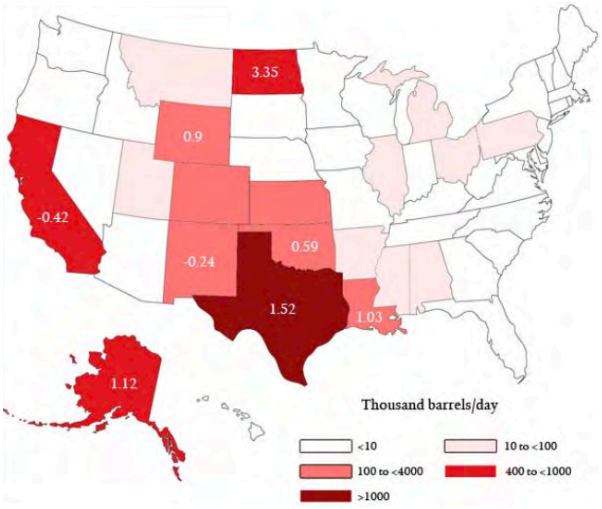


Figure 18. Shale oil and Employment growth in th e USA (2006-2012)

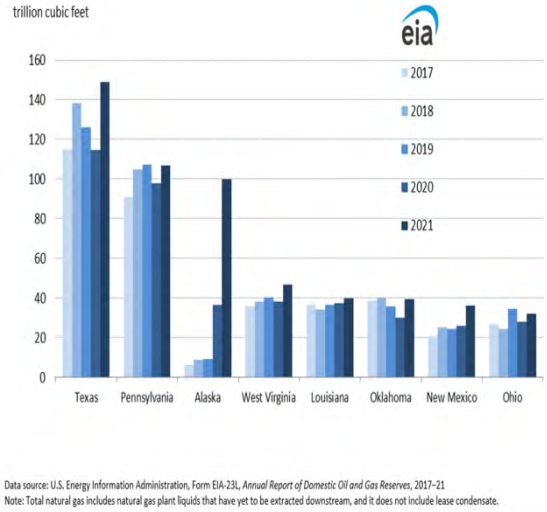


Figure 19. Proved reserves of the top eight U.S. natu ral gas reserves states, 2017-2021 (source EIA)

As of today, Texas's natural gas reserve is still increasing, and with the previous year as seen in the Figure 19 had the second-largest net increase in proved reserves. These growths in reserve underline the significance of Texas for meeting domestic energy needs and supporting the export market. It further cements **Texas's position as a key player in the American energy landscape and its fossil fuel path dependency**. The next chapter examine that as the largest producer of main energy resources and the backbone of the state's electricity sector, examine the entrenched dependence on fossil fuels.

Texas' Path Dependences

Path dependence theory originated in economics to explain technology adaptation processes and industry evolution[49], [50]. The concept of path dependence has numerous connotations, but the consensus among scholars is that the expression "history matters[51]" relates to path dependence in that there are dynamic processes that can be described as evolutionary[52]. Path dependence theory suggests that certain systems exhibit persistence and resistance to change, even when faced with unfavorable conditions or suboptimal outcomes.

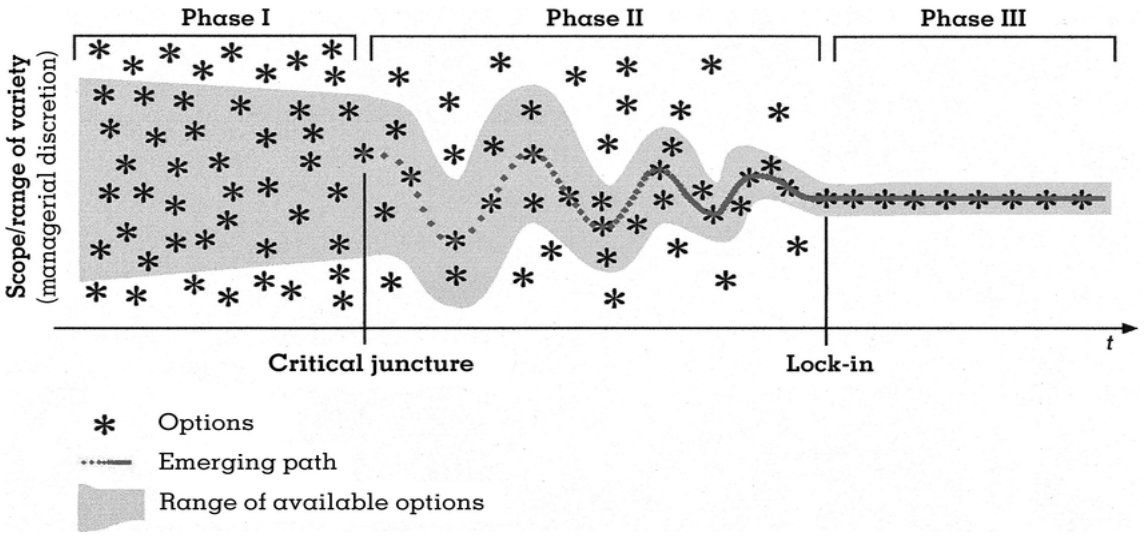


Figure 20. The constitution of an organizational Path

The Figure 20 provides a visual representation of the process encompassing the three stages[53]. It should be noted that while this framework offers a general model of path dependence, its operation is expected to vary depending on the specific conditions in different contexts, such as the balance between market forces and hierarchical structures. The term **"critical juncture[54]"** refers to a specific point in time when a particular choice or decision is made that has long-lasting consequences. In the context of path dependency, a critical juncture can set the course for future developments and lock in a particular path, **making it difficult to change or reverse**. Texas lies in its extensive investment and reliance on fossil fuel infrastructure, such as pipelines, refineries, and petrochemical facilities. These infrastructure developments have created a strong interdependence between the state's economy and the fossil fuel sector, making it challenging to transition to alternative energy sources [55].

The "lock-in effect[56]" is a phenomenon that occurs when a specific technology, standard, or practice becomes dominant, not necessarily because it is the best or most efficient, but because it has gained a critical mass of users or supporters. Once a technology or standard is locked in, it can be challenging to switch to an alternative, even if the alternative is more efficient or offers other advantages. As on example in [49] is QWERTY keyboards. In Texas, the economic well-being of many communities is closely tied to the success of the oil and gas industry, which further reinforces the path dependency. Additionally, the political influence of the fossil fuel industry in Texas plays a significant role in shaping policies and regulations that favor fossil fuel development, making it difficult to enact measures that

prioritize renewable energy or decarbonization[57]. In FY 2022, the Texas oil and natural gas industry paid $24.7 billion in state and local taxes and state royalties, funds that directly support Texas schools, teachers, roads, infrastructure, and essential services [58].

The electricity market in Texas is indeed an interesting example of path dependency and the lock-in effect. Texas has a unique electricity grid, known as the Electric Reliability Council of Texas (ERCOT), which is **largely isolated from the rest of the United States[59]**. This isolation can be traced back to decisions made in the early 20th century when Texas utilities chose to avoid federal regulation by not connecting their power lines to those in other states. This decision created a critical juncture in the development of Texas's electricity market, leading to the path dependency and lock-in effect we see today. This effect is that, despite the potential benefits of connecting the Texas grid to other regional grids, the costs, and complexities of doing so are significant[60]. This includes not only the physical infrastructure required to connect the grids but also the regulatory and political challenges that would come with such a change. As a result, Texas remains largely isolated in terms of its electricity market, even though there may be more efficient or resilient alternatives available. Consequently, this lock-in effect led the state more vulnerable to power outages and supply issues, as we saw during the winter storm in February 2021.

Coldest Winter in Texas

In February 2021, Texas experienced the coldest winter after being hit by Winter Storm Uri, causing extensive blackouts lasting nearly a week across the state. Consequently, the freeze event resulted in a confirmed death toll of at least 111 individuals and economic losses are estimated at $130 billion in Texas and some residential customers have received electric bills as high as $9,000 for the month [33], [61]. As Figure 21 shows, it was the longest duration of high prices lasting more than **64 hours. The ERCOT market had never experienced such an extended period of high prices as it did in 2021 ever before[62].** Due to the free market-

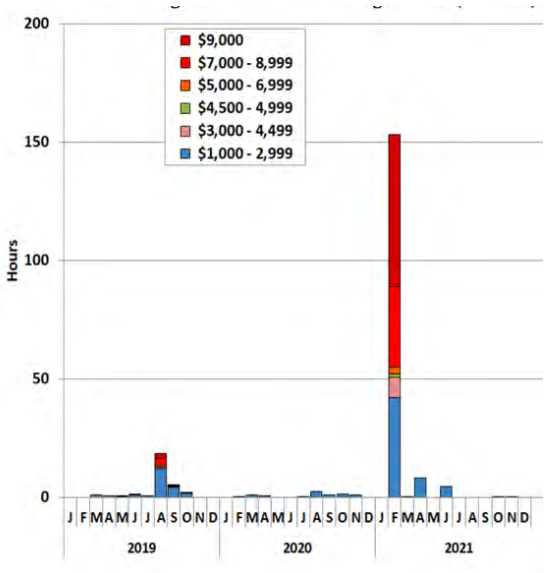


Figure 21. Duration of High Prices (with Uri) in 2019~2021 - real-time system-wide energy price

based pricing structure, the high demand for electricity during the crisis led to these exorbitant bills. In light of the extreme weather crisis, Texas better be prepared for more extreme situations in the future. Texas urgently needs and is continuously working on better strategies than before [63].

According to the analysis conducted under Senate Bill 3, the most significant and frequently cited issues that contributed to the power outages in Texas in 2021 were a lack of weatherization, insufficient oversight, breakdowns in communication, and failures of coordination within and between state regulatory agencies[64]. Furthermore, in accordance with a report jointly released by the Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corp (NERC)[65], the February 2021 storm resulted in about three-quarters of **the unplanned generating units to have outages, derate, and fail to start**, with a combination of freezing and fuel issues being the primary cause. The data reveals that natural gas was responsible for 87% of unplanned generator outages leading to less or no production and processing of energy. Of this, 43.4% of the natural gas supply issues were attributed to production declines caused by freezing temperatures and weather [66].

Figure 22. During the Winter Uri, frozen pipeline and house in Texas

These events have not only highlighted the need for ERCOT to improve its planning and preparation[67] for extreme weather events, but also recognized needs of restructure of system. In hopes of preventing similar tragedies, the FERC and NERC joint report recommends various measures including "to require **Balancing Authorities' operating plans** to prohibit use of critical natural gas infrastructure loads **for demand response**," the

implementation and cost compensation plans for retrofitting generation units, and **"rapidly deploying demand response [68]"**.

These Demand Response related recommendations are also shown in the white paper from the American Council for an Energy-Efficient Economy (ACEEE) [69] that conducted a simulation to evaluate the impact of implementing or expending 10 utilities energy efficiency (EE) and demand response (DR) programs in Texas. The study found that these programs could result in peak load reductions that exceed the 10,000 MW of new supply currently being considered by lawmakers. Specifically, implementing these programs between 2024 and 2030 could reduce summer peak loads by approximately 14,800 MW and winter peak loads by approximately 23,500 MW[70]. Given the significant differences between the winter 2020/2021 Peak Load Forecasts and Actual Loads, which were approximately 10,000~20,000 MW, it is imperative for Texas to move forward with these energy efficiency and demand response (DR) programs [68].

		ERCOT
Previous All-Time Winter Peak/Date:		65,750 1/17/2018
2020/2021 50/50 Forecast Winter Peak:		57,699
2020/2021 90/10 Forecast Winter Peak:		67,208
Feb. 2021 Actual Peak Load/ Date of Occurrence:		69,871 2/14/2021
Feb. 2021 Estimated Peak Load w/o load management/ Date of Occurrence:		76,819 2/15/2021
% Actual Peak Was Above Forecasts	**50/50:**	20.0%
	90/10:	2.9%
% Estimated Peak Was Above Forecasts	**50/50:**	33.1%
	90/10:	14.3%

Figure 23. Winter 2020/2021 Peak Load Forecasts and Actual Loads for Event Area (Source FERC, 32p)

Texas Electricity Market with Demand Response Program in C&I sector.

Texas, in response to the urgency created by extreme weather events, has acknowledged the imperative to confront its reliance on fossil fuels and transition towards a more sustainable energy future. In this section, to understand what can effectively implement the suggested measures within its distinctive market framework for Texas' grid stability and increase reliability, this section will analyze Texas' market structure including the ERCOT DR program, and energy mix.

How Texas Become The Deregulated Electricity Market?

One of the biggest reasons why Texas has a strong clean energy-based energy mix with a remarkable growth of renewable and is making strides to break its dependency on fossil fuels is because of its unique electricity market structure. One of the key factors that have enabled this progress is that Texas' energy market is an "intra-state" market that is isolated with limited connection to other states' grids. By establishing its own council, which is called the Electric Reliability Council of Texas (ERCOT) [31], Texas has allowed adoption of policies and market features that differ from those of other traditional markets [71].

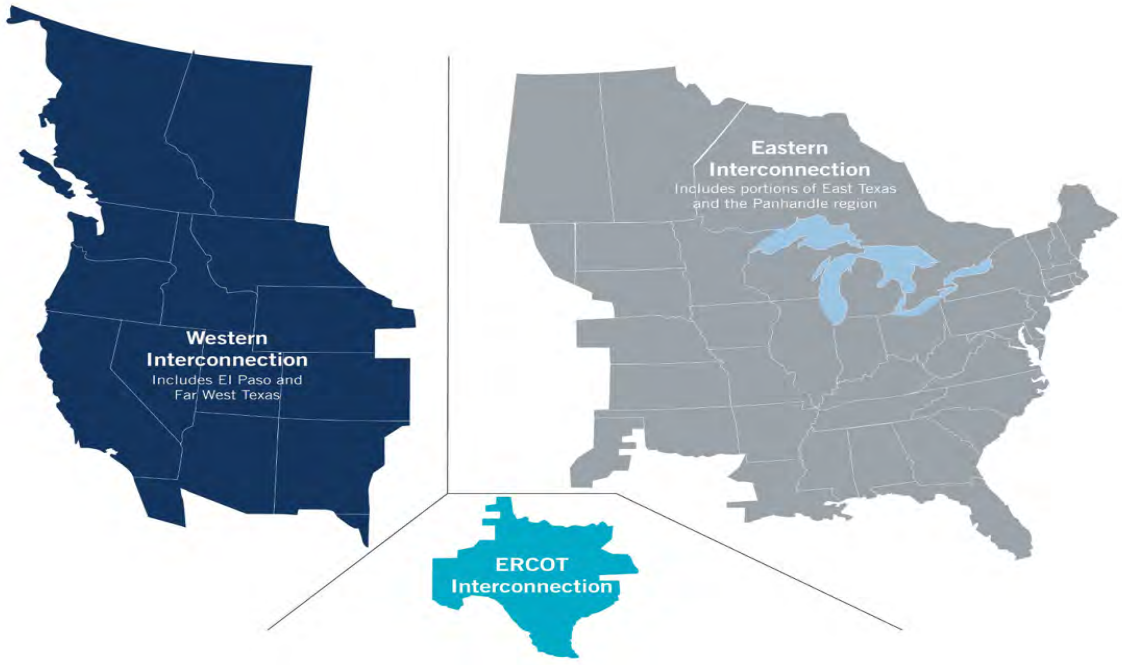


Figure 24. Isolated grid of Texas, ERCOT

This unique jurisdictional status has allowed Texas to become more flexible in shaping its electricity market and has contributed to the development of a unique market structure that is tailored to the state's specific needs. This uniqueness became affected by the Northeast Blackout in 1965[72]. During this Blackout around 30 million people got affected, and it led to the establishment of the National Electric Reliability Council (NERC) to oversee the national grid in the United States[73]. However, Texas, instead of joining the NERC region, decided to keep its own power grid independently in order to avoid federal oversight [74]. As a result, ERCOT was created as an independent system operator (ISO) that can ensure the Texas/ERCOT region grid (in Figure 25) reliability and flexibility[59] [60].

ERCOT is under the Public Utility Commission of Texas (PUCT) authority, which was built in 1975 for regulating the state's utilities such as electric, gas, water, and telecommunication utilities[77]. In the electricity utility regulation of PUCT, they are mainly responsible for regulating all investor-owned utilities (IOUs) to assure that utilities provide reasonable, adequate, and efficient services to their customers such as adaptation of clean energy, setting of prices, and oversight of utility planning processes [77].

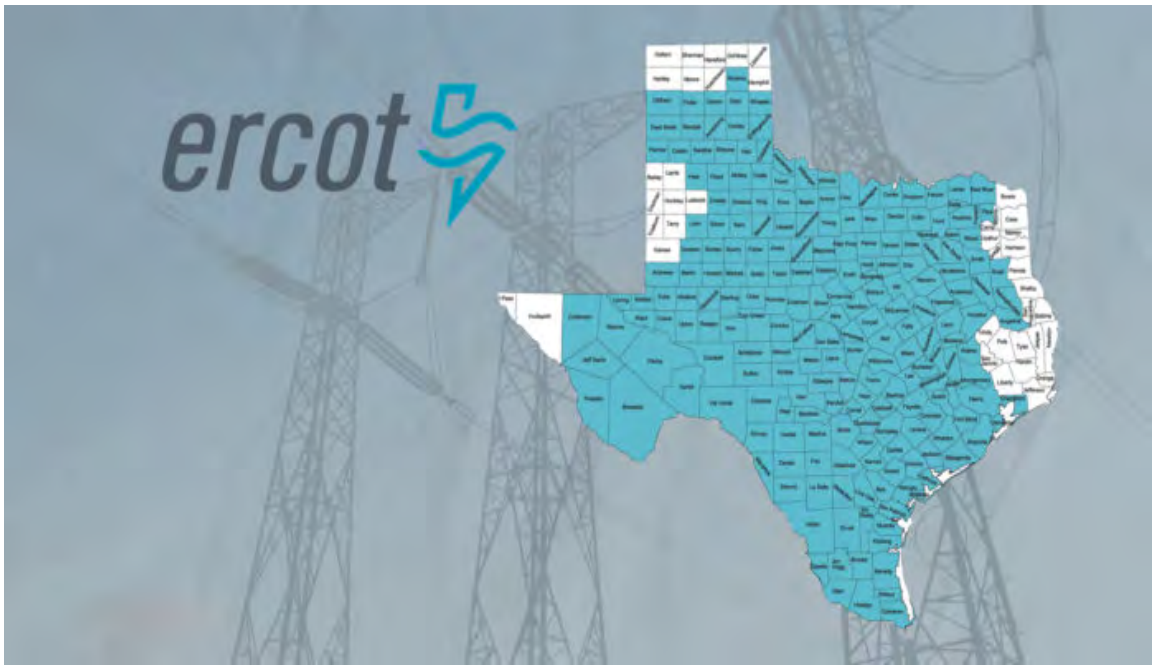


Figure 25. ERCOT region in Texas

Since the Federal Energy Regulatory Commission (FERC) encouraged competition among the wholesale electricity market in the late 2000s, the Texas energy market underwent significant changes as shown in Figure 26 [78]. In 1996 the wholesale power market was deregulated[79], and the Federal government issued Order 888, which required open access to utility transmission lines for other power companies. Additionally, the Texas legislature passed Senate Bill 7, which fundamentally changed how electric power was purchased by deregulating the retail market in Texas thus, it completed the current Texas' electricity market as shown in Figure 27.

Figure 26. Wholesale deregulation in Texas, Transmissi on and distribution service providers in Texas

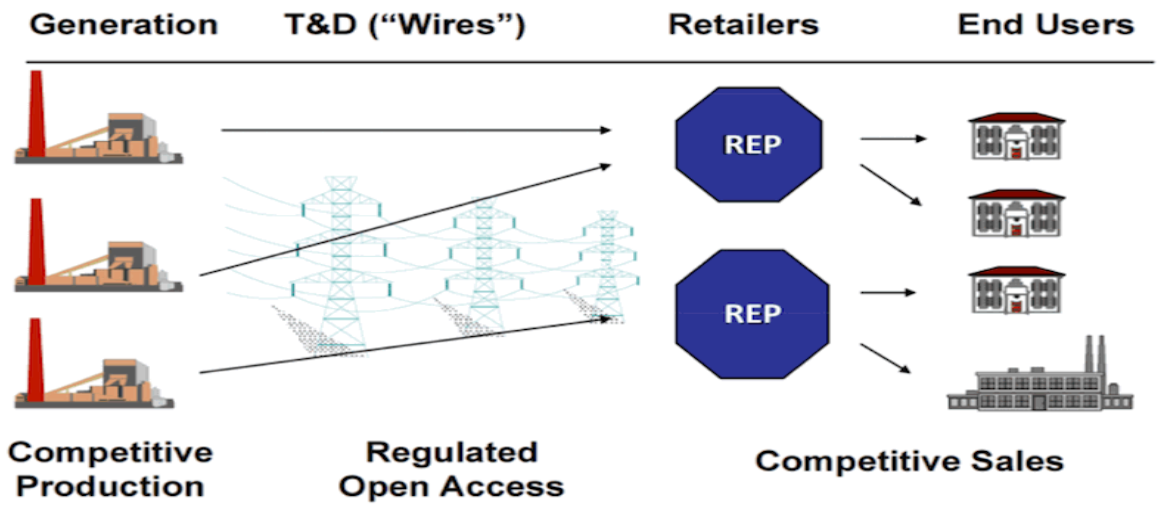


Figure 27. Deregulated ERCOT electricity market structure

Furthermore, in 1999, a renewable portfolio standard (RPS)[80] was passed by the Texas Legislature that required utilities to generate a certain percentage of their electricity from renewable sources. This policy's ultimate target was to promote the competitiveness of renewable energy financially. Hence, the RPS was a significant milestone for renewable energy development in Texas, as it provided a market for renewable energy developers and incentivized utilities to invest in renewable energy sources [81]. Ever since the starting point, it has been instrumental in promoting the development of renewable energy sources in Texas

and has helped to diversify the state's energy mix[81]. Furthermore, they implemented various legislation and initiatives to increase its sustainability and promote development of renewable energy sources such as Competitive Renewable Energy Zone (CREZ, in 2008), Energy Efficiency Standards, and Renewable Energy Tax Incentives [44]. These changes had a significant impact on the Texas electricity market, and they facilitated the development of a competitive market for electricity generation, which has incentivized the development of renewable energy sources and helped to drive down the cost of renewable energy.

As a result, currently Texas has the largest production capacity through wind energy and solar energy than any other state in the country. As of today, according to Statista as shown in Figure 28, Texas's energy generation mix mainly consists of natural gas which is the largest source of energy in Texas, followed by wind and coal. As the figure shows, wind energy is now the second-largest source of energy in the state. Solar energy is also growing in Texas, although it currently makes up a smaller share of the energy mix compared to natural gas, wind, and coal. It's worth noting that the energy mix in Texas has been shifting towards renewable energy sources.

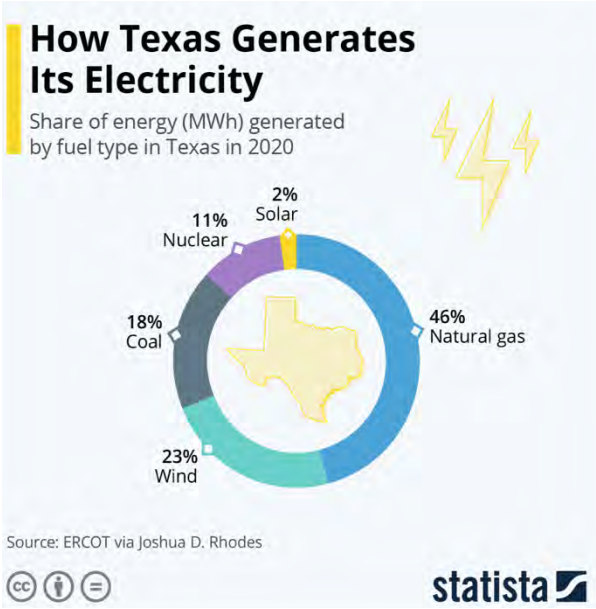


Figure 28. Texas Energy Mix in 2020

Texas' distinctive approach to restructuring its electricity market opens access for the transmission and distribution systems to all market players, with no exception by the sector, and has allowed for the integration of large amounts of renewable energy into the grid[82]. Also, ERCOT's electricity market structure led to the inclusion of a wide range of energy resources, including new renewable energy sources, energy storage, and demand response (DR) programs [71]. This has made renewable energy more competitive with fossil fuels, support the way to break the dependency on fossil fuels in Texas, and paved the way for increased innovation in the industry through an open market such as with aggregators. However, despite the successful expansion of renewable energy, the growth of the DR market structure has been lagging behind, posing a contrast to the overall progress.

Texas Demand Response Market with C&I Aggregator

Demand Response (DR) programs have been widely studied and proven to be effective in improving the reliability of the electricity system. These programs incentivize market participants to curtail or shift their electricity consumption, leading to a more balanced and stable grid operation[83]. According to EIA, utility-operated demand response programs successfully reduced approximately 3.7% of peak demand in 2017. With ERCOT facing scorching summers and a low reserve margin for generation during high-demand periods, the significance of demand response becomes evident. Future projections indicate a continuation of this challenging scenario, making demand response a crucial element in maintaining grid stability and averting potential blackouts within ERCOT.[84]

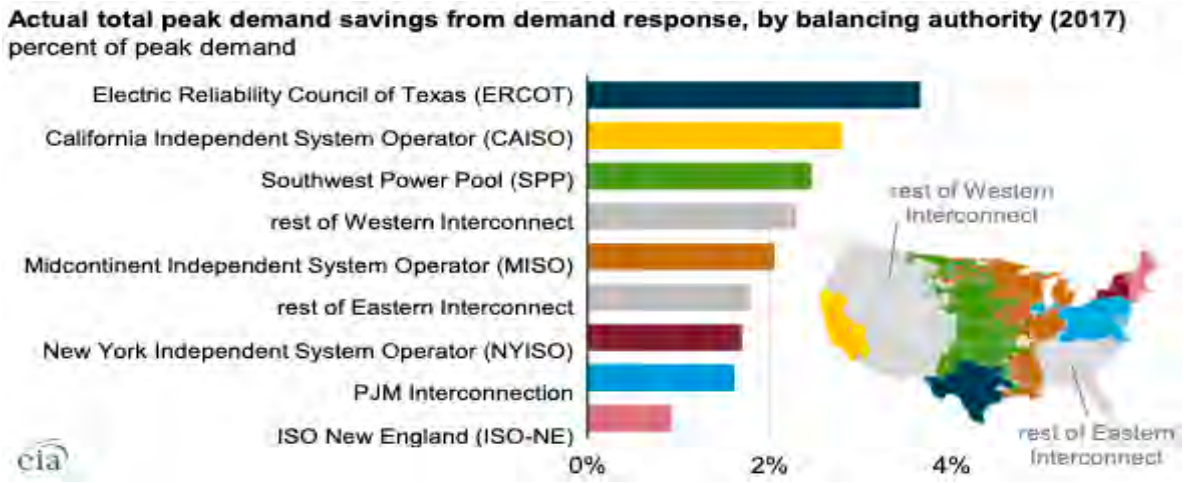


Figure 29. Peak demand saving from DR in the USA (2017)[84]

In Texas, there have been three major reasons that the DR program has been facilitated in the ERCOT region [78]. First, the ERCOT market is a deregulated market for all energy categories. Secondly, it was redesigned to the nodal market that had targeted more accurate and efficient prices of electricity and incentivized generators to be located in areas where electricity is needed most. According to the Texas Restricted review, *"As in other restructured markets, the beneficiaries of retail competition have been industrial and commercial energy consumers. They have realized significant energy cost savings by switching suppliers."* Third, Senate Bill 1125 was passed which ensures to diversify the load participants to all energy markets without discrimination by sector. As a result, ERCOT DR program is open to all customers including commercial, Industrial, and residential.

ERCOT DR Market Structure

DR program has diverse types of programs in the wholesale market as Figure 30 for Load Participation (LP[3]) which the relationship between different Demand Response (DR) and Demand-Side Management (DSM[4]) services, particularly the Dispatchable Demand Response Programs, is depicted. Meanwhile, it is divided into three main programs in the ERCOT market, which are Voluntary Load Reduction, Ancillary Services Market (AS, Load Resource), and Emergency Resource Services (ERS)[78]. Based on each market operation rule, LP participates in the Day-Ahead Operation which is planned a day before through auction, and Operating Period which is participating in the day in real-time based on price signal. Each program has a different purpose, having many options regarding various conditions such as resource type and sector. **In this dissertation will focus on the ERS and AS program which are under ERCOT administration and have a high potential in the C&I sector**[85]**.**

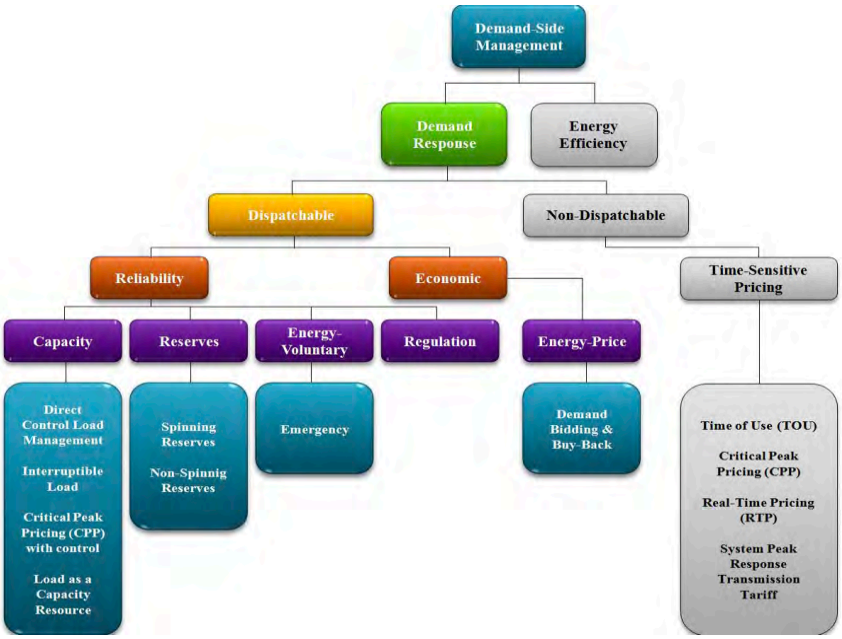


Figure 30. Wholesale Demand Response products and services

[3] *A Load capable of providing Ancillary Service to the ERCOT System and/or energy in the form of Demand response and registered with ERCOT as a Load Resource*. (ERCOT.com)

[4] [78]"Demand Side Management (DSM) is a portfolio of measures to improve the energy system at the side of consumption. It ranges from improving energy efficiency by using better materials, over smart energy tariffs with incentives for certain consumption patterns, up to sophisticated real-time control of distributed energy resources."

Within the ERCOT (Electric Reliability Council of Texas) system, several key actors play important roles in the Demand Response (DR) market. These actors include the Public Utility Commission of Texas (PUCT), ERCOT itself, Retail Electric Providers (REPs), Qualified Scheduling Entities (QSEs), and Aggregators. As Figures 31 and 32 show, the PUCT establishes the rules and oversight of all the actors, ERCOT manages the grid operations and operates programs for grid stability, REPs engage with consumers, QSEs represent market participants and scheduling, and the aggregators bring together multiple consumers under LSE[5] as optional role[6].

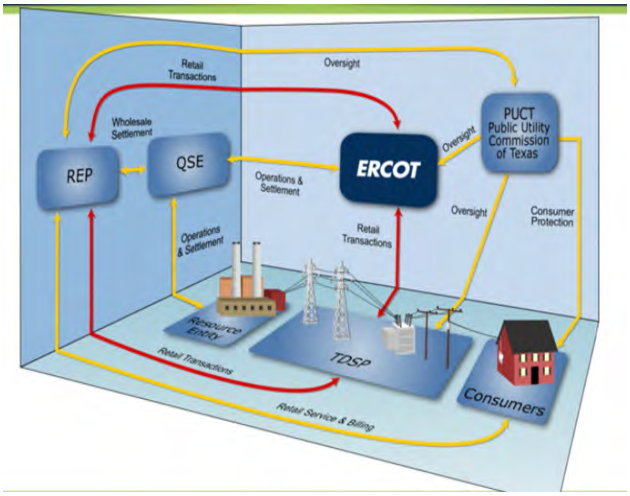


Figure 32. ERCOT market workflow and roles

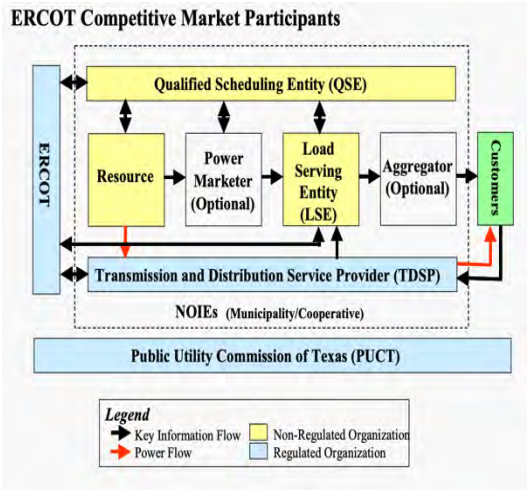


Figure 31. ERCOT market communication among participants

As one of the LSE is Retail Service Providers (REPs), who "provide a retail supply of electricity within the areas of ERCOT opened to retail competition."[71] Also, as one of wholesale market participants, currently, around 130 companies certified by PUCT[87], and act as intermediaries between consumers and ERCOT, facilitating their participation in DR programs and managing the necessary communication and coordination. According to Smart Electric Power Alliance report 2019 [88], ERCOT plans to reach 2,329 MW in ERS and AS programs by the end of 2018 [89] which is the 3rd biggest capacity among ISO in the USA. It also shows that enrolled DR capacity as Figure 33, **and C&I sector is accounted for around 60% of capacity**.

[5] [86] Load Serving Entities which are Retail Electric providers, Electrical Cooperatives, and Municipally Owned Utilities
[6] PUCT manage of each market participant's role and operation rule - https://www.puc.texas.gov/industry/electric/directories/default.aspx

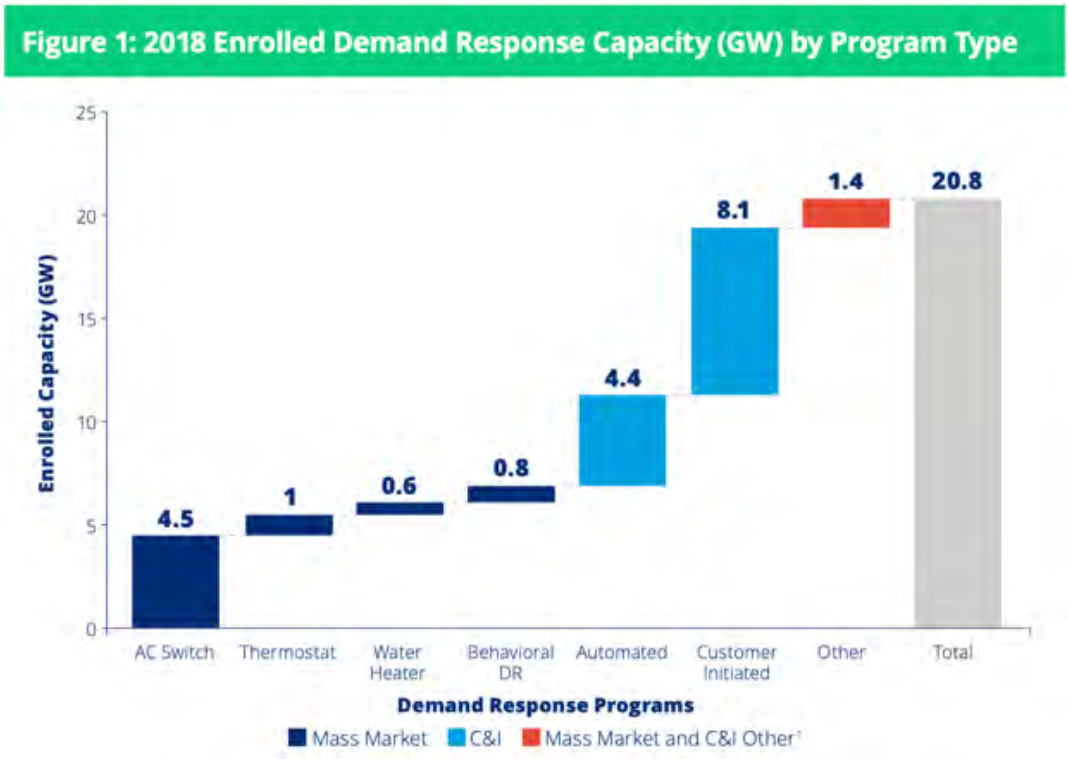


Figure 33. 2018 Enrolled Demand Response Capacity (GW) by Program Type in the USA

C&I Potential In The Market

The highlights of the significant participation of the C&I sector in the DR market, with numerous businesses and organizations recognizing the advantages of participation, including higher incentive payments and the favorable economies of scale associated with larger resources such as industrial facilities or commercial buildings. It vividly shows through in Figure 34, despite comprising a relatively small portion of demand-response customers (7% for commercial and less than 1% for industrial), commercial and industrial customers contribute significantly to energy savings and receive larger incentives. **Industrial customers accounted for over 50% of actual peak demand savings** [90].

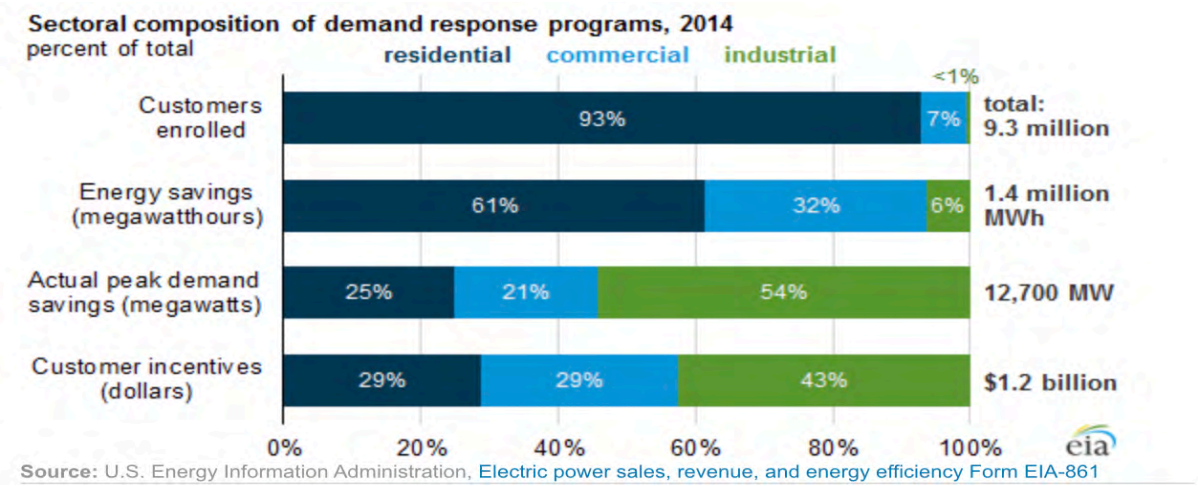


Figure 34. Sectoral composition of demand response programs, 2014

Also, from an economic perspective, the C&I sector is more scalable than residential sites for grid services. This is because C&I sites have lower acquisition costs and communication costs per MW for participating in grid services [91]. According to the Guidehouse (Navigant) in 2016 [92], 21 GW of DR capacity come from C&I sector in North America. Also, **C&I DR capacity is expected to reach around 56.5 GW [93] by 2027 and estimated to grow to 268GW market capacity in 2031 include Flexibility Markets [94].**

However, it has a high potential to expand capacity and a good environment for C&I sector participation, the growth of the C&I DR program is slowing down compared to the residential side. C&I is growing only 2.5% annually, compared to 14% in the residential sector[92]. According to Brett Feldman, a principal research analyst with Guidehouse and an author of a report [85], he noted that most of the largest customers are already participating or are well-informed about the programs and have decided not to participate for their own business reasons. This can be attributed, in part mentioned former, to the prevalent dependence on fossil fuels caused by the historically low cost of these energy sources. Given the cheaper nature of fossil fuels compared to investing in demand response, the C&I sector tends to prioritize avoiding the potential risks associated with emergency situations during regular business operations. Additionally, during an interview with Olaf Lohr, who in charge of Business Development in AutoGrid, noted that *the motivation for C&I sector involvement in ERCOT's DR market is comparatively lower than in other states, largely due to the affordability of their electricity bills*. These factors collectively contribute to a diminished incentive for C&I entities to invest in the transition toward cleaner energy sources[95].

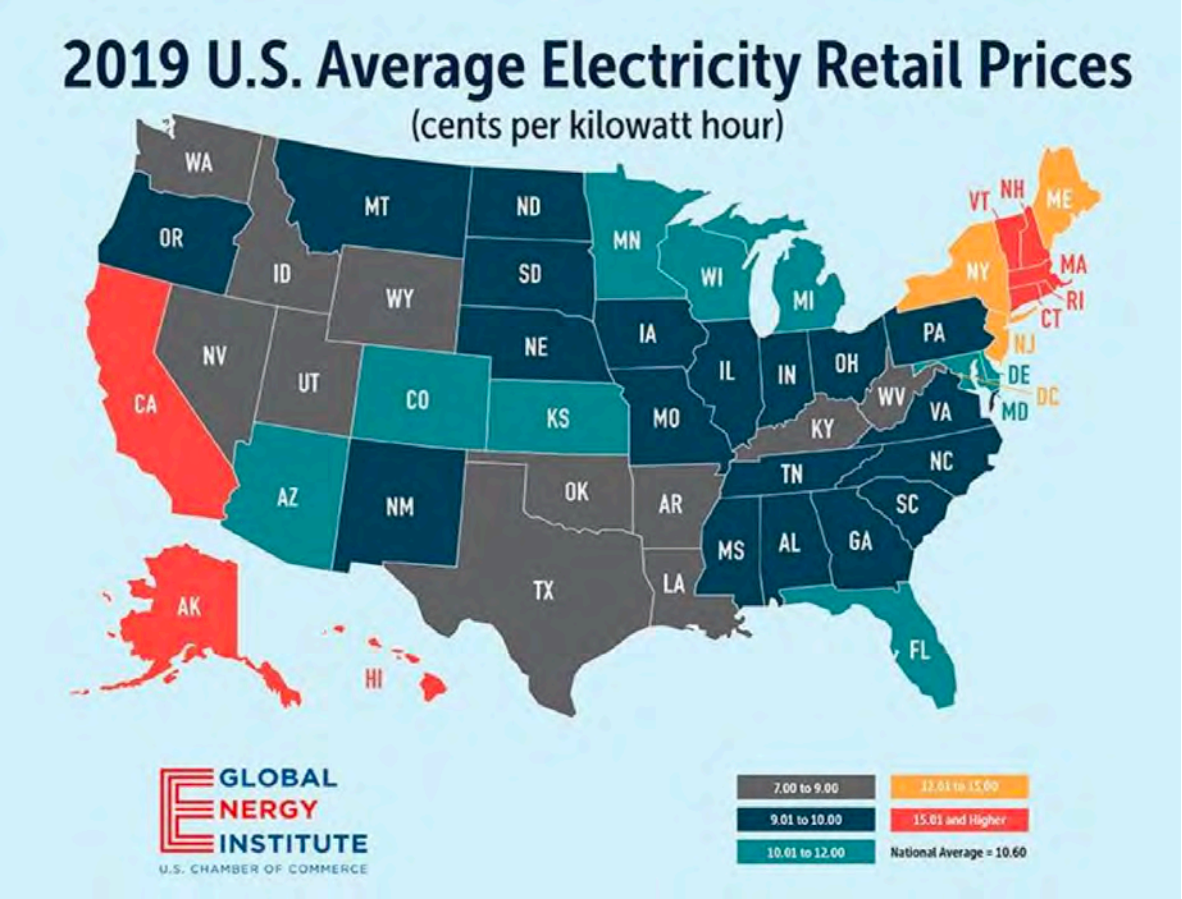


Figure 35. U.S Average Electricity Retail Prices, Texas is in the one of lowest price states.

However, C&I sector trends are also in changing. According to the findings of the "State of Commercial & Industrial Power Reliability" report[96], the C&I sector experiences blackout situations at least once a year[7], despite having a better service area compared to residential neighborhoods. The report reveals that a significant portion of C&I customers, 18 percent, encountered **financial losses of $100,000 or more from their most severe power outage in 2017. Additionally, 19 percent incurred costs exceeding $50,000**. As a result, C&I facilities have developed a sense of mistrust towards electric companies and are **increasingly inclined to invest in backup generators, such as battery systems, to mitigate the impact of blackouts on their businesses.**

[7] C&I sector's experiences of blackout further explanation can be found in Appendix 2.

Texas, with its robust Commercial and Industrial (C&I) sector and abundant distributed energy resources (DERs)[8] such as solar and wind, holds immense potential for the Demand Response (DR) market. It is known for its susceptibility to severe weather patterns like the devastating winter storm experienced in recent years and can leverage VPPs as a key tool for enhancing grid resilience and preventing future disasters[97].

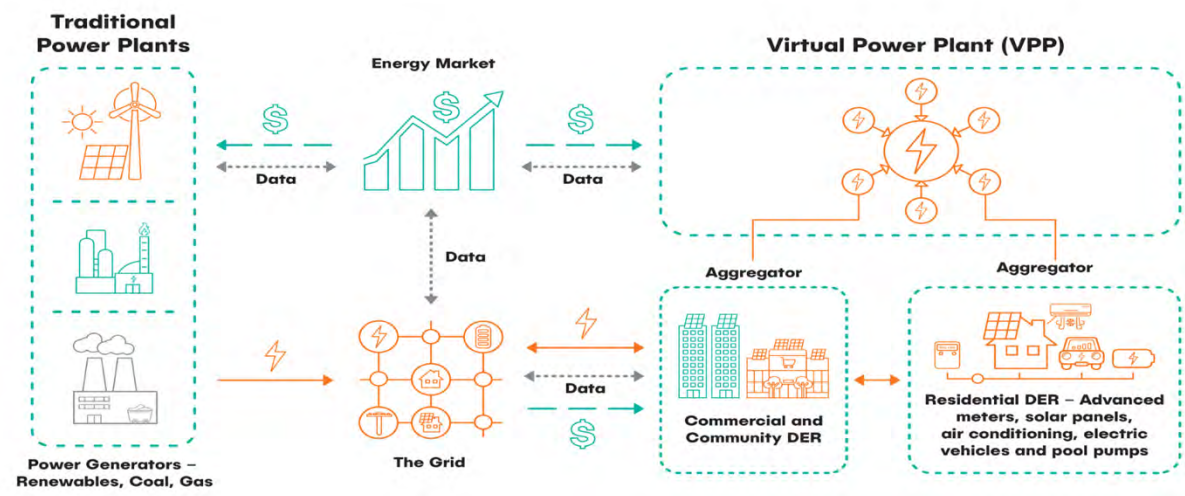


Figure 36. The Overview of VPP role with markets while comparing traditional power plants [98]

VPP (Virtual Power Plant) is a sophisticated aggregation of DERs that integrates and optimizes their capabilities to provide grid services as like Power Plant[98]. By harnessing the flexibility and responsiveness of DERs, VPPs can effectively balance supply and demand, enhance grid stability, and contribute to overall system reliability.

In Texas, the combination of thriving C&I sectors and the availability of DERs creates a favorable environment for the establishment of VPPs. With the state's significant solar and wind resources, these DERs can be effectively harnessed and integrated into VPPs to maximize their potential. To foster energy transition for grid stability the IRA can provide the necessary financial support and incentives to accelerate the deployment of VPPs and associated DERs in Texas. By allocating funds to enhance grid infrastructure, incentivize renewable energy investments, and support the expansion of VPP programs, the IRA can facilitate the transition to a more resilient and sustainable energy system in Texas.

[8] [10]Distributed energy resources (DER) refers to electric power generation resources that are directly connected to medium voltage (MV) or low voltage (LV) distribution systems, rather than to the bulk power transmission systems. DER includes both generation units such as fuel cells, PV, and energy storage technologies like batteries.

Breaking Path: Inflation Reduction Act (IRA)

In August 2021, The Inflation Reduction Act (IRA) was legislated into law, representing a historic milestone in Congress's efforts to address clean energy and climate change in the United States. The IRA is a comprehensive budget package that includes nearly $370 billion in investment to support clean energy development and mitigate the climate change impacts by incentivizing tax credits and grants[9], [99]. The IRA is focused grandly on establishing the United States of America to maintain the global leadership in clean energy technology, manufacturing, and innovation, driven *"Powered by American Workers* [9]*."* Around $370 billion will be pouring into the domestic market to expedite private investments in clean energy solutions *"in every sector of the economy and every corner of the country* [9]*,"* and create new economic opportunities

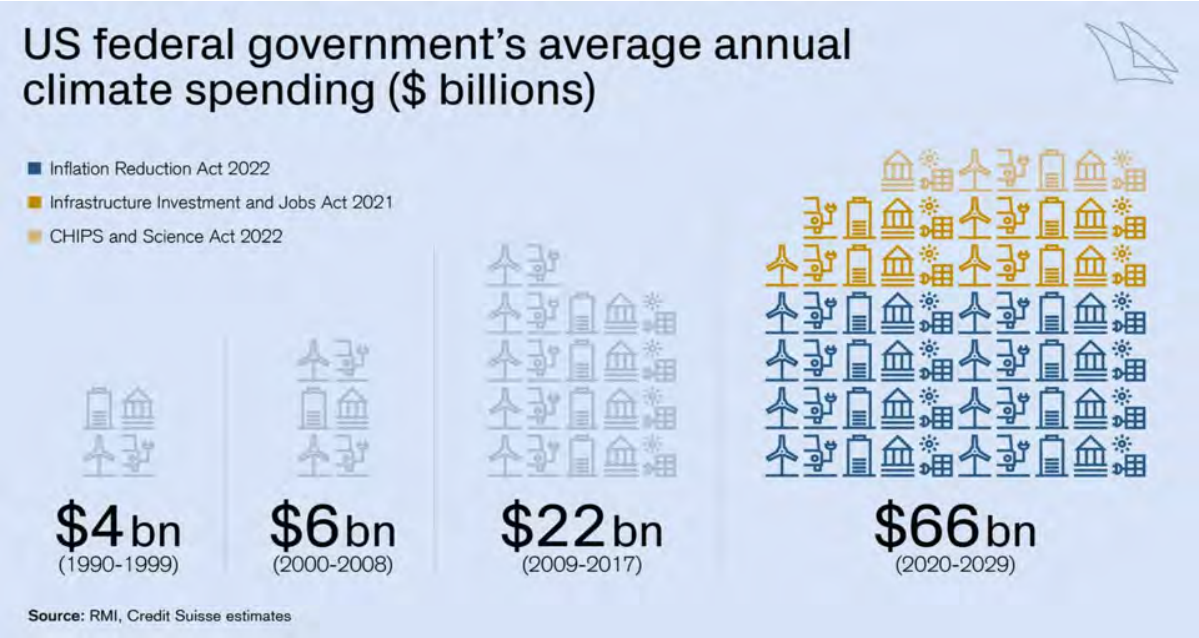


Figure 37. US federal government's average annual climate spending. Comparing to the past legislation shows IRA's significant amount of investment.

By utilizing the incentives, these organizations can reduce their greenhouse gas emissions and accelerate the transition to clean energy[100]. As seen in Figure 38, according to Rhodium Group Modeling[101], IRA is accelerating the emission reduction more than the current policy and the reduction capacity to closer to the US Paris Agreement 2030 target.

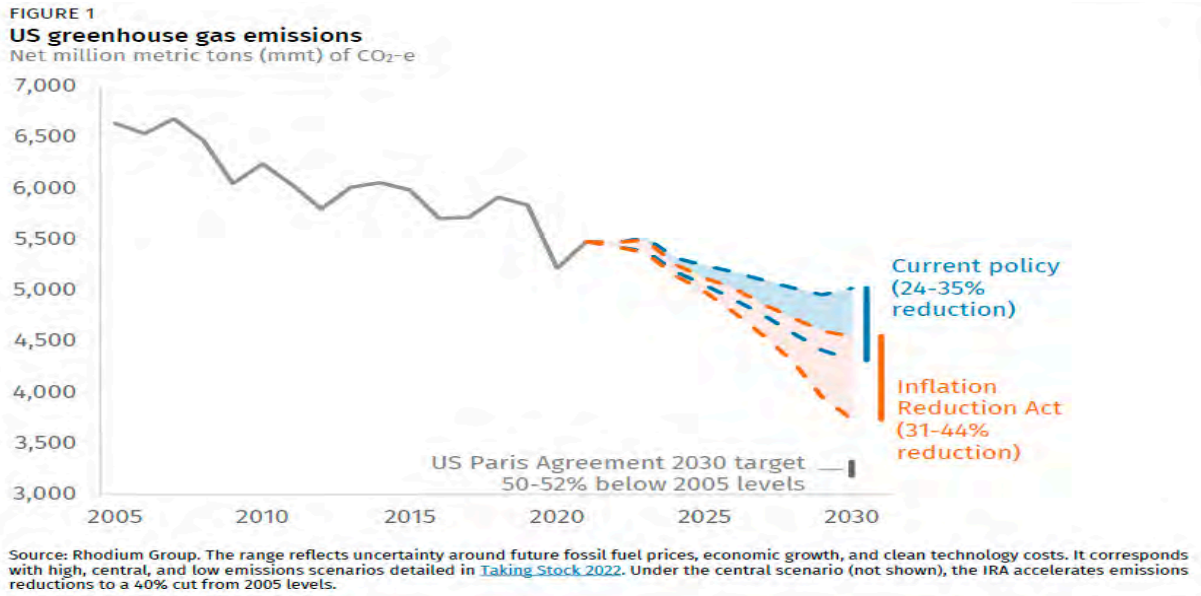
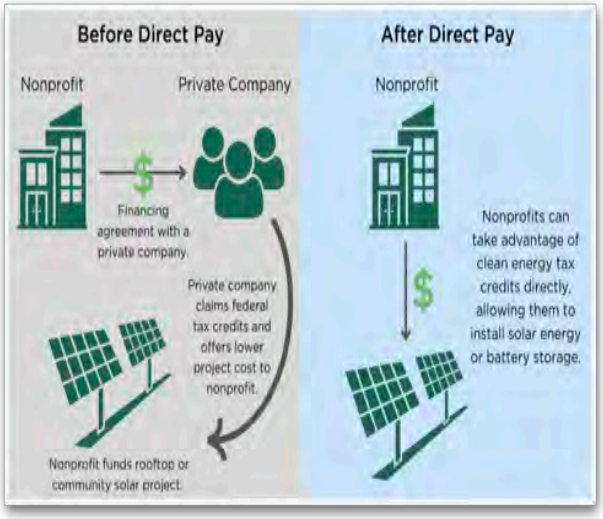


Figure 38. The impact of the IRA model by Rhodium Group, reduce net GHG emissions by 31% to 44% below 2005 levels in 2030. [101]

Regarding the renewable energy project tax provisions, it includes credits for the "Energy Communities" project, reforming of the traditional Investment Tax Credit (ITC) and the Production Tax Credit (PTC) criteria. The energy community, which is defined as a place in a history of employment in fossil fuel industries and higher unemployment rates than the U.S. average and IRA provides up to 10% renewable energy project tax credit[102]. Also, the IRA adds a new option for receiving ITC and PTC incentives directly, which lets non-taxable entities also have benefited from tax credit incentives. Moreover, the IRA introduces a new tax credit for a standalone Battery Energy Storage System (BESS) that receives a 30 percent tax credit via ITC - it may cover up to 70 percent with additional incentives[103]. As it used to be densely packed with solar projects in order to get benefits, now through IRA, it led BESS to a more diverse role in the energy sector such as helping decentralization, stabilization, and portfolio for electricity[104].

Furthermore, IRA intends to foster Electric Vehicle (EV) expansion as well through Clean Vehicle Credit which provides clean-vehicle purchasers a maximum of $7,500 credits if the clean-vehicle qualifies for conditions. Conditions based on the battery's components manufacturing, and the battery's critical mineral standards[105]. Despite the significant progress that has been made in lithium-ion technology, the IRA expects in terms of both performance and cost, that BESS will have significant improvement by unlocking investors, which are also expected to lead to battery technology advancement and competitiveness of EVs in the United States[106].



Item	Discount Type	Discount	Start Date
Solar Rooftop Installation	Tax Credit (ITC)	30%	Now
Small-Scale Wind Energy	Tax Credit (PTC)	30%	Now
Battery Storage	Tax Credit	30%	2023
Rooftop or Community Solar for Nonprofits	Rebate	30%	2023
Battery Storage for Nonprofits	Rebate	30%	2023

Figure 39. One of IRA incentives, ICT and PTC explain how it works by EESI. (Left; Direct Pay works, Right; Summary of IRA's Clear Energy Tax Credits)

According to Peter Cavan[9], "Previously, federal tax credits were only available for storage when it was paired with renewable generation, like solar. This change will likely drive up to $1 trillion in storage investments by the early 2030s." Furthermore, according to the Environmental and Energy Study Institute (EESI)[107], the extension of the ITC and PTC is expected to lead to solar capacity around quadrupling and wind capacity nearly doubling by the end of the decade. Considering the growth of intermittency resources in the United States, the need for energy storage will be increasing to provide frequency management and prepare grid reliability, which the new BESS tax credits will help to facilitate it.

[9] Director of Market Development for battery storage developer Convergent Energy and Power, in the Utility Dive article: a sets the stage for US energy storage thrive

IRA impacts on Texas

The Inflation Reduction Act is a testament to the United States' unwavering commitment to reducing its greenhouse gas emissions by 50% by 2030, and Texas, as a major contributor to the nation's energy production, holds a pivotal position in achieving this objective[17]. Notably, as shown in Figure 40 and 41, Texas is the largest producer of oil and natural gas in the country[108], while also leading in renewable energy production, particularly through wind power[109]. Furthermore, Texas boasts the highest capacity for utility-scale electric generator additions in the United States[110], underscoring its significant role in achieving the nation's goal.

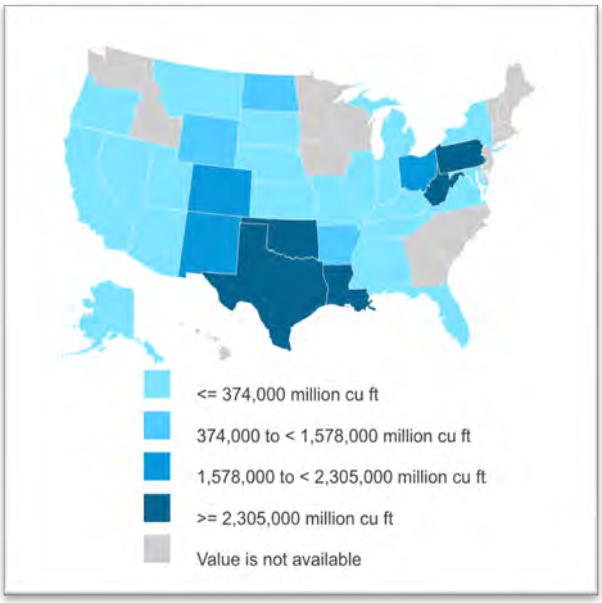


Figure 40. Natural Gas marketed production, 2021 (million cu ft) Source: EIA

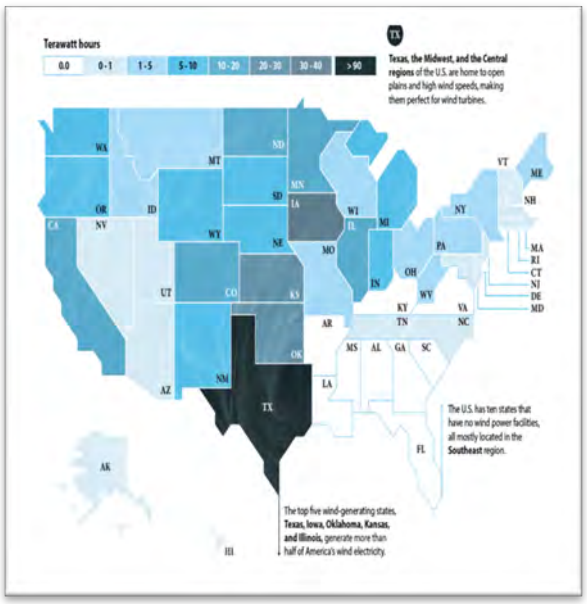


Figure 41. Wind electricity generation per State (2020-2021) Source Visualcapitalist

Interestingly, While Texas is undoubtedly a significant player in the nation's energy landscape, it is important to recognize that the Inflation Reduction Act will be the "carrot and stick" approach[111] to achieving national goals. Rather, the Act will take a comprehensive approach to reducing greenhouse gas emissions, which will involve a range of strategies and initiatives aimed at promoting sustainable energy practices and reducing carbon emissions across all sectors of the economy. Therefore, this subchapter will discuss the potential positive and negative impacts of the Inflation Reduction Act on Texas to understand how this legislation may affect their operations and business models on C&I sector aggregator in chapter 2.

(+) Distributed Energy Resource (DERs)

Texas has the potential to become a leader in renewable energy development, thanks to its abundant resources in wind and solar power. According to the Energy Information Administration (EIA), Texas is planning to install 2 GW of wind capacity and 7.7 GW of solar capacity in 2023[110]. This **increased investment in renewable energy** has the potential to create significant economic opportunities in the state, which shown in Figure 43, according to analysis by the Rocky Mountain Institute (RMI)[112]. As the state with the highest capacity for utility-scale electric generator additions in the United States, Texas is well-positioned to benefit from the Inflation Reduction Act's focus on promoting renewable energy and reducing greenhouse gas emissions. According to a recent report by the Texas Clean Energy Coalition, the Inflation Reduction Act could create up to 1.5 million new jobs in Texas' clean energy sector by 2030. This growth is expected to be driven by increased investment in wind and solar power, as well as energy efficiency and storage technologies. The Act will also support domestic manufacturing, with a focus on clean energy and transportation technologies. This will help to strengthen supply chains and support local economies, benefiting the 873,500 workers employed in manufacturing in Texas.

Figure 42. Planned 2023 U.S utility-scale electric generator additions.

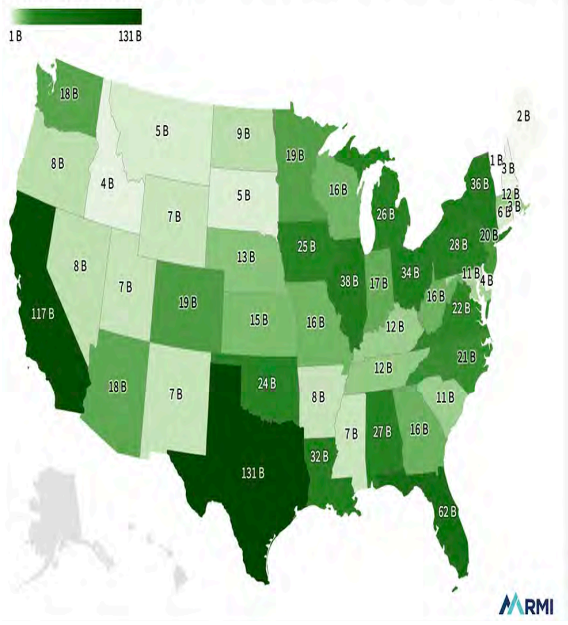


Figure 43. Investment in states through the IRA under climate ambitious scenario ($) by 2030

According to the Small Business Administration (SBA), small businesses make up 99.8% of all businesses in Texas[113], which means that the vast majority of businesses in the state will **be eligible for the benefits provided by the Inflation Reduction Act**, including tax credits for energy efficiency improvements and the purchase of clean energy vehicles. One of the tax credit benefits is that Commercial building owners can receive a tax credit of up to $5 per square foot to support energy efficiency improvements that deliver lower utility bills[114].

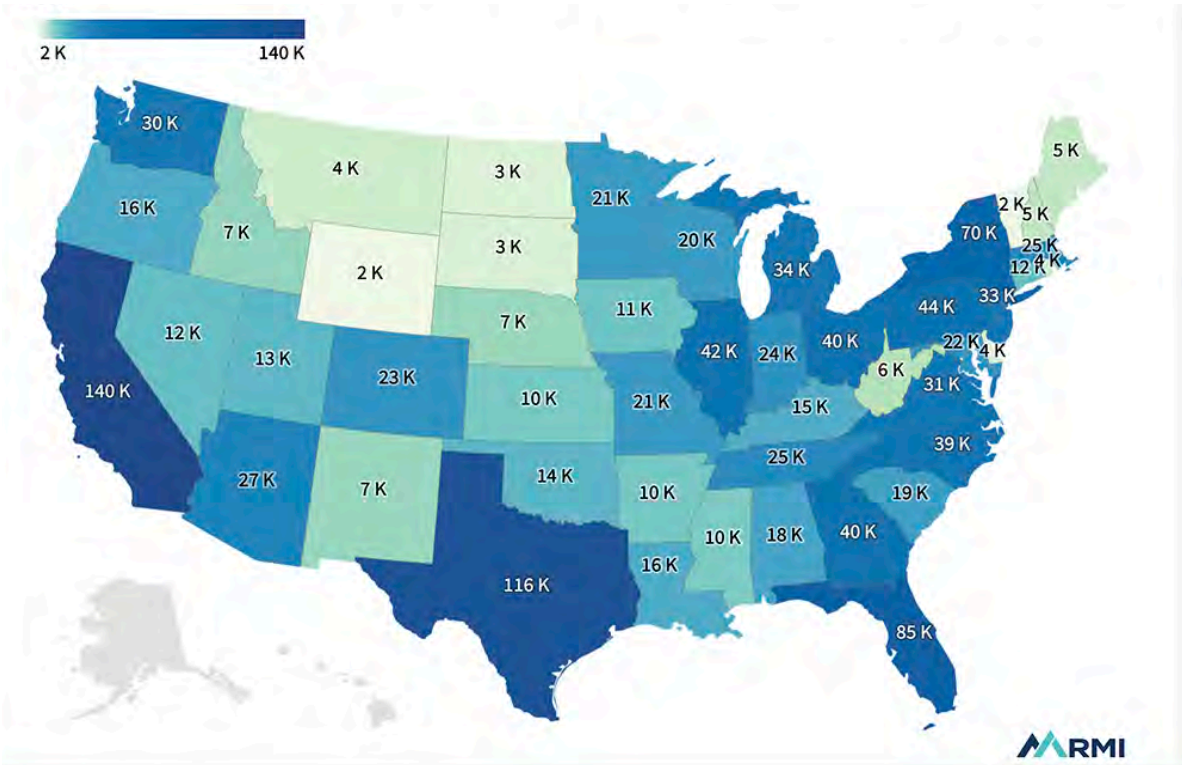


Figure 44. Potentially induced number of new jobs in 2030 through the IRA

(-) Methane Emissions

While the Inflation Reduction Act's methane reduction program is a positive step towards reducing greenhouse gas emissions, it would have negative impacts on the fossil fuel industry and the state of Texas. The IRA aims to reduce 30% of methane emissions from the oil and gas industry by 2030[115] through the facility's reported emissions under EPA's GHGRP[116]. The program would impose a fee on these emissions, starting at $900 per ton in 2024 and increasing to $1500 per ton by 2026. This fee is designed to incentivize companies to reduce their methane emissions and promote a more sustainable energy future[111].

The methane reduction program included in the IRA[117] would have a direct impact on Texas' oil and gas industry by encouraging companies to control their methane emissions, which have been identified as a significant contributor to greenhouse gas emissions[118]. The oil and gas industry is a significant employer in Texas, and reduced demand for fossil fuels could lead to job losses in the sector, which could have significant economic impacts on the state and its communities. While the world is changing energy transitioning from fossil fuels to clean energy, in accordance with Texas tax collection data from Comptroller Glenn Hegar, in contrast, Texas oil and natural gas industries are generating record-high revenue for the state through production taxes. In May 2022, natural gas producers in Texas paid the highest amount in history, with $525 million in natural gas production taxes, which 144% higher than August 2021[119]. Furthermore, the Texas oil and natural gas industry made a significant contribution to the state and local taxes and state royalties during Fiscal Year 2022, resulting in a record-breaking year. The revenue generated from the production of oil and natural gas, pipelines, refineries, and LNG facilities totaled $24.7 billion, which is equivalent to approximately $67 million per day.

In Figure 45, a yearly chart is particularly notable in 2022 because they exceed the total revenue generated by some previous years[58]. What we need to be noted here is that the substantial tax revenue generated from the thriving oil and natural gas industry in Texas remains a significant contributor to the state's funding for public schools and universities, roads, and essential services. Therefore, at present, Texas is facing the challenge of devising statewide adaption strategies to shift from fossil fuels to clean energy to combat the impacts of climate change as having a high responsibility as the biggest fossil fuel industry state.

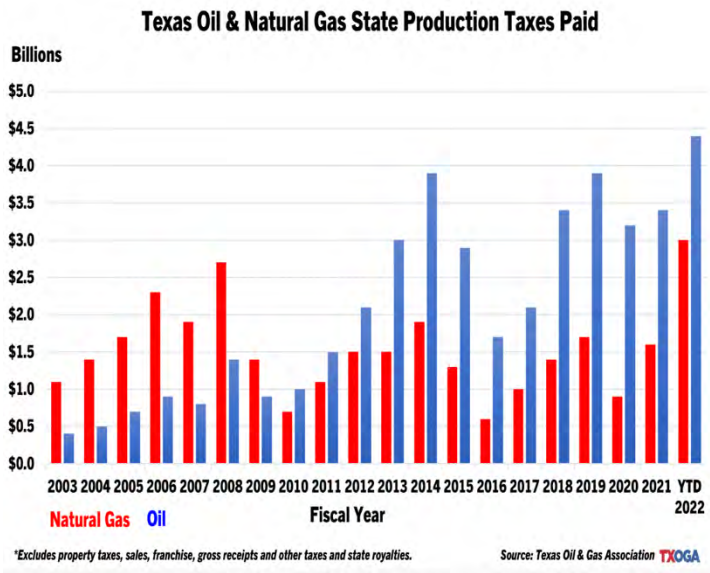


Figure 45 Texas Oil & Natural Gas State Production Taxes Paid 2003-2022

As shown above in Figure 45, the oil and gas industry is a significant source of tax revenue for Texas. Reduced profitability in the sector could lead to decreased tax revenue, impacting the state's ability to fund public services and infrastructure. The bill would eventually charge companies a fee on the emissions, though it offers financial assistance to protect smaller oil and gas operations. Potential job losses in the fossil fuel industry, particularly in the oil and gas sector, could have significant economic impacts on the state.

Chapter 2. The Impact of the IRA on the C&I Aggregator in Texas

Texas's commercial and industrial (C&I) aggregator market has been rapidly growing in recent years, driven by the increasing demand for renewable energy and the need for more efficient energy management systems. The Inflation Reduction Act (IRA) has played a significant role in accelerating the growth of this market by providing incentives for businesses and organizations to invest in more efficient and sustainable energy management systems. In this chapter, we will analyze the impact of the IRA on the C&I aggregator market in Texas. Specifically, we will explore the definition and characteristics of C&I aggregators, the market players and competition in Texas, and the current business models of C&I aggregators. We will also map the stakeholders involved in the C&I aggregator landscape, including public and private entities.

Definition and Characteristics of C&I Aggregator

The evolvement of aggregators has been becoming more diverse through it has allowed the various types of energy sources to participate in the market. Especially, as they can touch both sides of the role of "providing demand and supply-side flexibility service to the grid."[25] Since IRA was introduced, increased various types of aggregator roles and facilitated several new business models[120] in the energy market as DER providers grow in numbers[121]. As Figure 46, the sector map of companies shows[122], aggregator requires various interconnections and has led to the expansion of different roles and business models such as platform services and Smart home services.

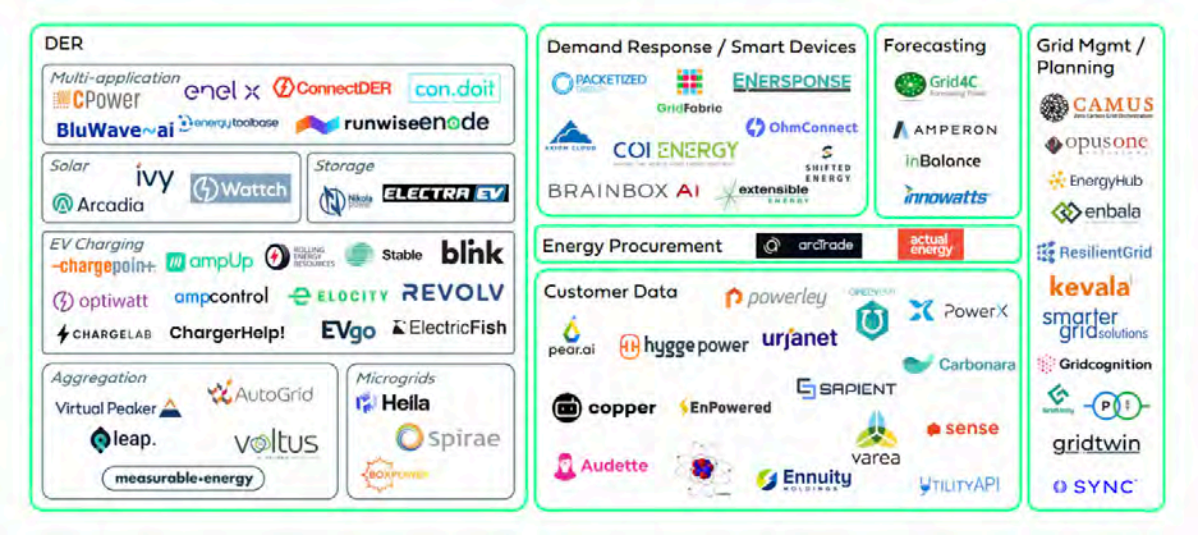


Figure 46. Market map of energy data connectivity startups (Source CTVC)

In this dissertation, the C&I aggregator is considering the market structure in the ERCOT market, which provides aggregate DERs capacity from the C&I sector to REP (Retail Energy Provider). It is neither registered as QSE (Qualified Scheduling Entities) nor REP. It is included companies in partnership with utilities for **managing DERs (VPP) as a service** and/or the company has its own renewable capacity to be able to sell, such as Leap, Maplewell, Virtual Peaker, and EnergyHub. Also, the C&I sector is included small and medium commercial & industrial sectors as well.

For instance to compare*, in California*[123] The wholesale-facing entities are called Demand Response Providers (DRPs). The investor-owned utilities (IOUs) also act as DRPs for their own DR programs, in competition with programs offered by independent, third-party DRPs. Some entities will handle both retail and wholesale transactions. The bidding of retail customers' load reductions in wholesale markets is often referred to as "Direct Participation".

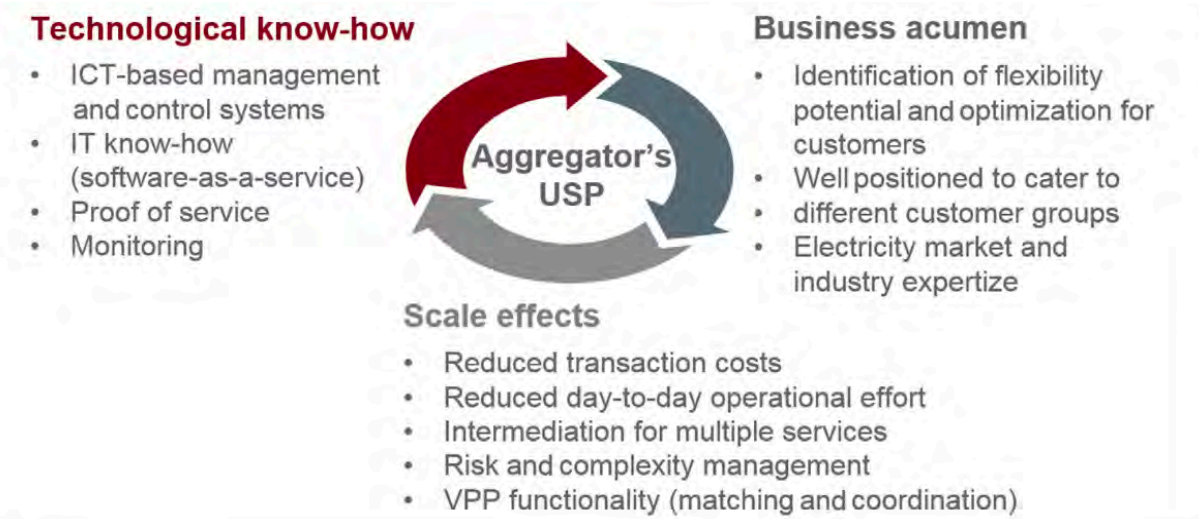


Figure 47. Technological know-how, business acumen, and scale effects form an aggregator's unique selling points.

C&I aggregators' characteristics to have competitiveness are diverse depending on the business model, but "The key consists in using **advanced automation solutions** to extract value from customer flexibility without affecting their comfort levels or operations."[124] According to Poplavskaya & de Vries, 2020[124, p. 5], aggregators have required **technical expertise** because making a decision that involves weighing various options can be a challenging task that requires careful consideration and analysis in order to participate the market. Furthermore, they need to have **polling resources that have the advantage of balancing portfolio** which allows for the combination of multiple technologies to overcome technical limitations, because "The value of aggregators stems from their potential to bundle not only different load or generation sources but also different value streams from multiple activities. […] The removal of transaction costs through **information and communication technology (ICT) solutions, the business acumen, and the benefits of scale effects** form an aggregator's unique selling points (USP), as is shown in Figure 47." As we have seen, C&I aggregator's definition and characteristics, to understand how they play a crucial role in the energy market, we will delve into the market players and competition in Texas.

Current C&I Aggregator Business Model

Aggregators offer a range of services that go beyond serving end users and distributed energy resources (DERs) such as providing a combination of business-to-consumer (B2C) services and business-to-business (B2B) solutions. "The main distinction of the aggregator

compared to the other actors, such as a supplier and BRP[10], is their ability to trade flexibility. This is called the flexibility trading function."[26] As aggregators are able to have multiple roles such as managing information and integrating different technologies through control and communication systems for aggregating resources data by providing reliability as a service[125]. Therefore, depending on what value will provide to the energy sector as an aggregator, has different revenue streams as shown in Figure 48.

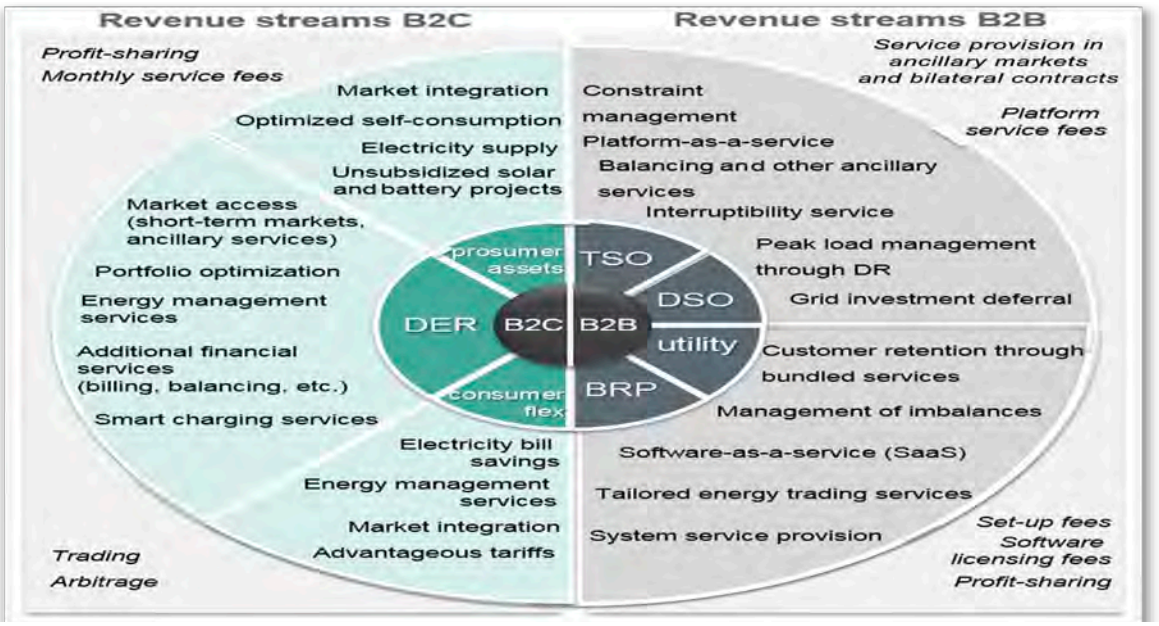


Figure 48. Potential roles of aggregators, their customer groups (inner circle), value propositions (outer circle), and revenue streams.

In this chapter, to identify the current business model for the C&I aggregator, we use the 'IEEE research framework'[26] which was developed based on the *canvas framework*[126] as one of the widely preferred frameworks for analyzing business models. There are 3 types of different roles, 1) aggregators with a supplier's role, 2) aggregators with Balance Responsible Parties, and 3) Independent aggregators.[26] However, considering the role of C&I aggregator in the ERCOT market as we defined it, there are limited business models which without partnership with REP, challenging to participate in the market. Therefore, in this chapter, we will analyze the C&I aggregator business model in the ERCOT market structure, based off adjustments made to the defined aggregator business model by IEEE with the canvas framework base.

[10] Balance Responsible Parties, A BRP is re- sponsible for submitting energy programmes that indicate the net energy that is planned to be taken from/fed into the grid for the next day, defined by IEEE. In this paper, presume ERCOT.

1. Supplier's Role; DR Market Participants

The DR market participants company with C&I sector resources to "trading flexibility obtained from their assets in the electricity market, […] to have a contract with BPR role."[26] The business model of providing DR is mostly the company that has its own platform or has a subsidiary company that develops the platform or partnership with a software company, and directly participates in the ERS market. This role can have a different business model depending on what market participates. Commonly, the ERCOT's DR market includes ERS and AC programs and is mainly activated for the C&I sector to protect the grid disruption[127]. The revenue is mainly from the AC program, as the ERS program is dispatched a maximum of 1~2 times only a year[128].

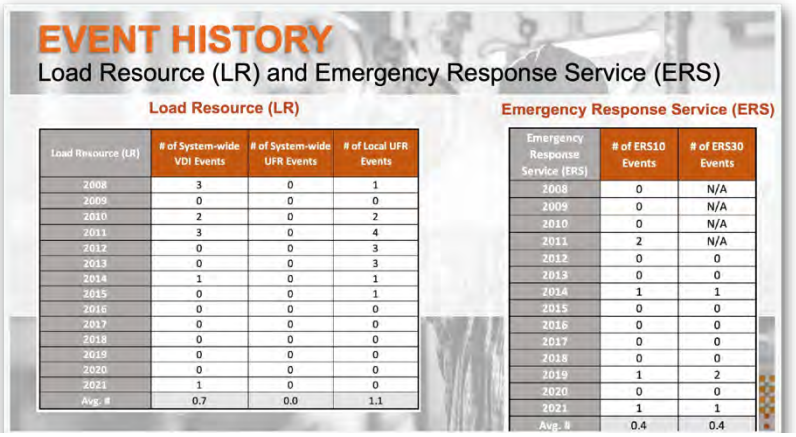
The representative company is CPower and EnerNOC (EnelX). This type of C&I aggregator focuses on delivering the energy demand capacity by reducing/increasing usage during peak periods. They work with (C&I) businesses to reduce/increase their resource pool's energy consumption during times of high demand which is dispatched from ERCOT, such as hot summer afternoons, by offering incentives and rewards. As program's main purpose, helps to stabilize the grid and prevent blackouts.

Figure 49. DR Participants business model example – CPower and EnelX

Currently, according to IEEE research about the New Ancillary Services (AS) Market for Texas, AS market has high potential and is essential for supporting the transmission of energy from resources to loads while ensuring the reliable operation of the transmission system of the service provider. "It is also a prevailing practice to co-optimize the provision of energy and ASs to achieve the most efficient capacity allocation of resources." In response, as a single Balancing Authority, ERCOT was triggered by Winter Storm Uri in 2021 to re-evaluation their market and the *Senate Bill 3*[129] also required to PUCT reform the ERCOT market to secure stability, and it led to PUCT approval of *the blueprint for redesign and*

directive.[129]. It includes an initiative for increasing "administrative procurement of **ancillary services** — including emergency response, fast frequency response, contingency reserves, non-spinning reserves, and voltage support — and create a de-facto capacity market through the existing day-ahead market."[130]

Considering past years that only 1~2 times AS events were dispatched in a year, these ERCOT market restructure changes will positively affect the aggregator business model. Also, it will anticipate the market expansion through not only the ERCOT market changes but also with IRA subsidy for new DERs implementation. Especially, as one of the fastest growing markets with battery storage systems in the ERCOT AS program[131], IRA battery subsidy will expect market potential by participating C&I which can install large sizes of BESS.



Load Resource (LR)	# of System-wide VDI Events	# of System-wide UFR Events	# of Local UFR Events
2008	3	0	1
2009	0	0	0
2010	2	0	2
2011	3	0	4
2012	0	0	3
2013	0	0	3
2014	1	0	1
2015	0	0	1
2016	0	0	0
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	1	0	0
Avg. #	0.7	0.0	1.1

Emergency Response Service (ERS)	# of ERS10 Events	# of ERS30 Events
2008	0	N/A
2009	0	N/A
2010	0	N/A
2011	2	N/A
2012	0	0
2013	0	0
2014	1	1
2015	0	0
2016	0	0
2017	0	0
2018	0	0
2019	1	2
2020	0	0
2021	1	1
Avg. #	0.4	0.4

Figure 50 CPower event history of DR in ERCOT market - 2022

2. *Independent Aggregator Role; Platform Service Provider*

When conducting the flexibility trading operation, an independent actor who has no ties to a supplier or a BRP is referred to as an independent aggregator but has an explicit agreement with BRP to participate in the market[26]. The Platform Service Provider has been playing a significant role in the broad electricity market by providing Software as a service (SaaS)[132] and plays a central role in making VPP a reality. Since VPP (Virtual Platform Plant) concept was proposed as first in 1997 by Shimon Awerbuch that cost-effective way to secure energy distribution efficiently by integrating DERs[133], its evolvement has recently exploded by various reasons such as skyrocketing renewable resources, market open, high technologies developments. Recently VPP concept also getting diverse, but the basic concept is, "VPP acts as a sustainable solution for the optimal operation of DERs and smooth power distribution to the loads. VPP presents **a platform to aggregate** all the DERs that promote system visibility and governance of the power management system and ensure better interactions among the system's different components." [133]Importance of the VPP concept

is that sophisticated software-based systems are utilized by VPPs to optimize value for both the end-user and distribution utility. [134]

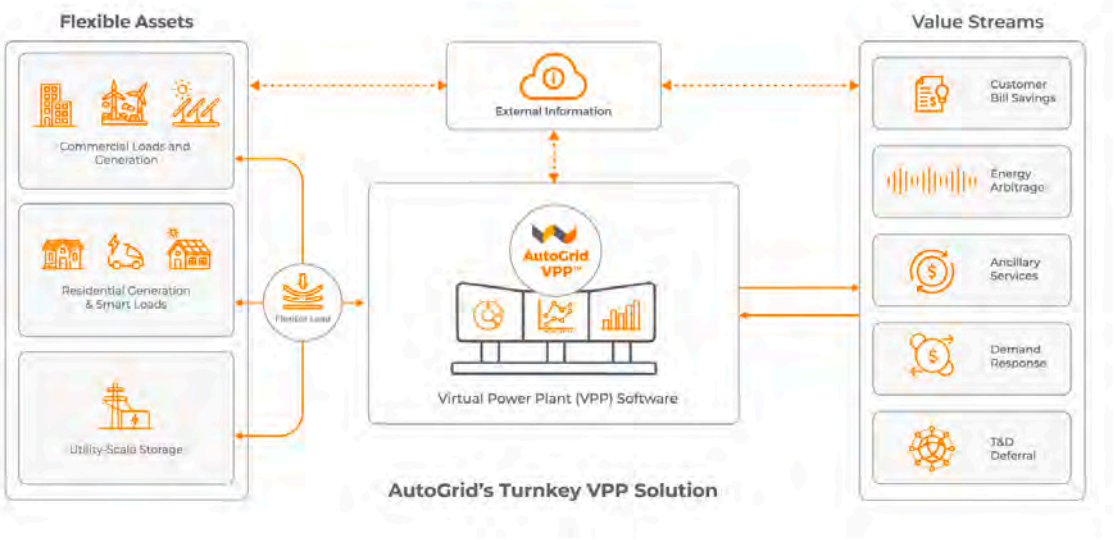


Figure 51. AuthoGrid VPP solution overview

As an independent aggregator business model, providing a platform for flexible market participation such as communication protocol, event performance analysis, simulating features, and optimizing, monitoring, and managing DERs. They service to REPs or DR market participant aggregators, as examples of platform service providers are AutoGrid, Virtual Peaker, and EnerNOC. Figure 51 shows how VPP platforms intercommunicate among the actors as a middleman. These VPP platform service providers offer services such as real-time monitoring, data analytics, and predictive maintenance to help businesses reduce their energy costs and improve their sustainability. According to market research, the Virtual Power Plant (VPP) Software as a Service market is expected to grow from its 2022 value of $648.1 million to $940.4 million by 2029, with a compound annual growth rate (CAGR) of 6.4% during the forecast period of 2023-2029[135]. Virtual power plants (VPPs) are emerging as a promising solution that utilizes Artificial Intelligence (AI) and automation to optimize energy production and consumption[136]. Based on AI algorithms, it can help to DERs optimal resource management, forecasting, scheduling, and portfolio for cost-effective market participation analysis. These functions are getting important as one of the keys to the platform provider's business competitiveness[137].

3. *Demand Aggregator & Generation Aggregator = DGA*

According to the IEEE study [138], the aggregator has a dual role as both an electricity industry player and an execution DR agent, as per the aggregator business model in Figure 52. Also, it proved that by increasing the use of DERs, investors may be more willing to expand the capacity of DERs such as energy storage systems, high-performance energy conversion equipment, and small renewable power generation systems. To effectively communicate with DERs, DR aggregators must have a means of remotely accessing appliances or pre-determined loads specified by the consumer. As various DERs connection needs, by partnering with owners of DERs such as EVs (Electric Vehicles) and V2G (Vehicle to Grid) systems, aggregators can tap into their available power and storage capabilities[139]. This partnership with renewable and OEM[11] providers can be a *win-win situation,* through leveraging their expertise in energy management and demand response, aggregators can help retailers design and implement more effective pricing strategies that incentivize customers to shift their energy usage to off-peak hours.

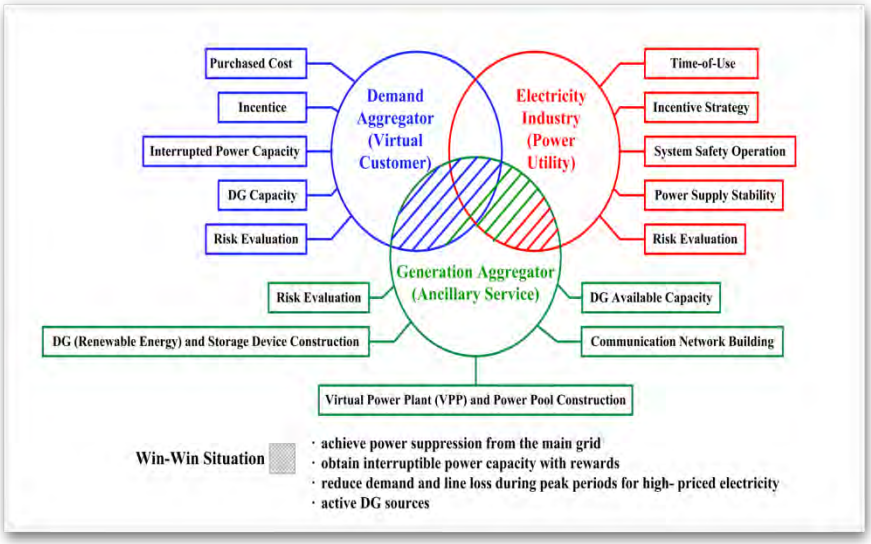


Figure 52. Win-win mode of power utility and aggregators (demand and generation).

[11] Original Equipment Manufacture: Presume PV, EV, Wind module manufacturers (ex. Turbine, PV module, Battery)

One representative business model is Ohm-ConnectEnergy (OCE)[140]. Although OCE currently focuses on the residential sector, we have analyzed it because we anticipate its rapid expansion into the C&I sector. The fundamental concept behind OCE's model is participating in the demand response (DR) market by leveraging client reduction capacity. However, what sets OCE apart is its unique approach of rewarding clients for their energy-saving efforts during high-demand times, referred to as 'Save Energy. Get Paid.'[141] These rewards come in the form of points that can be exchanged for cash or used to offset electricity bills. In 2020, OCE obtained the status of a retail electricity provider (REP) within ERCOT. Additionally, they introduced the Smart Device[140], a smart device aimed at facilitating more accurate and secure communication. This evolved business model not only integrates with smart devices for customer pattern analysis but also enables automatic energy usage reduction during peak times while participating in the wholesale market.

Figure 53. OhmConnect Business advertisement

As the Inflation Reduction Act (IRA) offers incentives for investments in renewable energy solutions, C&I aggregators are well-positioned to collaborate with renewable and OEM providers, generating synergies that enhance resource management flexibility. By working with businesses to install and maintain solar panels, wind turbines, and batteries, C&I aggregators can develop and implement advanced energy management strategies and demand response programs, ultimately contributing to a more sustainable and resilient energy infrastructure. Prominent examples of renewable and OEM providers in this collaboration include SunPower and LG Energy Solution (Battery).

Challenges to Moving Forwards with DERs

The commercial and industrial (C&I) sector is experiencing significant changes as distributed energy resources (DERs)[142] become more prevalent. However, aggregators in the C&I sector face several challenges that can make it difficult to operate effectively and

attract new customers. These challenges include interconnection to the grid, lack of standardization, and increasing competition from new entrants such as large tech companies.

1. *Interconnection To The Grid*

The increasing adoption of distributed energy resources (DERs) in the United States [143] is presenting a range of challenges for local distribution utilities and interconnection customers[144]. The traditional worst-case scenario approach to interconnection, which is typically used by utilities, is both too slow and expensive for DER developers. In this approach, if one or more DERs fail to meet the interconnection requirements, the entire interconnection process may need to be restarted, which can be a significant setback for aggregators. According to Power-magazine[145] interviewee Carrino [12], "In fact, the ***transmission grid continues to lose ground to new renewable projects***, causing increasing curtailments of renewables because the transmission system has not kept up in several U.S. markets."

This issue leads to the challenges that during these scale-ups and deployments of DER and electrification, is becoming increasingly difficult to balance frequency and will put a strain on utility hosting capacity, making interconnection a bottleneck. This issue can result in additional costs for aggregators due to the delay in connecting DER resources to the grid such as wasting electricity and project delay risk. For instance, currently, EV resources are a relatively small portion as a resource to participate markets from the C&I sector to consider the generation capacity and V2G infrastructure preparation situation. Since EVs growth has been skyrocketing by IRA[146], increasing potential as a resource for the market. However, building fast-charging facilities, which need EVs for participating the market, needs a long process[147] in order to get permission from the local municipalities or energy providers, or governments.[148] It could arise difficult for aggregators to schedule market participation and assure C&I customers business operations and ROI (Return on Investment). Consequently, the difficulty of finding a clear business model to cover the prices of risk, as well as the fact that many C&I clients could be hesitant to participate in the market. This can be a significant obstacle for aggregators, as it can limit their ability to attract new customers and differentiate themselves from competitors.

[12] Tony Carrino, director of Power and Utilities with Solomon Associates

2. Lack of Standardization

The IEEE Standards for DER are mainly focused on communication with the grid such as IEEE 1547 Series, IEEE2030 Series[149], or OpenADR for DR market participation. One of the aggregator challenges is the lack of standardization[143] across different appliances and devices[139] for integrating data in order to participate market. Each appliance may use its own communication protocol or standard, which can make it difficult for aggregators to integrate these devices into their demand response programs. This can result in a lock-in effect, where customers are locked into specific programs or vendors due to the lack of interoperability between different devices and communication protocols. This lack of standardization can also lead to higher costs and longer integration times for aggregators, as they must develop custom solutions for each device or appliance, they wish to integrate into their demand response programs. For instance, in case of EnerNOC, who is "mainly focuses on large loads, which sells DR resources to the transmission system operator and treats energy management services as its core business,"[150] developed in-house network operating center to directly control appliances from HVAC system to lighting for participating the market. [139]

Since the approval of FERC Order 2222, which mandates that aggregators be allowed to pool their DER resources into the wholesale transmission market, the electricity industry has undergone significant changes.[74] Additionally, IRA's the Investment Tax Credit (ITC) and other policies have accelerated the expansion of renewable energy resources, such as solar PV. According to the NREL report on Solar Industry Updates, the announced capacity of solar manufacturing has exceeded 85 GW, including 19 new manufacturing plants across the solar supply chain, which is a one of result of the IRA's impact on DER resource expansion.[151] This enormous expansion of DER without a common protocol could occurring not only aggregator business time-consuming and costly to integrate all different types of data communication based on each manufacturing protocol but also, lack of standardization can threaten life security. One of DER's resources BSS has superior potential in the C&I sector, as it is useful not only in stabilizing its own electricity but also has remarkable benefits as a participating resource for the DR market and arbitrage electricity cost. However, as one of the well-developed DR markets country South Korea which has approximately 67GW BESS installation capacity (2018~2022.SEP)[152], had been in jeopardy by the lithium-ion battery (BESS) fires in 2017~18. According to the investigation

committee formed by the Korean Ministry of Industry investigation result, one of the main reasons causing the fire was integration among the appliance system, “It was confirmed by the committee that gaps in the integration of the battery management system (BMS), energy management system (EMS), and power management system (PMS) can result in conditions that lead to a fire. **Integration issues included inadequate information sharing between systems, system operating sequence, and checking for abnormalities of the batteries after PCS maintenance or troubleshooting**.”[153] As this case shows, the lack of standardization across different appliances and devices remains a significant challenge for the industry. It led to facing challenges for aggregators in the C&I sector in the complexity of energy management [139] that different types of communication way and protocols, in large commercial and industrial facilities. These facilities often have a diverse range of energy-consuming equipment and systems, which can make it tricky to identify and implement energy-saving measures. Additionally, the energy needs of these facilities can vary significantly depending on factors such as weather, production schedules, and occupancy levels, making it challenging to develop effective demand response programs.

3. Increasing Competition

Aggregators in the commercial and industrial (C&I) sector face a range of challenges, including increasing competition from C&I clients who are becoming aggregators themselves. This trend is driven by several factors, including the desire for greater control over energy costs and the availability of new technologies that make it easier for companies to manage their energy use. According to UtilityDive, Apple, a company primarily known for its iPhones and iPads, is expanding its business into the electric power industry. On June 6, Apple filed an application with the Federal Energy Regulatory Commission (FERC) to sell electricity and other power grid services[154]. Interestingly, if it approved, Apple is also can sell the electricity to Ancillary Services[155].

This can make it difficult for traditional aggregators to differentiate themselves and attract new customers, as they may struggle to compete with the scale and resources of these new entrants. Additionally, the entry of large tech companies such as Amazon and Google into the energy market as aggregators can disrupt the traditional business models of aggregators. Since 2010 FREC has granted Google Energy, to achieve its goal that 100% renewable

energy and targeting 100% Carbon-Free Energy (CFE). They purchase over 7 GW of renewable and involve over 60 energy projects [156]. Based on the company's significant expertise in data analytics and cloud computing, they can use to offer energy management services that are more efficient and cost-effective than traditional approaches[157]. This competition can make it difficult for traditional aggregators to differentiate themselves and attract new customers, as they may struggle to compete with the scale and resources of these new entrants.

Competition and Stakeholder Mapping

The evolvement of technology, along with regulatory advancements and market deregulation, has paved the way for a diverse business model for C&I aggregators. These models have been shaped by the evolvement of Demand Response (DR) technology and the expansion of Distributed Energy Resources (DERs)[142]. As VPP is the smart approach for integrating DERs with such as DR programs[158], the competition among aggregators has witnessed a significant increase, fueled by the evolving landscape of technologies and the realization of the Virtual Power Plant (VPP) concept.

However, in Texas, C&I aggregator's market potential with VPPs faces specific challenges that are unique to the state's energy landscape. One of the significant challenges is the limited access of C&I aggregators to certain markets within ERCOT. While C&I aggregators can participate in the ERCOT Demand Response (DR) market and utility load management programs, they have limitations when it comes to participating in the Day-ahead/Real-Time energy or Reserves Markets directly. To access these markets, C&I aggregators need to partner with retail electricity providers (REPs) who have the necessary market participation capabilities. Therefore, in this chapter, we explore understanding competition and stakeholders in the market and in further detail, the challenges faced by C&I aggregators in Texas.

According to GuideHouse[159], expected VPP capacity growth is skyrocketing by 2029 as it shown in Figure 54 and it will enhance the increased importance of the DERs portfolio. In addition, one of the simulation results demonstrate[160] that providing DR services from the internal aggregators and participating in the local intraday demand response exchange market noticeably affects the VPP's decisions, **improving the profit by more than 7% and**

reducing the imposed imbalance penalty in the balancing market by nearly 50%. These findings underscore the significance of C&I aggregators in leveraging DR capabilities to optimize VPP operations and enhance financial outcomes.

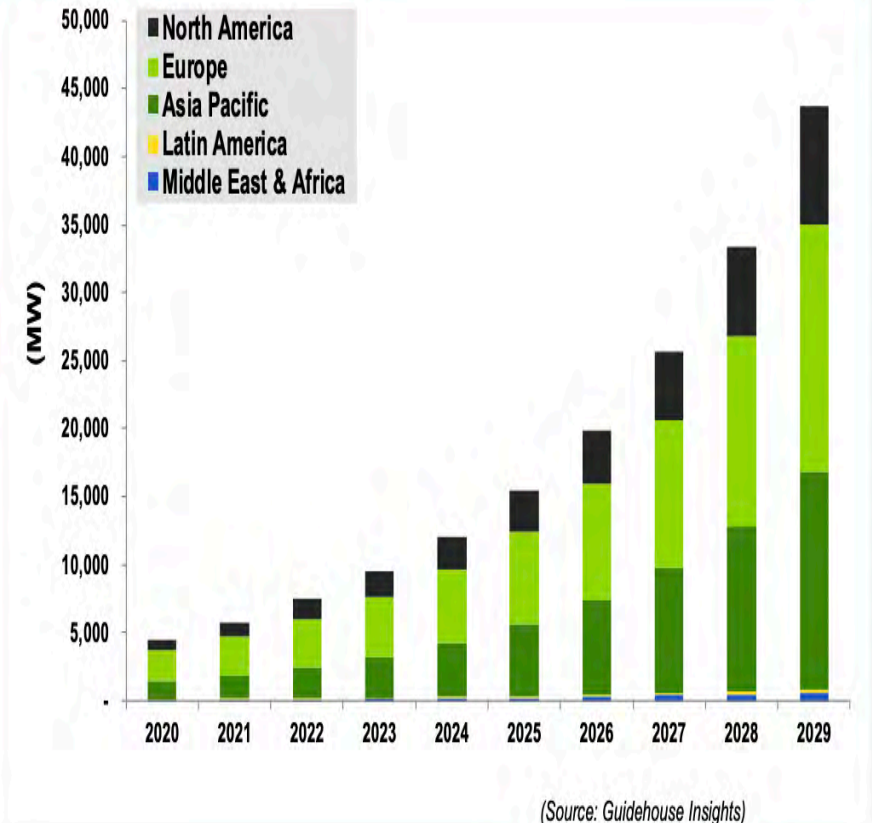


Figure 54. VPP Capacity by Region, World Markets: 2020-2029

Besides, while figure 55 referenced in the provided information is Europe-based, it is well illustrating about market players are increasing and changing to the combined role with VPP, Complement, and Asset[161]. These emerging market dynamics contribute to the heightened competition among aggregators, with each vying for a prominent role in the sector.

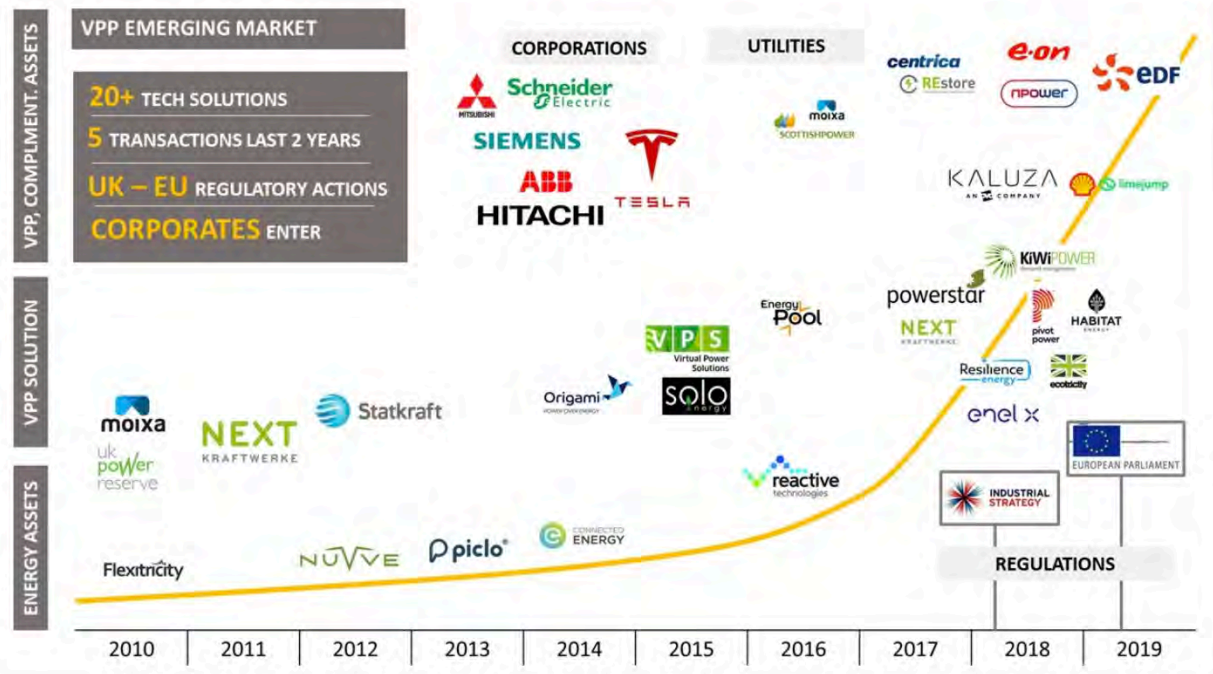


Figure 55. Evolution of the VPP market in the UK, Source: INSTA Associates, 2020

C&I Aggregator Competition but Why with REP?

The Inflation Reduction Act (IRA) leading spurred growth in the Distributed Energy Resources (DER) sector, it has had a significant impact on the C&I aggregator market competition in Texas, particularly. As IRA aims to reduce clean energy prices by subsiding DERs (Solar, Winds, EVs, etc), this has created an opportunity for C&I aggregators to step in and offer their services, such as helping businesses to optimize their DER resources and pool more resources to participate in the market. It demonstrates through the growth of investment in distributed resources that have a positive effect on the market. According to CPower[162], which C&I aggregator, "The IRA includes *a stand-alone Investment Tax Credit* for energy-storage projects, which effectively reduces a storage project's costs by 30%. […] a healthcare facility in Connecticut projects $186,000 in on-bill savings in the first year after installing a battery through CPower. Importantly, these on-bill savings are in addition to the performance incentives paid by utilities and grid operators."

However, although REPs and Aggregator have inherently different core business models[163], C&I aggregators face challenges from other market players, including retail electricity providers (REPs), who may offer similar services. **Since, the aggregator has the limitation of participating ERCOT DR market without REP**, if the company has the capacity enables to sell in the wholesale market **instead of becoming an aggregator, they**

choose to become a REP. To clearly understand, we asked *EnergyHub*[164] who is the actual field player as one of the C&I aggregators, about what ERCOT market the aggregator can participate in. They said, **"Aggregators can participate in ERS or the utility load management programs but can't participate in the Day-ahead/Real-Time energy or Reserves Markets directly (*the REPs need to participate in those markets*)."**

One of the cases is, according to CNBC, "Tesla hasn't functioned as the retail electricity provider where it sets up these systems. Instead, big batteries built by Tesla tend to help other companies in energy generation, storage, and consumption." However, they became a REP in the ERCOT market in 2021 after Winter storm Uri, "With a goal that the start of a big battery build out by Tesla in Angleton, Texas (near Houston), where it aims to connect a 100-megawatt energy storage system to the grid." [165]

Through these prominent corporate entities have shown interest in participating in wholesale energy markets, which further intensifies the competition for C&I aggregators. REP-certified company list from the Public Utility Commission of Texas (PUCT) indicates that the number of certified REP companies has experienced a more significant increase following the passage of the IRA, surpassing the growth observed in the previous year (New certified REP was 12 in 2021 and was 16 in 6 months from Aug 2022 to Feb 2023).

Furthermore, according to Fortune Business Insight[166], these major companies are strongly focusing on merging with the company that has potential technology in the VPP market. Especially the company characterized by the strong presence of major companies with extensive distribution networks in developed and emerging economies. It is shown that C&I aggregator competition is intensifying the competition not only REPs but also other industry participants, which is fueled by supportive government initiatives for renewable energy growth and a surge in mergers and acquisitions.

Stakeholder Mapping in ERCOT Market

In the highly competitive ERCOT market, where the role of aggregators is vague, conducting stakeholder mapping is of utmost importance for C&I aggregators to maintain a competitive edge. Stakeholder mapping provides a structured and systematic approach to analyzing the interests, power dynamics, and potential collaborations or conflicts among stakeholders. Therefore, in the upcoming section, to examine how can the C&I aggregators participate the wholesale market, we will employ the Power (Influence)/Interest matrix technique to visualize the influence and interest levels of various stakeholder groups based on their market roles[13]. The Power/interest matrix[167] is suggested by Mendelo(1991) that "analyze our stakeholder groups based on **Power** (the ability to **influence** our organization strategy or project resources) and **Interest** (how interested they are in the organization or project succeeding)."[168] It is typically classified into four quadrants in the matrix; High power, high interest / High power, low interest/ Low power, high interest/ low power, and low interest. This matrix helps identify potential partnerships, collaborations that can enhance the market position and competitive advantage of C&I aggregators. Furthermore, through a comprehensive analysis, it is anticipated that the matrix will provide valuable insights into the extent of influence held by various stakeholders and its impact on decision-making pathways. The findings of stakeholder mapping, presented in Figure 56, are based on, as Table 1, an assessment of stakeholders' roles, motivations, levels of involvement, and either resistance or support, culminating in a comprehensive stakeholder mapping.

[13] Market role and company list: https://quickelectricity.com/texas-electricity-explained/

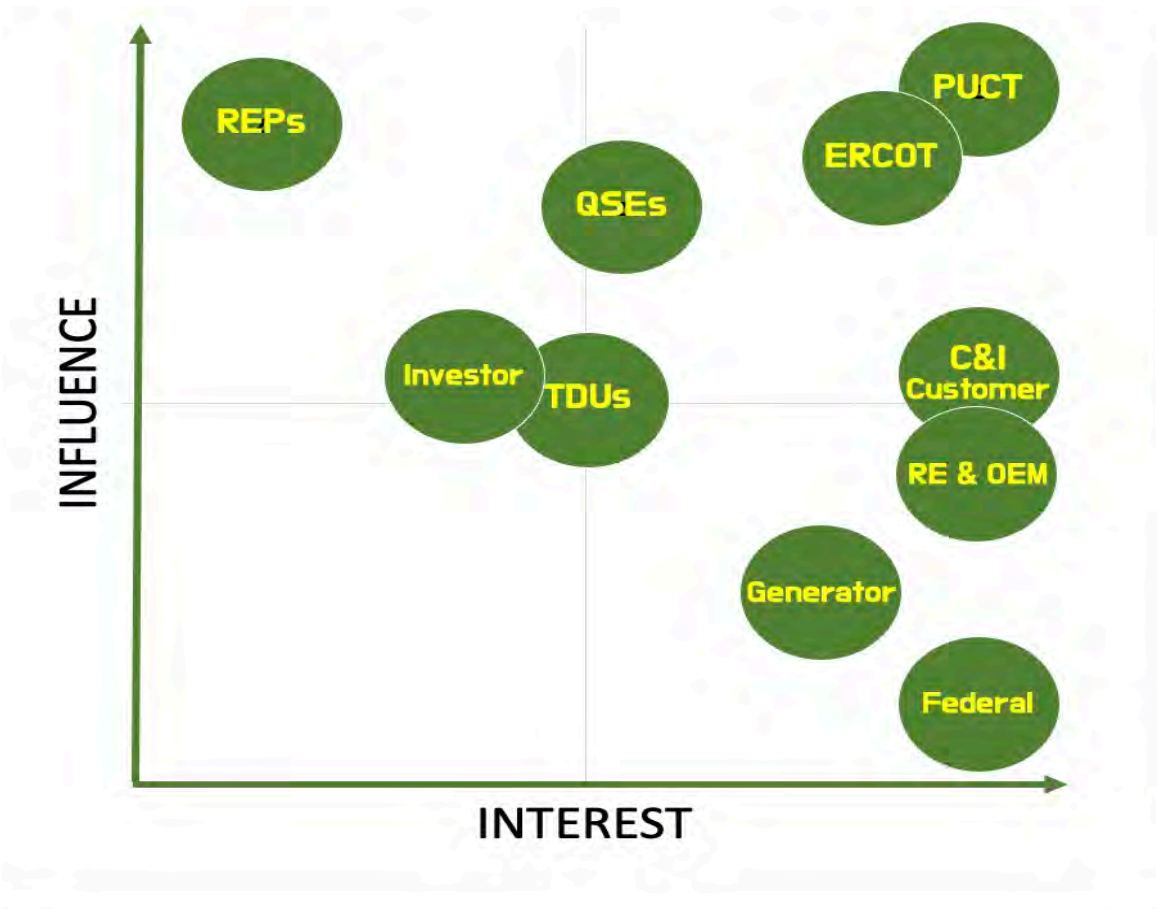


Figure 56. C&I Aggregator's participate in wholesale market stakeholder mapping, Influence-Interest Matrix (Source Author)

Stakeholder	Categories in ERCOT	Description of role (General/Potential)	Motivation	Resistance or support (Both - <, > weight to)	Level of Involvement	[Level of Interest] Core interest(s)	Influence
ERCOT	-	- Resource capacity planning (such as ancillary services) - Procure balancing supply/demand frequency - Maintain grid reliability (such as Transmission congestion management) - Overseeing the wholesale electricity market	- Promote stability electricity grid, market operation - Integrate of renewable resource with less intermittency - Protect grid from Blackout, congestions - Stranthen grid from extream weather	**[Both R < S]** Considering ensuring the electric grid's reliability, intermittency and interconnection with DERs can create resistance. However, to improve market efficiency and enhance grid reliability, They have to adopt innovative technologies and diverse the energy resource to prevent emergency situation as like 2021	**[High]** ERCOT is main role to provide market access and facilitate settlement processes while enforcing compliance with market rules.	**[High]** Ensure Reliability of the electric grid in Texas	**[High]** As regulate their participation in the wholesale electricity market, their influence is high, and as operate AS market their design, and pricing mechanism are a high impact on aggregator expansion.
PUCT	-	- Regulate/governance and oversight the electric utility industry in Texas - Regulatory authority responsible for licensing and certifying market participants	- A fair and comptitive market enviroment - Cost-effective electricity generation and delivery - Fosters investment, use of renewable energy, - Innovation of electric makret environment	**[Support]** Since DERs increasement is one of innovation way to expand capacity and increase grid stability, PUCT are move forward to support DR and DERs acceptance on to grid	**[High]** Since 2021, Winter Storm Uri, PUCT strongly request to ERCOT change the market structure to keep the grid stable and prepare for extreme weather situations. As one of the ways is to increase clean resources (DERs) and DR expansion for a fast response from grid fluctuation.	**[High]** - Ensuring provision of reliable, affordable, and Safe electricity service to end-user - Balance the interests of consumer, utilities, and other stakeholders while promoting comptition and protecting the public interest	**[High]** As regulate the market participation and operation by PUCT, influence level is very high. Also, their decisions and policies can impact the aggregator's ability to operate in the Texas electricity market.
QSEs	-	- Intermediaries between electricity market participant and ERCOT - Submit Balanced Schedules to ERCOT - Submit Ancillary Service Bids - Clear all finalcial settlement with ERCOT - Real time monitoring grid condition	- Efficient management electricity resource - Minimize imbalances - Optimize scheduling - Maximize economic value of their portfolios	**[Both, R < S]** - Resistance : Considering QSE's role, increase risk in real-time and DER resources intermittency is a risk for balancing the grid - Support: However, creating diverse portfolios for resources and maximizing the economic value by competition can increase	**[High]** QSEs actively engage with aggregators by coordinating resource schedules, managing energy imbalances, and settling financial transactions.	**[Moderate]** - Optimize management scheduling and dispatch of electricity resources withihn the ERCOT market - Balancing transaction	**[High]** a direct influence on aggregators as they interact with them in the wholesale electricity market. QSEs can engage aggregators as participants in their portfolios, providing access to electricity markets, and facilitating trading and scheduling activities.

Stakeholder	Categories in ERCOT	Description of role (General/Potential)	Motivation	Resistance or support (Both - <, > weight to)	Level of Involvement	[Level of Interest] Core interest(s)	Influence
Generator	Resource Entities (RE)	Meet the electricity demand by generating electricity Eunsuring reliable electricity generation	- Market demand - Profitability - Optimize generation assets	**[Both, R < S]** - Resistance for the aggregator who generate it self and selling to the market - Support for increasing the customers to provide generation capacity is benefit for generator company.	**[High]** Unless the generator becomes an aggregator, as it is positive impacts such as increasing partnerships and consumers or become aggregator's resource, its involvement level will be high	**[High]** Expand electricity production and supply Increase efficient electricity generation	**[Low]** As potential customer is aggregator for generator company, can influence through supply capacity or pricing but it may not influence for aggregator expansion.
TDUs	Load Serving Entities (LSEs)	Operation, Maintenance, and Expansion of electrical grid infrastructure	Improve grid efficiency and quality	**[Both, R > S]** - Resistance for stability of the grid - Support for expand capacity through DR+DER with less investement	**[Moderate]** - Technical aspect : high, such as grid interconnection for DER, compliance with grid codes - Market operate aspect: Low, Market oversight by ERCOT and PUCT	**[Moderate]** - Maintain a relibility of Power line and Station - Stable delivery of electricity to end-user - Minimizing system losses and disruptions	**[Mid]** As open market, there are no limited to use grid, however as they also operate DR market, their partner aggregator can influence
REPs	- Competitive Retailers (CRs)	Intermediaries between the wholesale electricity market and retail customers, which is purchase electricity from wholesales market and sell to end user customer	- Increase end-users - Cost-effective purchase - Increase sales revenue - Competitiveness	**[Resistance]** As aggregator only through REPs enable to participate the Day-ahead and Real-time wholesale market, to not lose their vested rights, will have high resistance	**[High]** - As the market participation route, and potentially being aggregator, involvement will be high. - To access customer data, aggregator need to communicate with REPs	**[Low]** - Selling electricity to end-user - Offer compitive pricing and quality service and electricity to increase end-user	**[High]** - As they provide a potential market for aggregator services, and the only route to participate wholesale market, influence will be high. - Also, to access various customer data, need REPs
Stakeholder	Categories in ERCOT	Description of role (General/Potential)	Motivation	Resistance or support (Both - <, > weight to)	Level of Involvement	[Level of Interest] Core interest(s)	Influence
C&I Customer	End User	- Purchase and consume electricity (Over 60% of Texas electricity) - Enrol in DR program and invest to renewables implement	Benefit of incentives, Save own energy cost, Enhance business operation sustainability, Commitment on climate change (ex ESG, GHG reduction)	**[Support]** high value to participate C&I aggregator pool is finnancial incentives which high interetst of C&I customers. Also, with solution, they can manage more efficiently their energy consumption.	**[High]** Financial benefit, Reduce energy cost and efficient energy consumption	**[High]** - Reducing electricity costs - Financial benefits - Ensuring energy reliability - Otimizing energy usage.	**[High]** Directly influence to C&I aggregator business model. High potential to influence gird stability, if has its own renewable generation such as BESS.
Renewable and OEM company	-	- Manufacturing renewable energy technologies - Supplying renewable energy resources. *invest in the construction and operation of renewable energy facilities, such as solar farms, wind turbines, and energy storage systems.)	- Renewable needs from industry - Environmental concerns, energy sustainability, and business opportunities in the renewable energy sector - Investment on Renewable and related technologies	**[Support]** Aggregator increasing is one of investors/needs increasing	**[Low]** Partnership relation	**[High]** - To develop, produce, and supply renewable energy resources and equipment - Expanding renewable energy generation capacity - Deploying renewable technologies - Promoting sustainable energy solutions/projects	**[Moderate]** As DERs expantion is one of biggest part for needing aggrergator. However, their influence is inside of aggregator business not expansion to wholesales market
Fedral Government	-	- Shaping energy policies, regulating the electricity market in the national level - Estabilishes rules and standards - Provides funding and incentivs for clean energy initiatives	- Achieve NDC goal - Economic growth - Promoting technological innoavation - Fostering energy independence - Improving public health	**[Support]** To increase clean energy in the USA to acheive their goal, such as IRA, FERC 2222	**[Low]** As ERCOT market is out of Federal government oversight region, it is low but still have choice to get Federal support	**[High]** - Affordability and Sustainability electricity supply - National Energy Security - Environmental Objectives	**[Moderate]** Government programs and incentives, such as tax credits, grants, loan guarantees, and research funding, can incentivize aggregators to invest in renewable energy projects, adopt energy-efficient practices, or engage in demand response programs.
Investor	-	Funding and financing energy projects	Potential financial rewards associated with energy investments	**[Both]** - Resistance : Fossil fuel investors - Support : Clean energy investors	**[Low]** Either way make more benefit is good for investor	**[Mid]** - Financial returns	**[High]** Increase invesement on aggregator has more potential to participate in wholesale market

Table 1 C&I Aggregator's participate in wholesale market stakeholder analysis, Influence-Interest Matrix (Source Author)[14]

By conducting an analysis using the Power/Influence Matrix, it becomes evident that the accelerating energy transition towards cleaner sources in the United States has generated substantial interest among key industry players regarding the expansion of C&I aggregators into the wholesale market. This matrix represents that C&I's wholesale market participation is a potential avenue for these stakeholders to advance their own interests by facilitating the integration of cleaner and more reliable electricity capacity into the market. However, the analysis reveals that Retail Electric Providers (REPs) exhibit a relatively lower level of interest in the expansion of C&I aggregators into the wholesale market. This limited interest can pose challenges and create difficulties in extending the role of C&I aggregators.

[14] ERCOT (Electric Reliability Council of Texas), QSE (Qualified Schedule Entities), PUCT (Public Utility Commission of Texas), TDSP (Transmission and Distribution Utilities), OEM (Original Equipment Manufacturing)

Regulatory Compliance and Operational Challenges

The slower interest from REPs may stem from various factors, such as concerns about market competition, regulatory complexities, or uncertainties regarding the financial implications of wholesale market participation. One of the biggest reason that this paper expect is oligopoly market structure lead from 'lock-in effect'[15][169] for the retailers, aggregators and resources. In the SPEER[16] report, it is well explained about why lock-in situation cause and became oligopoly, "This limitation is present because if the market pays third parties for demand response at the same level as it does generation, the market operator will in turn collect less revenue for energy consumed than the total cost paid out. [...] Regardless of the fact that demand response may create total market savings far in excess of this gap in revenues collected by the market, who pays for this cost may be of primary interest to a market participant."[170] Furthermore, it is shown by comparing with similar structures in other counties that deregulated the electricity market. Despite ERCOT being a deregulated market, a comparison with Japan reveals a distinct market structure wherein Japan possesses over 700 retail electricity providers (REP)[171], whereas ERCOT has a significantly lower count of approximately 130 REP companies. The reason for this infers that occurs for 2 main reasons. First, giving the limited capacity of demand response participation and avoid to additional payment for DR contributing to the market. Second is the DR resource's wholesale market participation route is limited.

ERCOT's DR Program Structures Limitation,

ERCOT's Demand Response (DR) programs, *which C&I aggregators can participate in with/without REPs*, offer two types: Emergency Resource Services (ERS) and Load Resources (LS) Ancillary Service. As discussed in Chapter 1 and shown in Figure 57, the ERS program consists of two product types: 10-minute and 30-minute, designed for emergency situations where the reserve capacity level drops below a certain threshold. When reaching to EEA[17]1 level, ERCOT can initiate DR through ERS program[172]. Although EEA1 couldn't remain the grid stable, it faced EEA 2 level, which reserves are lower than

[15] The lock-in effect refers to a situation in which consumers are dependent on a single manufacturer or supplier for a specific service and cannot move to another vendor without substantial costs or inconvenience.
[16] The South-central Partnership for Energy Efficiency as a Resource (SPEER), is a regional energy efficiency organization (REEO) that aims to accelerate the adoption of advanced building systems and energy efficient products and services in our region, Texas and Oklahoma.
[17] Energy Emergency Alert, by ERCOT

1,750 MW or frequency cannot remain above 59.91HZ, it is not anticipated to retrieve within 30 minutes. Thus, ERCOT seeks to reduce demand by allowing to initiate Load Resource program - and/or ERS, if available[172]

In EEA3, which represents a blackout scenario, “ERCOT orders local utilities to institute mandatory rotating outages to reduce demand on the system. (ERCOT Crisis Communications Procedures, 2018)”

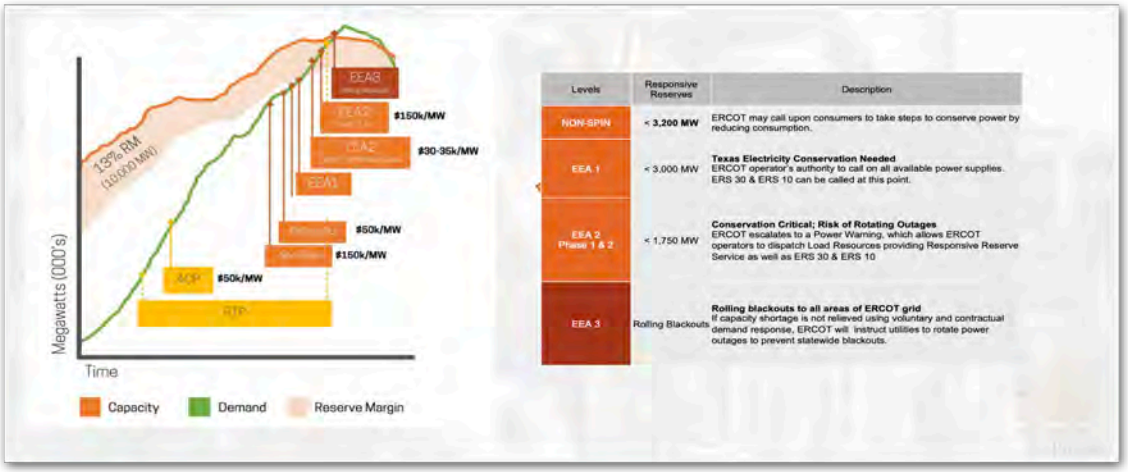


Figure 57. ERCOT Energy Emergency Level (Source: CPower 2022)

According to CPower, the Load Resource program has the “most lucrative potential”, especially during the summer when demand is near peak. It brought high energy prices by tight ERCOT reserve margin, and lack of supply while high demand. Hence, the LP program is popular among the participants, interestingly ERCOT put a cap on the total purchase capacity of LP around 1,4000 MW ~ 1,750 MW. Therefore, for instance, even if the market is available 3,000 MW to cover emergency situations through LP but **only able to buy limited capacity by the cap**.[173]

In the "2019 Utility Demand Response Market Snapshot" report by the Smart Electric Power Alliance[174], it is noted that by the end of 2018, ERCOT had awarded a combination of 2,329 MW in its Responsive Reserve Service (RRS) and procured in the Emergency Response Service (ERS) programs. This represented approximately **only 3% of ERCOT's total capacity in 2018.** Consequently, in 2021 during the winter storm, one of the main reasons the electricity system failed, and Texan had to have experienced a freezing winter was the lack of diverse emergency resources, the only main resource was Natural Gas during the period which did not enable about 40% of it during the crisis.

Figure 58. Emergency Response event example: Natural Gas was the most significant generator during the Winter Storm Uri 2021.

In the Texas electricity wholesale market, there is even no space for innovative technology to support the market during emergencies as shown in the ESR line of Figure 58. Even if the IRA supports funding, if there are no changes in market structure it will cause challenges in the coming summer and winter for Texans.

ERCOT's DR Program Participation Routes Limitation

In the Texas wholesale market, C&I aggregators face limitations in their participation routes for ERCOT's Demand Response (DR) programs, which restricts their ability to fully capture the benefits of DR. Especially, this becomes particularly challenging as the upcoming winter, is forecasted to be colder in 2023[175] and through the winter crisis in Texas highlights the vulnerability of critical infrastructures when faced with events that surpass their design limits [176]. In California, which is open for aggregators in the wholesale market through DRAM (Demand Response Auction Mechanism), their reserve capacity is increasing by aggregator participation which has brought 700 MW of DERs in 3 years[177]. ERCOT's DR programs can also be a powerful tool for managing grid stability during periods of high demand. However, in the 87th Texas Legislature 2021, did not approve weatherization on the demand side or address broader issues of demand response that might diminish the need for electricity [178].

In the context of Texas, where there are several utilities[18] and retail electric providers (REPs), the presence of utility-owned demand response (DR) programs and the reliance on REPs as key partners can create a perception that new DER aggregators are potential competitors or disruptors to the existing business models. According to EnergyHub talk about Texas[164], "The avoided cost of energy in Texas is set at $80/kW-year. However, the TDU programs compensate aggregators approximately $31/kW-year for DR. Even $80/kW-year is artificially low, ignoring the full benefit that DERs provide to the grid, especially during scarcity conditions." This inference arises from the fact that utilities and REPs have traditionally held control over the electricity market and may be hesitant to relinquish their established roles and revenue streams to emerging aggregators. Also, the AutoGrid's Business Development Manager Olaf Lohr mentioned that *Aggregators becoming a REP could be achieved if the scale is sufficient, as shown by Tesla Electric and Octopus Energy with the ADER pilot, but it still has its own challenges and complexities.* In addition, according to Google, "The biggest limitation to widespread participation of DERs in the ERCOT wholesale market is that direct participation by third-party DR Qualified Scheduling Entities (QSEs), and therefore third-party demand response providers, is prohibited," [179]

Furthermore, as mentioned in the IEA report[180], for facilitating value stacking for DER one of the co-ordination models called the 'Total TSO model' is that operates with DERs fully integrated into the power system as shown in Figure 59. "All DERs have direct access to the TSO markets, and *the DSO (=REP)* ***retains only the traditional distribution utility role of maintaining reliable and safe distribution operations.***" It can lead to challenges in fostering partnerships and gaining support from these entities, as they may perceive aggregators as encroaching on their territory.

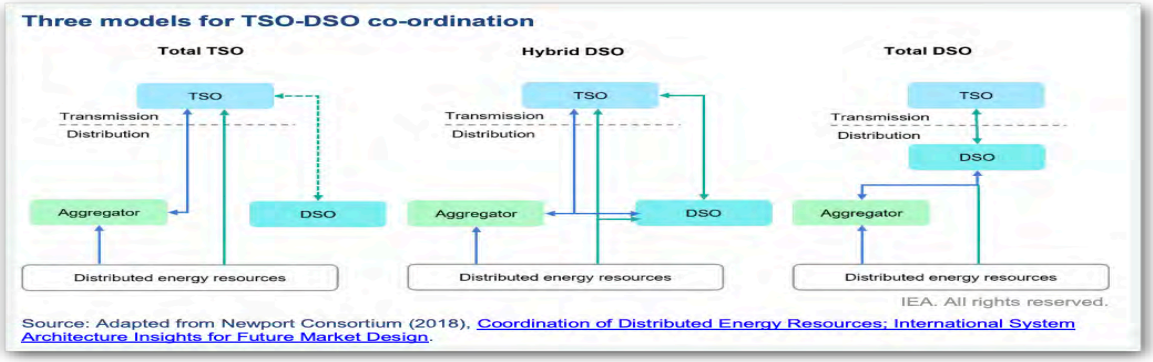


Figure 59. Three models for TSO-DSO co-ordination with aggregator (IEA)

[18] Utility list in ERCOT https://www.puc.texas.gov/industry/electric/directories/iou/search_iou.aspx

Lack of Clarity of Aggregator's Role

In generally known, the aggregator is "a grouping of agents in a power system (i.e., consumers, producers, prosumers, or any mix thereof) to act as a single entity when **engaging in power system markets (both wholesale and retail) or selling services to the operator** (MIT, 2016)."[25]. Furthermore, the value of an aggregator is providing load flexibility by lies in managing and pooling[163]. However, the definition provided by the Public Utility Commission of Texas (PUCT) focuses on aggregators who help customers negotiate better rates with Retail Electric Providers (REPs). According to the PUCT[181], an aggregator is "a buyer's agent that joins customers together as a single purchasing unit and **negotiates on their behalf for the purchase of electricity service in Texas.** Generally, an aggregator will **be compensated by the REP** but may take payments from the customers in certain circumstances--either way the aggregator must inform the customer of its compensation method." When it compare with energy broker[182], which helps to "find the best plan for your electricity needs, negotiate a contract with a Retail Electricity Provider (REP)," only difference is aggregator able to pooling the demand of multiple customers. This lack of clarity of the aggregator role does not applicable to any of the suggested DER integrated aggregator models as below, which means their DER acceptance may be slower than any other states. Furthermore, according to the potential of distributed energy resources in ERCOT, and the importance of getting it right report[183], "**Most retail electric providers do not have programs to compensate excess generation of solar power**. In anticipation of growing DER deployment, ERCOT is considering a shift to locational pricing which would give DERs the ability to respond more accurately to real-time market price signals."

The role of an aggregator in the energy sector is multifaceted, encompassing the management and pooling of various agents within a power system to optimize market engagement and provide load flexibility. While the Public Utility Commission of Texas (PUCT) defines aggregators as entities that negotiate better rates for customers, this definition does not fully capture the potential of distributed energy resource (DER) integrated aggregator models. The limited clarity surrounding the aggregator's role may hinder the adoption of DERs in Texas.

Chapter 3. Through IRA, Texas C&I aggregator Opportunities

Notwithstanding the obstacles that Texas faced, commercial and industrial (C&I) aggregators operating in Texas have the potential to make a substantial contribution to the ongoing energy transition and offer customers valuable services through IRA investment. Through the resolution of regulatory impediments, the utilization of technological innovations, and the demonstration of their value proposition, C&I aggregators can surmount challenges and prosper in the dynamic and ever-changing energy market of Texas. Therefore, in this chapter, analyzes the opportunities to create or accelerate the business models that can help C&I aggregators take advantage of the incentives provided by the IRA.

Increasing Market Opportunities with DERs

Improved integration of distributed energy resources (DERs) across all states can provide a multitude of benefits to the electricity system. According to ESIG's DER integrate reports, these benefits include decreased wholesale costs for day-ahead energy, real-time energy, resource adequacy capacity, and ancillary services, as well as reduced transmission congestion, lower transmission infrastructure costs, and a decrease in greenhouse gas emissions. Since IRA's greatest investment on DERs, it influenced investments towards scale up for deploying DERs. As one of C&I aggregator, Leap[121], mentioned about IRA as a game changer of DERs that "Billions of dollars in tax credits, loans and grants are directed towards reducing the cost to manufacture and purchase a wide array of clean energy technologies. […] we've seen tremendous growth in the number of DER providers looking to create new value streams from their assets through grid revenue opportunities."

One of the biggest opportunities through IRA for C&I aggregator is Battery Energy Storage System (BESS)'s credits expansion as one of DERs resource. According to InfoLink consulting[184], before IRA, BESS have to be connected with solar to get benefit such as front-of-the-meter (FTM) and commercial and industrial (C&I) ESS were only eligible for the ITC if they were charged with 75% solar energy. If an ESS was paired entirely with solar, it could receive a 26% ITC, while a 75% solar pairing would result in a 19.5% ITC. However, the IRA not only extends the ITC until 2032 but also removes these restrictions, **allowing standalone energy storage assets to qualify for the credit.** Consequently, the BESS

installation forecasting capacity is skyrocketing both FTM[19] and BTM[20] C&I market, which potential available capacity for stabilizing grid. Also, IRA supports reducing the upfront cost of batteries[185] through IRA credits on Battery manufacturing.

ITC		2020	2021	2022	2023	2024	2025-2032	2033	2034	2035	2036
Before	C&I	26%	26%	26%	22%	10%	10%	10%	10%	10%	N/A
	Residential	26%	26%	22%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
After	C&I	26%	26%	30%	30%	30%	30%	26%	22.5%	15%	N/A
	Residential	26%	26%	30%	30%	30%	30%	26%	22%	N/A	N/A

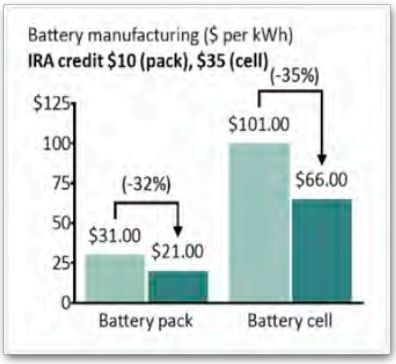


Figure 60. Before and After benefit of IRA incentive on ITC and Battery manufacturing credits

According to POMCube,[186] one of the BESS development companies Eolian announced that 200-MW energy storage project in Texas. It is first applied to the IRA tax credit for independent energy storage and will construct two interconnected battery facilities. Furthermore, in accordance the S&P Global Market Intelligence Power Forecast, in some sector of ERCOT will reach to 80% of full equity return for investor by BESS. Also, BESS pipeline is account for 40% of country[187].

Why Does BESS Increase in C&I Sector Help C&I Aggregator Expansion?

When the C&I sector installs BESS, there are various services to operate such as Figure 61 shown[188], more than one of these applications, "Demand side management/peak shaving, electric service reliability/resilience, energy arbitrage, fast response frequency regulation, Micro-grids, off-grid systems, utility demand response programs, load leveling, backup power, and transmission/distribution system deferral[189]." Shortly summarize 3

[19] In Front of the Meter: describes the power that is generated off-site, away from the point of consumption. An example of this is a utility power plant, the power from which is distributed over a wide area for use by electricity consumers. (Source by SolarRevies: https://www.solarreviews.com/blog/behind-the-meter)

[20] Behind the Meter: is used to describe the power that is produced and consumed on-site. A common type of behind-the-meter system is a residential solar system: solar panels on the roof generate electricity, which is then fed into the home below for use. (Source by SolarRevies: https://www.solarreviews.com/blog/behind-the-meter)

main reasons that C&I aggregator can fulfill customer needs and have opportunities through BESS.

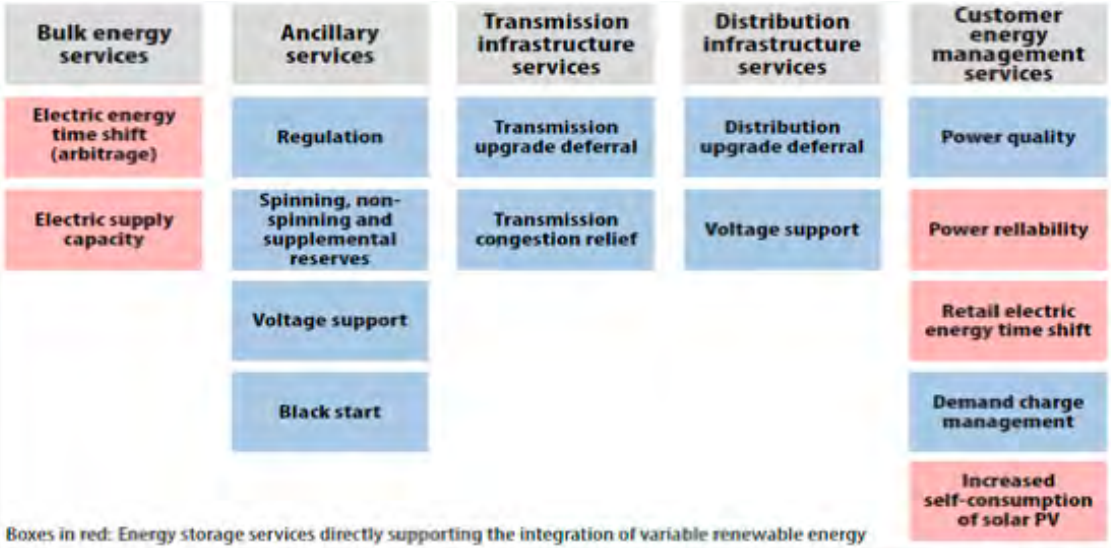


Figure 61. BESS Applications

- **Grid reliability and resiliency:** BESS provides enhanced flexibility and control over energy consumption, allowing C&I aggregators **to optimize their energy management strategies**[190] **and add efficiency**[191]. BESS can provide **backup power and help maintain grid stability** during peak demand periods or unexpected outages, making them an attractive solution for C&I customers.
- **Demand response and peak shaving**[192]**:** BESS enables C&I aggregators to participate in demand response programs more effectively. With the ability to rapidly respond to grid signals and adjust energy usage, C&I aggregators can offer valuable DR and Ancillary services to grid operators. This participation in programs can **provide additional revenue to clients and** C&I aggregators with strengthen their market position.
- **Renewable energy integration:** the increasing penetration of renewable energy sources, such as solar and wind, in the C&I sector creates intermittent energy generation patterns. BESS can help address this **intermittency by storing surplus renewable energy** and releasing it when needed, **improving grid reliability, and enabling a smoother integration of renewable resources**[193]. Especially, when its integrated into VPPs will create synergies for C&I aggregators.

The increasing adoption of BESS in the C&I sector in Texas is helping C&I aggregators expand by providing a more reliable and resilient power supply, integrating renewable energy sources, offering demand response and peak shaving services, and capitalizing on ancillary services opportunities in a favorable regulatory environment[194].

IRA Encourages Bottom-up Approach to Change ERCOT.

In August 2021, following the passage of the Inflation Reduction Act (IRA), has played a pivotal role in encouraging a bottom-up approach[195] within ERCOT. Previously, ERCOT primarily relied on centralized decision-making and control over the electricity market, which is “opaque and hard to scale up[196]". However, ERCOT started to change its structure by leveraging the IRA. It was driven by the growing demands of end customers for a resilient and reliable grid in the face of extreme weather events. These changes are by incentivizing end customers to actively participate in the energy market, the IRA has facilitated the bottom-up approach within ERCOT, empowering individual customers and enabling them to contribute to the stability and reliability of the grid. According to interviewee ‘A’ and Eric Van Orden, the Virtual Peaker's Director of Technology partnership, *IRA attracts residential and commercial customers such as upgrading their energy efficiency and purchasing EV cars. Therefore, market trends are changing* ***as more bottom-up approaches*** *that clients need increase for using the company’s technologies.* Additionally, as an expert in VPP technology Eric Van Orden also mentioned that “IRA leads the Deployment of renewable energy and electrification, and it is going to drive its needs in the markets overall.”

In accordance with EnergyTech, ERCOT has approved a pilot project[197], called the Aggregated Distributed Energy Resources (ADER)[198], aimed at assessing **the integration of aggregated distributed energy resources (DERs) into the ERCOT wholesale electricity market**. This authorization follows a directive from the Public Utilities Commission in Texas (PUCT)[199] to study the impact of DERs on the competitive grid market. The pilot project has the potential as the first VPP project to facilitate the inclusion of significant amounts of generation capacity, ranging from megawatts to potential gigawatts, from various sources such as rooftop solar installations, and residential and **commercial BESS**. According to the ERCOT, the initial participation capacity will be restricted to 80 MW of registered capacity and 40 MW of Non-Spinning Reserve Service (Non-Spin)[200]. This project aims to provide insights into the capabilities of aggregated DERs in terms of **reliability enhancement, wholesale market improvement, investment incentives, potential reduction in transmission and distribution investments, and improved load management during emergencies.** The pilot is anticipated to have a duration of three years[201].

In addition, the aggregators are moving fast to conduct the expansion of resource interconnection in the ERCOT VPP market since the pilot project is authorized. As one of the C&I aggregators AutoGrid that involved in the ADER project as 'ADER provider[201]' has been investing in advanced software platforms and control systems that can effectively manage the diverse array of generation assets within the VPP.

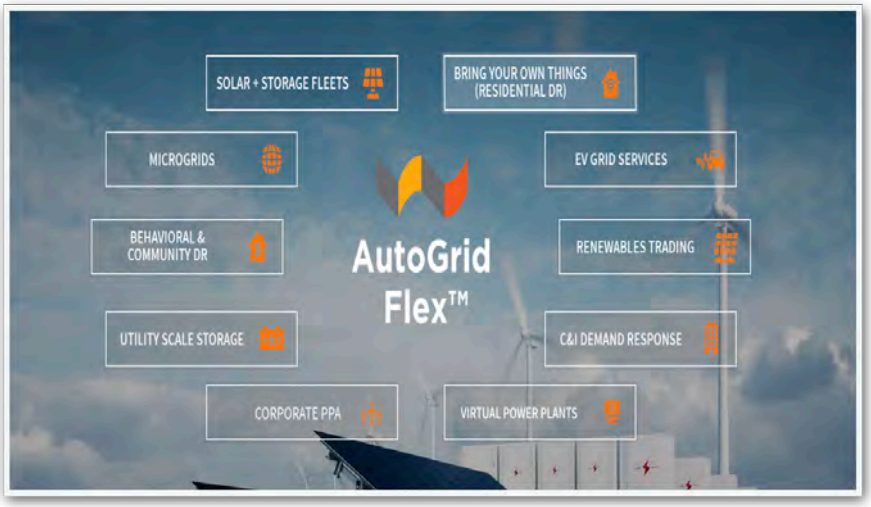


Figure 62. AutoGrid's service

AutoGrid Olaf Lohr who in charge of Business Development said, "IRA pushing the market more open. Also, participants' capacity is getting bigger, and an increasing number of new stakeholders entering to markets. **It helped to company have the VPP business model's confidence."**

These changes have been reluctant to embrace the bottom-up approach within ERCOT, as it required a significant shift in their traditional operations technically and systematically and decision-making processes to accept DERs. As it shown, although PUCT emphasized the need for the implementation of new ancillary services to strengthen reliability, ERCOT's staff response was **"the complexity of a major system upgrade may slow projects.**[202]**"** However, when it comes to extreme weather issues in summer again soon enough, which ERCOT grid reached the New peak demand record, PUCT decided to raise the budget add $25 million for Demand Response (ERS program) and it was effective immediately[203]. The combination of customer demands, investment provided by the IRA, and the need to address reliability concerns pushed ERCOT to embrace these changes and prepare for market expansion.

Especially, As IRA has triggered a bottom-up approach towards a significant shift within ERCOT, they recognized the need to adapt its structure to meet the increasing demands for a resilient grid. ***The bottom-up approach of IRA*** is incentivizing to have empowered individual customers to actively participate in the energy market, resulting in changing market trends and increased adoption of energy-efficient practices and technologies. These changes, coupled with the emphasis on implementing new ancillary services, demonstrate ERCOT's willingness to adapt to address reliability concerns and improve grid stability.

Potential Collaborations and Partnerships with Other Market Players

The Inflation Reduction Act (IRA) has the potential to foster collaborations and partnerships between other market players, particularly in the realm of Commercial and Industrial (C&I) aggregation. With the IRA incentivizing end customers to actively participate in the energy market, C&I aggregators can play a vital role in facilitating this engagement and maximizing the benefits for businesses. By working together, C&I aggregators can develop innovative business models, financial mechanisms, and market structures that incentivize C&I customers to actively participate in energy markets[204], such as DR, VPP pilots.

1. Collaboration with Real Estate

Real Estate is one of the key market players that can potentially collaborate and partner with the Inflation Reduction Act (IRA) [204] to capitalize on the opportunities presented by C&I aggregation. Real estate developers and property owners have a significant stake in energy consumption and cost management within their properties. By partnering with the C&I aggregators, real estate entities can optimize their energy usage, reduce costs, contribute to grid stability and as assets of VPP, can expect potential incentive as well.

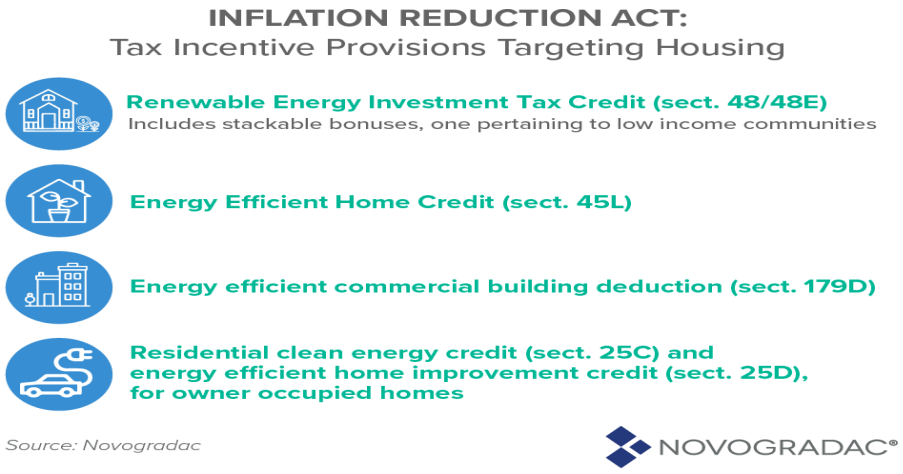


Figure 63. IRA targeting housing Tax incentive

One of the representative beneficial tax credits from IRA for commercial real estate encompasses various incentives aimed at **promoting energy efficiency and renewable energy adoption**. These tax credits provide financial support and incentives for commercial real estate entities to invest in sustainable practices and technologies. Some key tax credits available under the IRA for commercial real estate include:

1. *(179D) Energy Efficient Commercial Buildings Deduction*: This tax credit encourages commercial real estate owners to improve the energy efficiency of their buildings such as lighting, HVAC.[21] The standard deduction is up to a maximum $5.00 per square foot and it includes new and exist buildings, C&I customer who has their own building can expect to have investment for improving their buildings. By implementing energy-saving measures, commercial real estate entities can benefit from reduced energy costs and not only lower carbon footprints while enjoying tax incentives but also have premium for the building value. According to Calvert Research and Management, recently buildings with green certifications are ***often in higher demand and enjoy a rent premium***. The International law firm Vision&Elkins also have expectations of the energy transition opportunities and found the analysis that Green certification in real estate **yields a sales have a premium of 7.6% and a rent premium of 6.0%**[205] and "A survey conducted by JLL found that **63% of leading investors 'strongly agree' that green strategies** can drive higher occupancy, higher rents, higher tenant retention and overall higher value"

2. *Clean Energy Production & Investment Tax Credit*[206]: These credits are designed to extend the Production Tax Credit (PTC) and Investment Tax Credit (ITC) and are intended to be technology-neutral. It aims to encourage investment in clean energy generation and facilitate the transition to a more sustainable and environmentally friendly energy sector. According to NOVOCO consulting company, providing financial incentive which "with the **PTC at $26 per megawatt-hour** as adjusted by inflation annually and the **ITC at 30% of eligible costs** if they adhere to the labor requirements on prevailing wages and apprenticeship programs,"[207] is introduce new investors to the market. We expect that these tax credits incentivize commercial real estate entities to invest in clean energy production and renewable energy projects for the installation and operation of renewable energy systems, such as solar panels or wind turbines, on commercial properties.

3. *Renewable Energy in Rural Communities*[208]: To rural electrify, around $11 billion will invest for rural communities, which is the largest investment since 1936. This empowering program is enable for rural electric cooperatives to install renewables and technologies for zero-emission. As defined by Novoco[209], target Energy Community is "an area where a coal-fired power plant has closed since 2010, or a coal mine has closed since 2000; or a metropolitan or non-metropolitan statistical area where 0.17% or more direct employment, or at least 25% of local tax revenues, are related to extraction, processing, transport, or storage of coal, oil, or natural gas, and unemployment is at or above the national average in the previous year." As shown in Figure 64, surround Texas is the target for this fund and it expect to create rural regions to create renewable related jobs and real estate investment. [210]

[21] Heating, ventilation, and air conditioning https://www.trane.com/residential/en/resources/glossary/what-is-hvac/

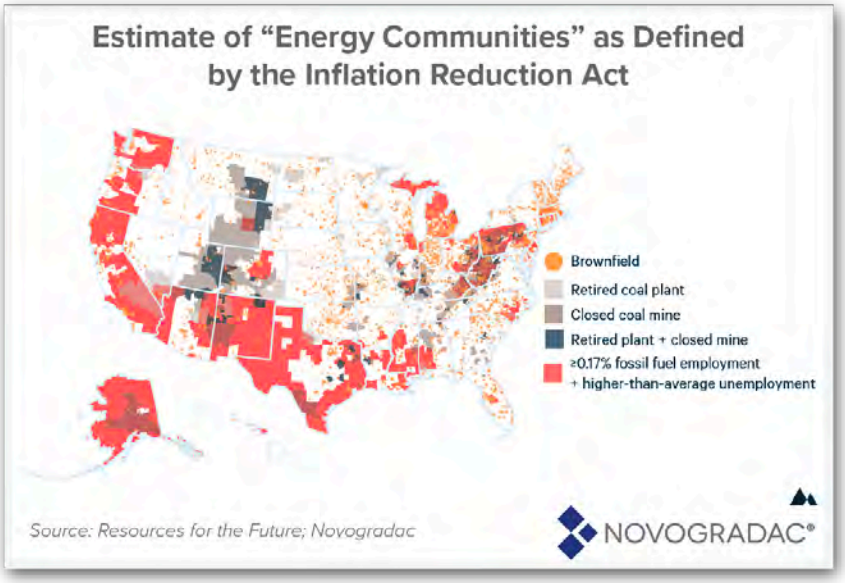


Figure 64. Estimate of "Energy Communities" area as defined by the IRA.

By leveraging these tax credits, the expansion of renewables and subsequently, increasing in the need for renewable energy solutions, leads to the creation of new potential partnerships and projects with commercial real estate entities. Partnerships with C&I aggregators can enable real estate entities to actively participate in demand response programs, which is not only enhance their sustainability profiles but also reduce operating costs while making additional incentives, increase property value, and attract environmentally conscious tenants.

2. *Partnership with OEM Company*

OEM (Original Equipment Manufacturer) companies have the opportunity to benefit from collaborations with Commercial and Industrial (C&I) aggregators by leveraging the IRA. By partnering with C&I aggregators, OEM companies can offer their energy-related equipment and technologies to help businesses optimize their energy usage and reduce costs. C&I aggregators can integrate OEM products into their aggregation platforms, enabling businesses to participate in demand response programs and energy management initiatives. This collaboration allows OEM companies to showcase their energy-efficient solutions and increase market penetration.

Figure 65. EnergyHub announced a collaboration with EVOCHARGE

The integration of EnergyHub and EvoCharge, as mentioned in the Utility Dive[211] press release, showcases how companies can collaborate to create innovative solutions in the energy and automotive sectors. It shows that OEMs partnering with electric vehicle (EV) charging infrastructure providers to expand the availability of charging stations while leveraging IRA's EV charger credits[212]. As with previous tax credits, the maximum amount for businesses installing EV chargers was capped at $30,000, applicable to projects finalized before the previous year's conclusion. However, with the implementation of the IRA, businesses completing EV charger installation projects after 2022 **can now benefit from an increased tax credit of up to $100,000 per EV charger,** representing a significant enhancement compared to the previous limit. Especially the collaboration with the DER aggregator and EV OEM company is one of the innovative partnerships to be competitive in the market.

3. *On-going Partnership Projects*

One of represents a significant step forward movement is the project from RMI (Rocky Mountain Institute) that launched **the 'Virtual Power Plant Partnership,' called VP3**[213], with over 10 industry members. These members are Ford, General Motors, Google Nest, OhmConnect, Olivine, SPAN, SunPower, Sunrun, SwitchDin, and Virtual Peaker. RMI states that the coordination of distributed energy resources through virtual power plants, which bring together individual energy resources to operate collectively, has the potential to decrease energy demand in the United States by approximately 200 GW by the year 2050.[214]

The collaboration between RMI, General Motors, and Google Nest demonstrates the potential for technology companies, automakers, and energy experts to work together in developing innovative solutions for the energy sector. By leveraging their respective expertise, these companies can create VPPs that optimize energy consumption, reduce greenhouse gas emissions, and contribute to a more resilient and sustainable energy grid.

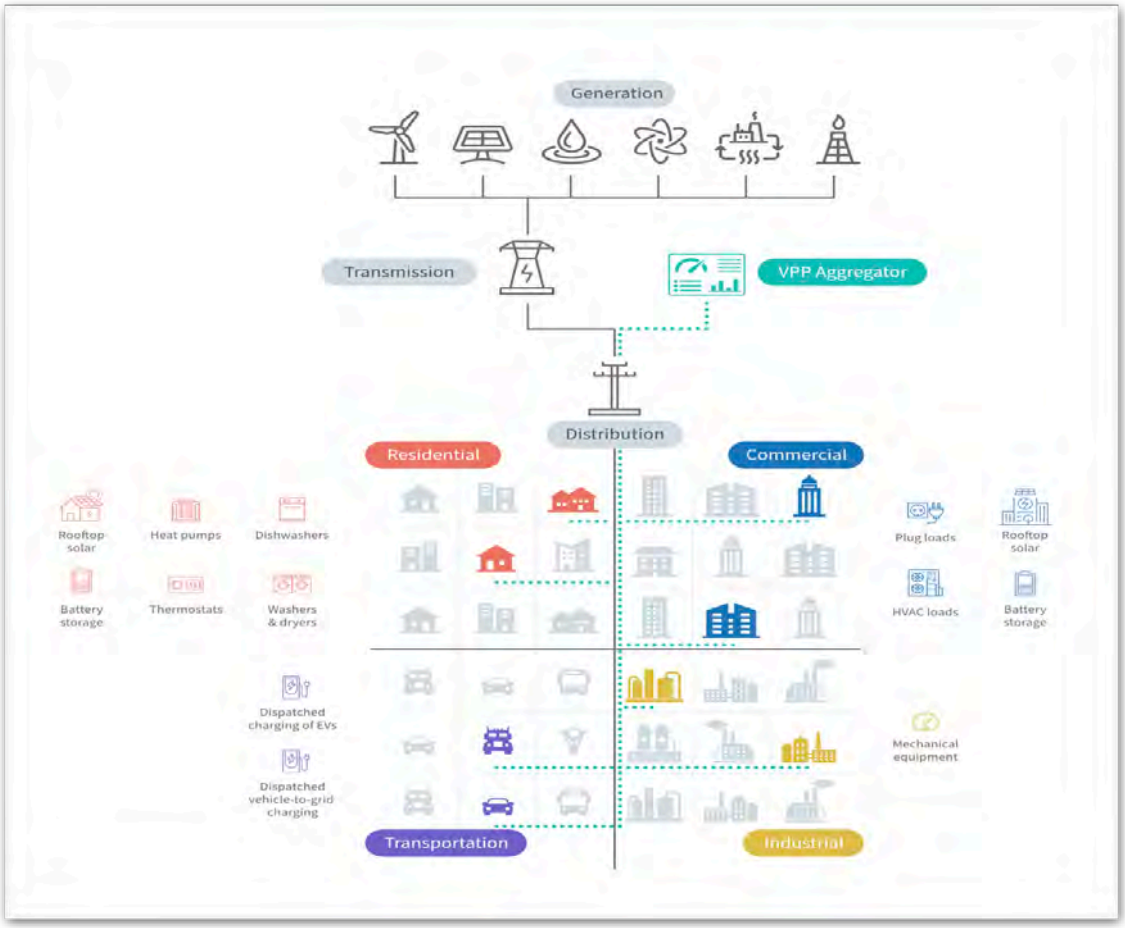


Figure 66. VP3 project overviews

As the project expands, market opportunities include the C&I aggregators business by enabling them to participate in demand response programs and provide grid services, such as load shifting and peak demand reduction with DERs. In the view of the Virtual Peaker's Director of Technology partnership Eric Van Orden is that "Virtual Peaker's development of making demand as controllable as a gas turbine generator for almost a decade. *Given the increased data analytics and load forecasting capabilities being built today, combined with years of experience with targeted device control/optimization (from batteries to EVs to thermostats and more), this concept is likely to become a reality in the next couple years*.

Because of the systematic nature of building a Virtual Power Plant (VPP), in addition to creating the technology, a broad shift in the utility/market mindset is necessary whereby utilization of DERs to support the grid is not only a customer program but a tool in the control room. For that reason, more than a dozen organizations, including Virtual Peaker, are collaborating through RMI's Virtual Power Plant Partnership (VP3) to align around the best practices and roadmaps with many stakeholders as well as identify supportive policies for VPPs." We anticipate that these partnerships will deliver the best practice of VPP that identifying optimal approaches and enlightening policymakers about the advantages of aggregating distributed resources.

Chapter 4. Conclusion

Texas has a rich historical significance as a state that has been instrumental in upholding the United States' position as a major global power in fossil fuels by the shale revolution. Unfortunately, as the trend changed, past heroes were changed to villains, and Texas became one of the biggest CO2 emitters in the United States. Requiring Texas to have to find ways to reduce their emissions to not get a penalty. The deeply entrenched fossil fuel-based industry, economy, and political structures pose considerable challenges to implementing an energy transition change. The Texas electricity market is mainly operated by ERCOT and PUCT's oversight. Demand Response (DR), which is one of the innovative ways to keep the grid reliably, **posing limitations for aggregators.** Limitation starts from **the vague definition of aggregators, limited market participation, limited participation capacity,** and even an oligopoly structure of Retail Electric Providers (REPs), creating a "glass wall," all creating substantial hurdles. In other words, although it is a deregulated market, it is **operated by main key players with partnerships the innovative movement has been slow.** No matter how slow, the recurring instances of extreme weather events in the 21st century, blackouts for days, and hundreds of people dying during the winter in Texas, have prompted the need for substantial changes. Furthermore, the increasing frequency of disastrous situations necessitated urgent actions and increased investments to support the state's resilience.

As if it were to answer Texas's situation, the IRA has emerged as a beacon of hope for Texas to invest in DERs such as PVs, Wind, and Battery Energy Storage System implementation. This is at a crucial juncture where it has the opportunity to initiate transformative changes with significant rewards, particularly by leveraging the Inflation Reduction Act (IRA). Considering urgency and size, the C&I sector was the perfect suit for the ERCOT situation. By leveraging the IRA, a faster and bigger installation of potential is now in the C&I sector. One of the effective renewable resources 'BESS,' has a high potential, but upfront costs made it slow implementation. However, since IRA implemented incentives to BESS, the C&I sector has been willing to invest for themselves to protect from blackout but also gain interest and revenue by market participation, which will lead to a more stable capacity for the grid. In Particular, the grid stability for ERCOT, the implementation of cost-effective and efficient measures such as Virtual Power Plants (VPP) in improving the grid infrastructure has been

identified as a key market-driven solution, especially for interviewees and aggregator business models, which have been positively influenced by the IRA helping aggregators.

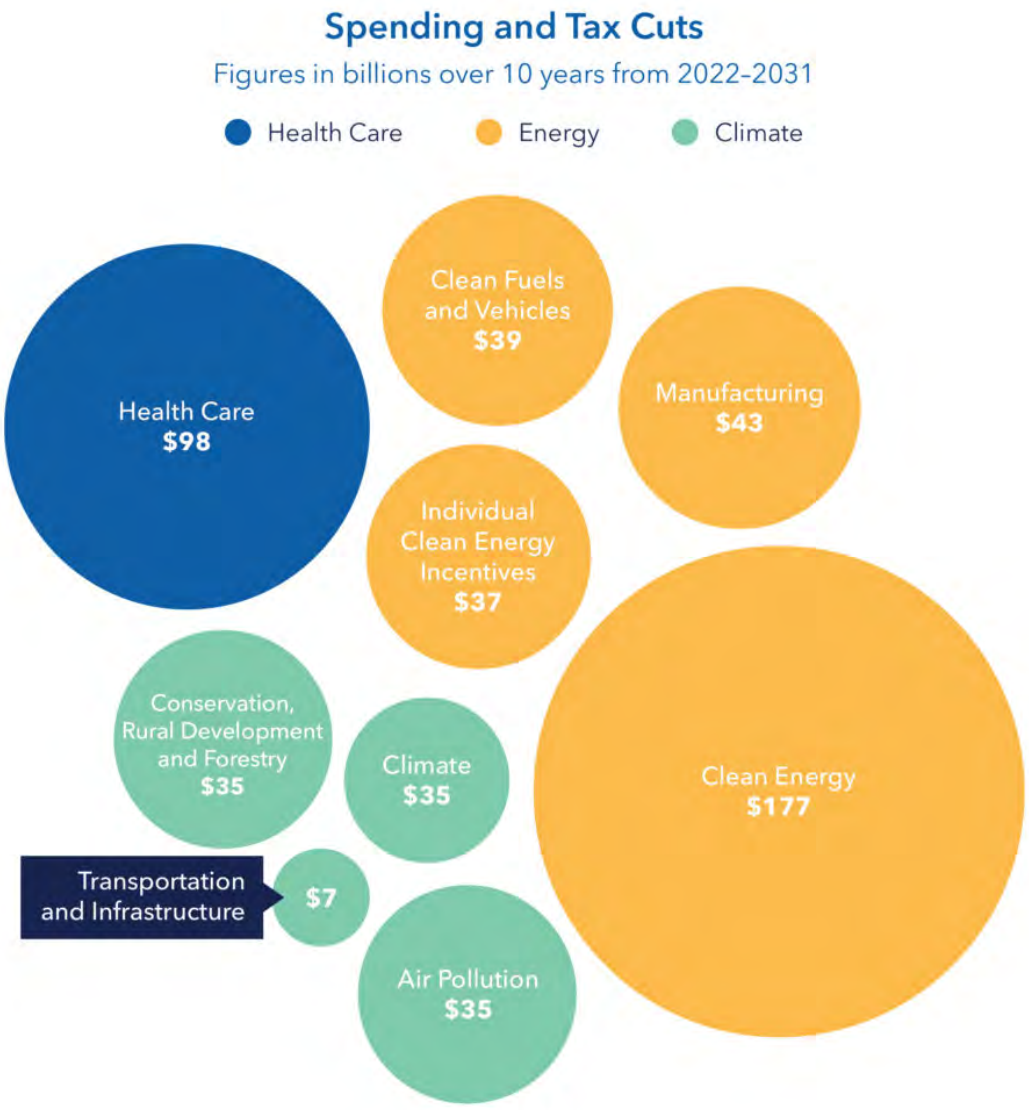
One of the biggest challenges for the C&I aggregators is discovered by stakeholder mapping. **High-influence actors have the lowest interest in the aggregator's wholesale market participation**, which leads to lags in the expansion of positive impact for the ERCOT grids. Also, the market structure led to the lowest interest of REPs in it because the aggregator's available participants' wholesale market is either non-dispatched or one or two-dispatched programs in a year. Therefore, aggregators as alternative options find partnerships with REPs to participate in other wholesale markets such as day-ahead or real-time markets. Although it has the capability to inject clean capacity into the market, ERCOT wasn't ready to accept diverse actors.

The best way to raise its potential is if ERCOT can utilize its unique isolated market structure. Since they already have experience in integrating other players into the market and do not need federal oversight, ERCOT has the potential to move faster than any other state to transition while using IRA investment. As it is, ERCOT has been actively modifying its market structure and initiating DER pilot projects to create a more open environment for aggregators. The participation of market entities like AutoGrid and VirtualPeaker has been on the rise. These changes lead to potential opportunities to create new business models and partnerships, such as VP3, which is a collaborative project with software and hardware that is "tapping VPP's true potential" while leveraging the IRA investment.

However, it is essential to acknowledge the limitations of this dissertation, particularly regarding the Inflation Reduction Act (IRA) and its relatively short period of activity within the industry. As the IRA has been in effect for less than a year, the full extent of its impact and effectiveness in driving significant changes within the industry is still emerging. While this research highlights the potential benefits and opportunities associated with leveraging the IRA, it is essential to recognize that the long-term outcomes and implications are yet to be fully realized. Future studies and analyses will be valuable in assessing the true impact of the IRA based on longitudinal research and its role in facilitating the desired transition towards a more sustainable energy sector by comparing it with other countries that have similar legislation or structures.

This thesis explores the challenges and opportunities for aggregators in the Commercial and Industrial (C&I) sector, aiming to accelerate the energy transition in Texas. It aims to enhance grid stability in ERCOT and stimulate increased investment; it is crucial to prioritize the encouragement of aggregators in the market and provide incentives for active C&I participation. By leveraging the expertise resources of aggregators and fostering C&I engagement, Texas can pave the way for a successful energy transition while ensuring a more resilient and sustainable future. *Texas can demonstrate its ability to swiftly respond and effectively diversify resources in the market by leveraging the Inflation Reduction Act (IRA) to accelerate the role of aggregators and encourage the adoption of Virtual Power Plants (VPP) in the ERCOT market.* Quoting PUC chair Peter Lake's sentiment, ***"We adore working with our federal partners, but Texas can move fast and do it right when something goes wrong."*** **Now is the opportune moment for Texas to demonstrate its agility and capability to swiftly diversify resources in the market and accelerate the role of aggregators, particularly in encouraging the implementation of Virtual Power Plants (VPP) in the ERCOT market.** By actively involving VPPs in the electricity market, Texas can showcase its ability to adapt and respond effectively to challenges while fostering a more resilient and sustainable energy ecosystem.

Appendix1. Understanding how much IRA spending and tax cut by sector [215]



Appendix 2. “Discovering the Truth About C&I Power Reliability” [96]

Chart 1: U.S. C&I Outage Frequency, by Industry, 2017

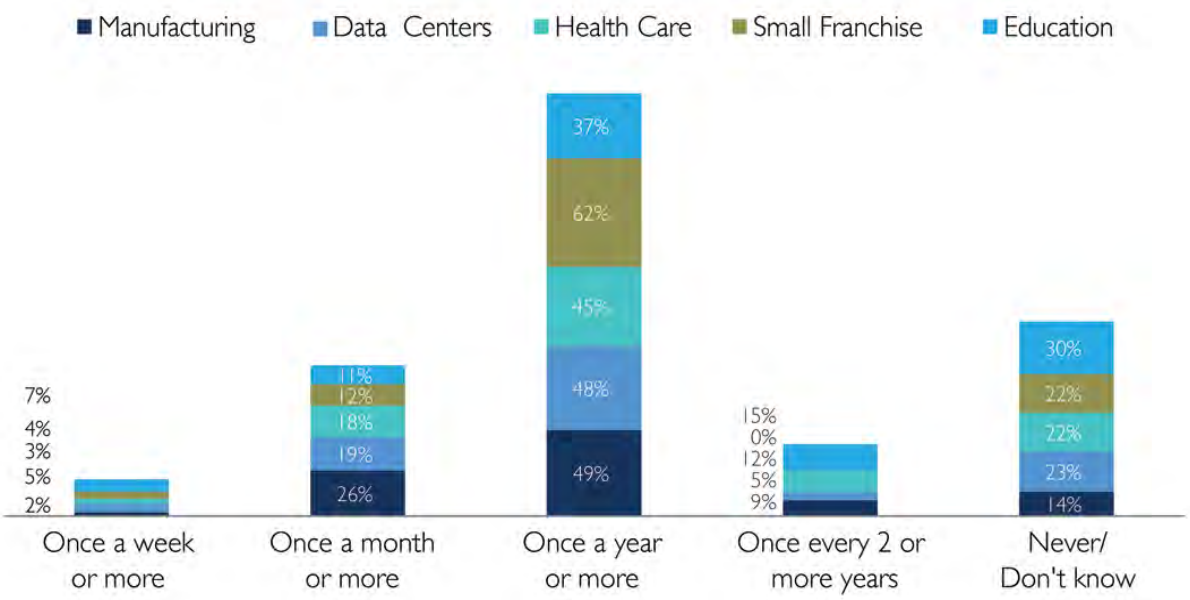


Chart 2: U.S. C&I Impacts because of Power Outages, 2017

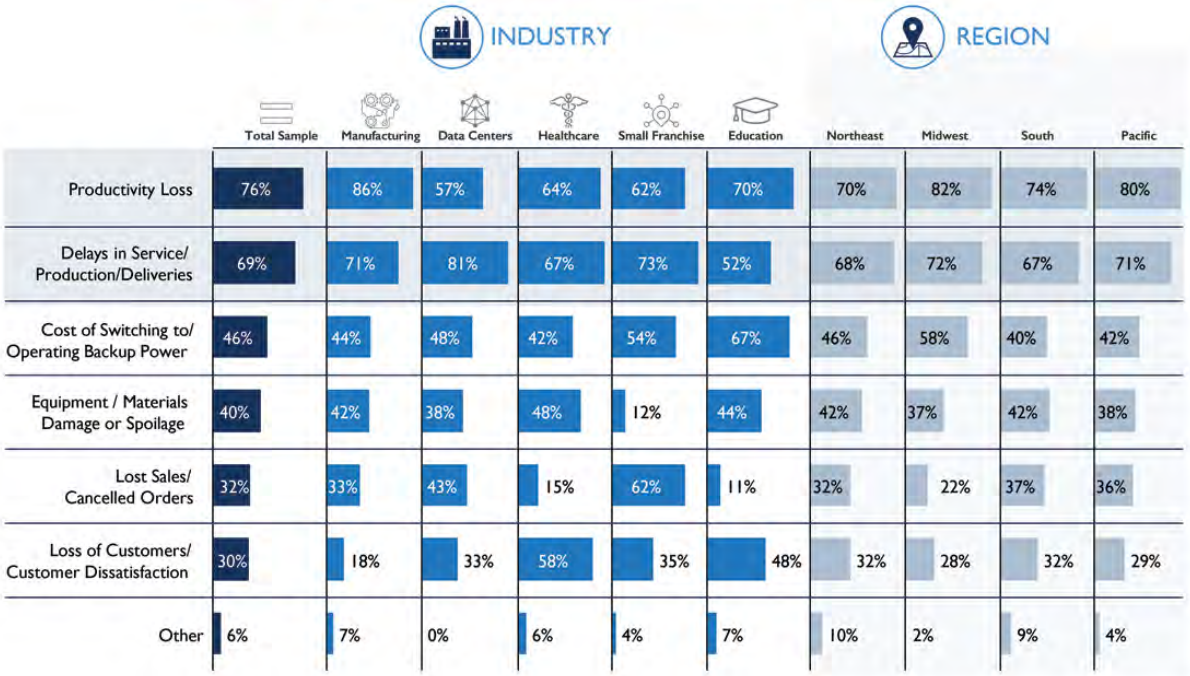
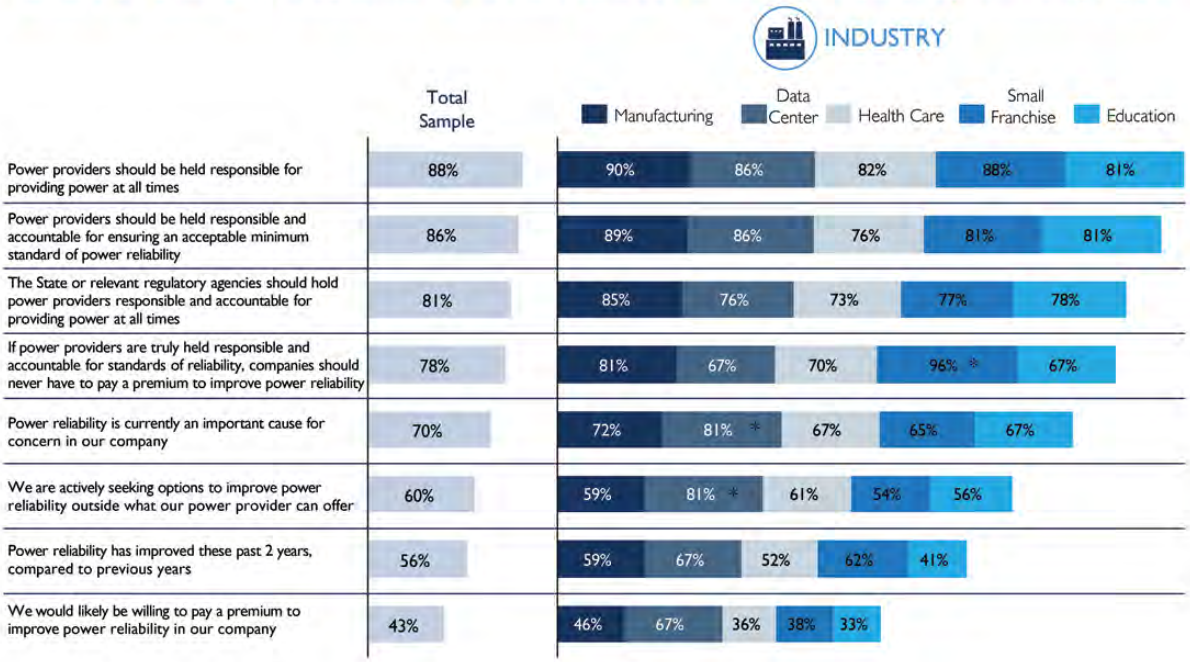


Chart 3: U.S. C&I Customer's Review about Power Providers, by Industry, 2017



References

[1] H. Ritchie, M. Roser, and P. Rosado, "CO_2 and Greenhouse Gas Emissions," *Our World Data*, May 2020, Accessed: Jun. 13, 2023. [Online]. Available: https://ourworldindata.org/co2/country/united-states

[2] "National Climate Task Force," *The White House*. https://www.whitehouse.gov/climate/ (accessed Jun. 12, 2023).

[3] D. Lashof, "Tracking Progress: Climate Action Under the Biden Administration," Jan. 2023, Accessed: Jun. 13, 2023. [Online]. Available: https://www.wri.org/insights/biden-administration-tracking-climate-action-progress

[4] J. Kerry, "The Long-Term Strategy of the United States, Pathways to Net-Zero Greenhouse Gas Emissions by 2050".

[5] T. W. House, "Fact Sheet: The Bipartisan Infrastructure Deal," *The White House*, Nov. 06, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/ (accessed Jun. 13, 2023).

[6] T. W. House, "UPDATED FACT SHEET: Bipartisan Infrastructure Investment and Jobs Act," *The White House*, Aug. 03, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/02/updated-fact-sheet-bipartisan-infrastructure-investment-and-jobs-act/ (accessed Jun. 13, 2023).

[7] U. S. C. Staff, "Here, we share the facts and debunk the fallacies about the Infrastructure Investment and Jobs Act.," Nov. 10, 2021. https://www.uschamber.com/infrastructure/the-bipartisan-infrastructure-bill-fact-vs-fallacy (accessed Jun. 13, 2023).

[8] "Piano • Client Dashboard." https://o.prod.theintercept.com/checkout/template/cacheableShow?aid=hsZyoAWmIE&templateId=OTPC8O14X6I8&templateVariantId=OTV6XFN1QEP5P&offerId=fakeOfferId&experienceId=EXPMJTQ5XJIA&iframeId=offer_78c579f134e0413a9669-0&displayMode=inline&pianoIdUrl=https%3A%2F%2Fid.tinypass.com%2Fid%2F&widget=template&url=https%3A%2F%2Ftheintercept.com (accessed Jun. 13, 2023).

[9] "Inflation Reduction Act Guidebook | Clean Energy," *The White House*. https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/ (accessed Jun. 12, 2023).

[10] M. F. Akorede, H. Hizam, and E. Pouresmaeil, "Distributed energy resources and benefits to the environment," *Renew. Sustain. Energy Rev.*, vol. 14, no. 2, pp. 724–734, Feb. 2010, doi: 10.1016/j.rser.2009.10.025.

[11] T. W. House, "BY THE NUMBERS: The Inflation Reduction Act," *The White House*, Aug. 15, 2022. https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/15/by-the-numbers-the-inflation-reduction-act/ (accessed Jun. 15, 2023).

[12] "How the Inflation Reduction Act Will Help the United States to Lead in the Clean Energy Economy," *Council on Foreign Relations*. https://www.cfr.org/blog/how-inflation-reduction-act-will-help-united-states-lead-clean-energy-economy (accessed Jun. 15, 2023).

[13] "What Businesses, Communities and Workers Gain from the IRA," Dec. 06, 2022. https://www.enelnorthamerica.com/insights/blogs/impact-of-inflation-reduction-act (accessed Jun. 15, 2023).

[14] "Energy Facts: Impact of the Investing in America Agenda on Texas," *Energy.gov*. https://www.energy.gov/articles/energy-facts-impact-investing-america-agenda-texas (accessed Jun. 15, 2023).

[15] M. P. News Inside Climate, "Texas environmentalists push the EPA to crack down on methane emissions, saying state agencies have 'failed us,'" *The Texas Tribune*, Jan. 25, 2023. https://www.texastribune.org/2023/01/25/texas-epa-methane-rule-public-comment-tceq/ (accessed Jun. 15, 2023).

[16] "Yes, Texas' Deregulated Electricity Market Has Problems, but It Can (and Should) Be Fixed," *POWER Magazine*. https://www.powermag.com/blog/yes-texas-deregulated-electricity-market-has-problems-but-it-can-and-should-be-fixed/ (accessed Jun. 15, 2023).

[17] "The Inflation Reduction Act - Texas Impact." https://texasimpact.org/the-inflation-reduction-act/ (accessed Jun. 15, 2023).
[18] A. Kennedy, "Mapped: Renewable Energy and Battery Installations in the U.S. in 2023," *Visual Capitalist*, May 30, 2023. https://www.visualcapitalist.com/mapped-renewable-energy-and-battery-installations-in-the-u-s-in-2023/ (accessed Jun. 13, 2023).
[19] J. Robertson, "U.S. States Ranked by Carbon Dioxide Emissions per Capita - Solar Power Guide - Infographic." https://solarpower.guide/solar-energy-insights/states-ranked-carbon-dioxide-emissions (accessed Jun. 15, 2023).
[20] G. Harman, "Texas Ranks Among Most Climate Vulnerable Areas on Earth," *Deceleration*, Feb. 21, 2023. https://deceleration.news/2023/02/21/texas-climate-risk-data/ (accessed Jun. 16, 2023).
[21] "Texas electricity demand hits record high as heat wave continues," *Austin American-Statesman*. https://www.statesman.com/story/business/2022/07/06/texas-power-grid-electricity-demand-hits-record-high/65368086007/ (accessed Jun. 16, 2023).
[22] "Texas electrical grid remains vulnerable to extreme weather events." https://www.dallasfed.org/research/economics/2023/0117 (accessed Jun. 16, 2023).
[23] J. Ramach, "3 Crazy Facts About Texas Energy Production," *ElectricityRates.com*, Jan. 26, 2021. https://electricityrates.com/how-to-compare/energy-choice-blog/3-crazy-facts-about-texas-energy-production/ (accessed Jun. 13, 2023).
[24] "The Inflation Reduction Act Could Supercharge Solar and the Right Partner can Maximize Your Benefits," *Empower Energies*. https://www.empowerenergies.com/blog/inflation-reduction-act-maximize-benefits (accessed Jun. 16, 2023).
[25] "Aggregators – Innovation Landscape Brief," 2019.
[26] O. Okur, P. Heijnen, and Z. Lukszo, "Aggregator's Business Models: Challenges Faced by Different Roles," in *2020 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe)*, The Hague, Netherlands: IEEE, Oct. 2020, pp. 484–488. doi: 10.1109/ISGT-Europe47291.2020.9248707.
[27] "Texas grid operators are plugging into virtual power plants," *Emerging Tech Brew*. https://www.emergingtechbrew.com/stories/2022/08/15/texas-grid-operators-are-plugging-into-virtual-power-plants (accessed Jun. 16, 2023).
[28] R. Hledik, "Real Reliability: The Value of Virtual Power".
[29] J. Engel, "Study finds virtual power plants could provide resource adequacy and save utilities billions," *Renewable Energy World*, May 04, 2023. https://www.renewableenergyworld.com/solar/der-solar/study-finds-virtual-power-plants-could-provide-resource-adequacy-and-save-utilities-billions/ (accessed Jun. 16, 2023).
[30] S. P. A. Brown, "The Shale Gas and Tight Oil Boom: U.S. States' Economic Gains and Vulnerabilities," pp. 2–7p, Oct. 2013.
[31] "Study: Hydraulic Fracturing Is 'Game-Changer' for U.S. Economy – The Heartland Institute." https://heartland.org/opinion/study-hydraulic-fracturing-is-game-changer-for-us-economy/ (accessed Jun. 12, 2023).
[32] S. P. A. Brown, "The Shale Gas and Tight Oil Boom: U.S. States' Economic Gains and Vulnerabilities".
[33] J. W. Busby *et al.*, "Cascading risks: Understanding the 2021 winter blackout in Texas," *Energy Res. Soc. Sci.*, vol. 77, p. 102106, Jul. 2021, doi: 10.1016/j.erss.2021.102106.
[34] "The US Coal Industry in the Nineteenth Century." https://eh.net/encyclopedia/the-us-coal-industry-in-the-nineteenth-century-2/ (accessed Jun. 12, 2023).
[35] "The history of energy in the United States | National Grid Group." https://www.nationalgrid.com/stories/energy-explained/history-energy-united-states (accessed Jun. 12, 2023).
[36] "U.S. natural gas storage capacity increased slightly in 2016." https://www.eia.gov/todayinenergy/detail.php?id=30632 (accessed Jun. 12, 2023).
[37] C. Baraniuk, "Why the US hides 700 million barrels of oil underground." https://www.bbc.com/future/article/20150921-why-the-us-hides-700-million-barrels-of-oil-underground (accessed Jun. 12, 2023).
[38] "Six U.S. states accounted for over half of the primary energy produced in 2019." https://www.eia.gov/todayinenergy/detail.php?id=49356 (accessed Jun. 12, 2023).
[39] B. Wells, "First Texas Oil Boom," *American Oil & Gas Historical Society*, Jun. 02, 2023.

https://aoghs.org/petroleum-pioneers/texas-oil-boom-in-corsicana/ (accessed Jun. 12, 2023).
[40] "Spindletop: The Gusher That Launched The Oil Industry." https://www.amusingplanet.com/2021/01/spindletop-gusher-that-launched-oil.html (accessed Jun. 12, 2023).
[41] C. Hernandez, "Texas History: The discovery at Spindletop that changed the oil industry forever," *KPRC*, Mar. 31, 2020. https://www.click2houston.com/houston-life/2020/03/31/texas-history-the-discovery-at-spindletop-that-changed-the-oil-industry-forever/ (accessed Jun. 12, 2023).
[42] "Texas." https://www.universalroyaltyco.com/resources/texas-oil-gas-royalties/ (accessed Jun. 12, 2023).
[43] "Natural gas pipelines - U.S. Energy Information Administration (EIA)." https://www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php (accessed Jun. 12, 2023).
[44] "Texas Energy Sector: Past and Future." Accessed: Jun. 12, 2023. [Online]. Available: https://ctr.utexas.edu/wp-content/uploads/pubs/0_6513_1B.pdf
[45] "Once-Oil-Dependent Texas Economy to Keep Growing as Renewable Energy Expands - Dallasfed.org." https://www.dallasfed.org/research/swe/2021/swe2103/swe2103b (accessed Jun. 12, 2023).
[46] "History of Oil Discoveries in Texas | TX Almanac." https://www.texasalmanac.com/articles/history-of-oil-discoveries-in-texas (accessed Jun. 12, 2023).
[47] "TSHA | Oil and Gas Industry." https://www.tshaonline.org/handbook/entries/oil-and-gas-industry (accessed Jun. 12, 2023).
[48] E. Ridlington, F. Group, J. Rumpler, E. A. Research, and P. Center, "Fracking by the Numbers".
[49] P. David, "Clio and the economics of QWERTY," *Am. Econ. Rev.*, vol. 75, pp. 332–7, May 1985.
[50] W. B. Arthur, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *Econ. J.*, vol. 99, no. 394, pp. 116–131, Mar. 1989, doi: 10.2307/2234208.
[51] "Path dependence | Definition & Facts | Britannica." https://www.britannica.com/topic/path-dependence (accessed Jun. 12, 2023).
[52] C. S. Leonard, "Path Dependence, its critics, and the quest for 'historical economics'".
[53] J. R. Sydow, G. S. Gg, and J. Koch, "ORGANIZATIONAL PATH DEPENDENCE: OPENING THE BLACK BOX," *Acad. Manage. Rev.*, 2009.
[54] "Shaping the Political Arena: Critical Junctures, the Labor Movement, and Regime Dynamics in Latin America on JSTOR." https://www.jstor.org/stable/j.ctvpj74pj (accessed Jun. 12, 2023).
[55] "Oil and Gas Map of Texas 2018.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://www.beg.utexas.edu/files/content/beg/research/starr/Oil%20and%20Gas%20Map%20of%20Texas%202018.pdf
[56] W. Arthur, *Increasing Returns and Path Dependence in the Economy*. Ann Arbor, MI: University of Michigan Press, 1994. doi: 10.3998/mpub.10029.
[57] P. S. and M. Ferman, "Texas Democrats try to convince voters they aren't bad for oil and gas," *The Texas Tribune*, Sep. 27, 2022. https://www.texastribune.org/2022/09/27/texas-democrats-oil-gas/ (accessed Jun. 12, 2023).
[58] "Economic Benefits," *Texas Oil & Gas Association*. https://www.txoga.org/our-industry/economic-benefits/ (accessed Jun. 12, 2023).
[59] "Connecting Past and Future: A History of Texas' Isolated Power Grid," *Baker Institute*. https://www.bakerinstitute.org/research/connecting-past-and-future-history-texas-isolated-power-grid (accessed Jun. 12, 2023).
[60] R. Oxner, "Texas could connect to national power grids without losing autonomy, former grid regulator says," *The Texas Tribune*, Feb. 15, 2022. https://www.texastribune.org/2022/02/14/texas-national-power-grids/ (accessed Jun. 12, 2023).
[61] "$9,000 power bill during Texas blackout prompts class-action lawsuit," Feb. 26, 2021. https://www.cbsnews.com/news/texas-power-outage-griddy-lawsuit-electricity-bills-2021-03-26/ (accessed Jun. 12, 2023).
[62] "2021-State-of-the-Market-Report.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://www.potomaceconomics.com/wp-content/uploads/2022/05/2021-State-of-the-Market-

Report.pdf
[63] "2021UPDATE_Climate-ExecutiveSummary-Flyer.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://climatexas.tamu.edu/files/2021UPDATE_Climate-ExecutiveSummary-Flyer.pdf#climatexas.tamu.edu:%20/files/2021UPDATE_Climate-ExecutiveSummary-Flyer.pdf
[64] E. D. and M. Ferman, "Texas Legislature approves bills to require power plants to 'weatherize,' among other measures to overhaul electric grid," *The Texas Tribune*, May 27, 2021. https://www.texastribune.org/2021/05/26/texas-power-grid-reform-legislature/ (accessed Jun. 12, 2023).
[65] "Final Report on February 2021 Freeze Underscores Winterization Recommendations | Federal Energy Regulatory Commission." https://www.ferc.gov/news-events/news/final-report-february-2021-freeze-underscores-winterization-recommendations (accessed Jun. 12, 2023).
[66] "A year after widespread blackouts, Texas grid prepares for looming winter freeze," *Utility Dive*. https://www.utilitydive.com/news/a-year-after-widespread-blackouts-texas-grid-prepares-for-looming-winter-f/618081/ (accessed Jun. 12, 2023).
[67] S. Littlechild and L. Kiesling, "Hayek and the Texas blackout," Energy Policy Research Group, University of Cambridge, 2021. Accessed: Jun. 12, 2023. [Online]. Available: https://www.jstor.org/stable/resrep34137
[68] "The February 2021 Cold Weather Outages in Texas and the South Central United States | FERC, NERC and Regional Entity Staff Report | Federal Energy Regulatory Commission." https://www.ferc.gov/media/february-2021-cold-weather-outages-texas-and-south-central-united-states-ferc-nerc-and (accessed Jun. 12, 2023).
[69] "ENERGY EFFICIENCY AND DEMAND-RESPONSE: TOOLS TO ADDRESS TEXAS' RELIABILITY CHALLENGES: SUMMARY.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://www.aceee.org/sites/default/files/pdfs/b2302_-_encrypt_1_1.pdf
[70] "Efficiency, demand response could cut Texas winter peak loads 23.5 GW, save billions over new gas: ACEEE," *Utility Dive*. https://www.utilitydive.com/news/efficiency-demand-response-cut-texas-winter-peak-loads-ACEEE/650155/ (accessed Jun. 12, 2023).
[71] J. Zarnikau, "Demand participation in the restructured Electric Reliability Council of Texas market," *Energy*, vol. 35, pp. 1536–1543, Apr. 2010, doi: 10.1016/j.energy.2009.03.018.
[72] "The Great Northeast Blackout," *HISTORY*. https://www.history.com/this-day-in-history/the-great-northeast-blackout (accessed Jun. 12, 2023).
[73] "NERCHistoryBook.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://www.nerc.com/AboutNERC/Resource%20Documents/NERCHistoryBook.pdf
[74] K. Galbraith, "Texplainer: Why does Texas have its own power grid?," *The Texas Tribune*, Feb. 08, 2011. https://www.texastribune.org/2011/02/08/texplainer-why-does-texas-have-its-own-power-grid/ (accessed Jun. 12, 2023).
[75] "Just Who Is ERCOT? - Reform Austin." https://www.reformaustin.org/disasters/just-who-is-ercot/ (accessed Jun. 12, 2023).
[76] A. Energy, "Energy Deregulation in Texas: A Complete Guide for Beginners," *Amigo Energy*, Aug. 15, 2022. https://amigoenergy.com/blog/energy-deregulation-in-texas-guide-for-beginners/ (accessed Jun. 12, 2023).
[77] "Background Document: An Overview of PUCs for State Environment and Energy Officials," 2010.
[78] W.-J. Lee, F. L. Quilumba, J. Shi, and S.-H. Huang, "Demand response — An assessment of load participation in the ERCOT nodal market," in *2012 IEEE Power and Energy Society General Meeting*, Jul. 2012, pp. 1–10. doi: 10.1109/PESGM.2012.6344981.
[79] "Deregulated Cities & Electric Coops in Texas Map | Energy Ogre." https://www.energyogre.com/ (accessed Jun. 12, 2023).
[80] "renewables-portfolio-standard-renewables-portfolio-standard.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://www.energy.gov/oe/articles/renewables-portfolio-standard-renewables-portfolio-standard
[81] R. Wiser and O. Langniss, "The Renewables Portfolio Standard in Texas: An Early Assessment".
[82] "THE-STORY-OF-ERCOT.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://tcaptx.com/downloads/THE-STORY-OF-ERCOT.pdf

[83] M. H. Albadi and E. F. El-Saadany, "A summary of demand response in electricity markets," *Electr. Power Syst. Res.*, vol. 78, no. 11, pp. 1989–1996, Nov. 2008, doi: 10.1016/j.epsr.2008.04.002.
[84] "Demand-side management programs save energy and reduce peak demand." https://www.eia.gov/todayinenergy/detail.php?id=38872 (accessed Jun. 13, 2023).
[85] "Commercial and Industrial Demand Response and Flexibility Markets." https://guidehouseinsights.com/reports/Commercial-and-Industrial-Demand-Response-and-Flexibility-Markets (accessed Jun. 13, 2023).
[86] "ERCOT MARKET EDUCATION - ppt download." https://slideplayer.com/slide/12023817/ (accessed Jun. 13, 2023).
[87] "Alphabetical Directory of Retail Electric Providers." https://www.puc.texas.gov/industry/electric/directories/rep/alpha_rep.aspx (accessed Jun. 13, 2023).
[88] "2019_Utility_Demand_Response_Market_Snapshot.pdf."
[89] "ERCOT Annual Report 2017_Demand_Response." m http://www.ercot.com/content/wcm/lists/94805/2017_Annual_Report_of_Demand_Response_in_the_ERCOT_Region.docx (accessed Jun. 12, 2023).
[90] "Demand response saves electricity during times of high demand." https://www.eia.gov/todayinenergy/detail.php?id=24872 (accessed Jun. 13, 2023).
[91] Sponsor, "C&I opportunities in demand response and value stacking," *PV Tech*, Mar. 30, 2020. https://www.pv-tech.org/ci-opportunities-in-demand-response-and-value-stacking/ (accessed Jun. 13, 2023).
[92] "C&I demand response growth is slowing, but more opportunities could emerge from the utility sector," *Utility Dive*. https://www.utilitydive.com/news/ci-demand-response-growth-is-slowing-but-more-opportunities-could-emerge/421532/ (accessed Jun. 13, 2023).
[93] "EnergyHub commercial and industrial fact sheet.pdf." Accessed: Jun. 13, 2023. [Online]. Available: https://cdn2.hubspot.net/hubfs/415845/Fact%20sheets/EnergyHub%20commercial%20and%20industrial%20fact%20sheet.pdf
[94] "Press Release | Commercial and Industrial Demand Response and Flexibility Markets Estimated to Grow to 268 GW in 2031 at a Compound Annual Growth Rate of 15%." https://guidehouseinsights.com/news-and-views/commercial-and-industrial-demand-response-and-flexibility-markets-estimated-to-grow-to-268-gw-in-203 (accessed Jun. 13, 2023).
[95] "2019 US Average Electricity Retail Prices." Accessed: Jun. 16, 2023. [Online]. Available: https://www.globalenergyinstitute.org/sites/default/files/2021-03/023955_gei_electricitypricemap_handout_2019_2pages.pdf
[96] "Discovering the Truth About C&I Power Reliability," *Electric Energy Online*. https://electricenergyonline.com/energy/magazine/1145/article/Discovering-the-Truth-About-C-I-Power-Reliability.htm (accessed Jun. 13, 2023).
[97] "The Importance of VPPs to Support America's Energy Resilience | SEIA." https://www.seia.org/blog/importance-vpps-support-americas-energy-resilience (accessed Jun. 16, 2023).
[98] "Virtual Power Plants: Running renewable energy in the cloud," *Western Power*, Dec. 01, 2021. https://www.westernpower.com.au/community/news-opinion/virtual-power-plants-running-renewable-energy-in-the-cloud/ (accessed Jun. 16, 2023).
[99] "Salesforce." https://c40.my.salesforce.com/sfc/p/#36000001Enhz/a/1Q000000ggm5/R0tppOcJtJz8JRz_FJJEpoqEAVvF7O3zEMtCyi6z09E (accessed Jun. 15, 2023).
[100] O. US EPA, "Summary of Inflation Reduction Act provisions related to renewable energy," Nov. 21, 2022. https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy (accessed Jun. 16, 2023).
[101] "A Congressional Climate Breakthrough," *Rhodium Group*. https://rhg.com/research/inflation-reduction-act/ (accessed Jun. 16, 2023).
[102] D. Gearino, "Texas could benefit from Inflation Reduction Act's 'layer cake' of clean energy tax breaks," *San Antonio Express-News*, May 26, 2023. https://www.expressnews.com/business/article/inflation-reduction-act-energy-communities-texas-18097708.php (accessed Jun. 16, 2023).

[103] "IRA sets the stage for US energy storage to thrive | Utility Dive." https://www.utilitydive.com/spons/ira-sets-the-stage-for-us-energy-storage-to-thrive/635665/ (accessed Jun. 16, 2023).
[104] "Energy storage wins a long-sought victory with Inflation Reduction Act," *Canary Media*, Aug. 12, 2022. https://www.canarymedia.com/articles/energy-storage/energy-storage-would-win-long-sought-victory-with-inflation-reduction-act (accessed Jun. 16, 2023).
[105] "IRA EV Tax Credits: Requirements for Domestic Manufacturing | Bipartisan Policy Center." https://bipartisanpolicy.org/blog/ira-ev-tax-credits/ (accessed Jun. 16, 2023).
[106] "Financing standalone battery storage: the Inflation Reduction Act unlocks the tax equity investor," *Financier Worldwide*. https://www.financierworldwide.com/financing-standalone-battery-storage-the-inflation-reduction-act-unlocks-the-tax-equity-investor (accessed Jun. 16, 2023).
[107] "Clean Energy Tax Credits Get a Boost in New Climate Law | Article | EESI." https://www.eesi.org/articles/view/clean-energy-tax-credits-get-a-boost-in-new-climate-law (accessed Jun. 16, 2023).
[108] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." https://www.eia.gov/state/rankings/?sid=TX (accessed Jun. 16, 2023).
[109] N. Conte, "Mapped: U.S. Wind Electricity Generation by State," *Visual Capitalist*, Apr. 14, 2022. https://www.visualcapitalist.com/mapped-u-s-wind-electricity-generation-by-state/ (accessed Jun. 16, 2023).
[110] "More than half of new U.S. electric-generating capacity in 2023 will be solar." https://www.eia.gov/todayinenergy/detail.php?id=55419 (accessed Jun. 16, 2023).
[111] https://www.oilandgaslawyerblog.com/author/jmcfarland1, "Inflation Reduction Act Tackles Methane Emissions," *Oil and Gas Lawyer Blog*, Aug. 08, 2022. https://www.oilandgaslawyerblog.com/inflation-reduction-act-tackles-methane-emissions/ (accessed Jun. 16, 2023).
[112] "IRA is Huge Boon for States in Energy, Jobs, Health | Climate Denial Crock of the Week." https://climatecrocks.com/2023/02/13/ira-is-huge-boon-for-states-in-energy-jobs-health/ (accessed Jun. 16, 2023).
[113] "Small-Business-Economic-Profile-TX.pdf." Accessed: Jun. 16, 2023. [Online]. Available: https://advocacy.sba.gov/wp-content/uploads/2022/08/Small-Business-Economic-Profile-TX.pdf
[114] "Texas.pdf." Accessed: Jun. 16, 2023. [Online]. Available: https://www.whitehouse.gov/wp-content/uploads/2022/08/Texas.pdf
[115] P. Ecology, "Methane pricing in the US Inflation Reduction Act." https://processecology.com/articles/the-introduction-of-methane-pricing-in-the-us-inflation-reduction-act (accessed Jun. 16, 2023).
[116] O. US EPA, "Greenhouse Gas Reporting Program (GHGRP)," Jun. 10, 2014. https://www.epa.gov/ghgreporting (accessed Jun. 16, 2023).
[117] "Guidehouse Guide to the Inflation Reduction Act for Energy Providers." https://guidehouse.com/insights/energy/2022/guidehouse-guide-to-the-inflation-reduction-act-for-energy-providers (accessed Jun. 16, 2023).
[118] M. Choi, "Texas Dems uniformly vote for Biden's cornerstone climate and health care legislation," *The Texas Tribune*, Aug. 12, 2022. https://www.texastribune.org/2022/08/11/texas-democrats-inflation-reduction-act-climate/ (accessed Jun. 16, 2023).
[119] "Texas Comptroller Glenn Hegar Announces Revenue for Fiscal 2022, August State Sales Tax Collections." https://comptroller.texas.gov/about/media-center/news/20220901-texas-comptroller-glenn-hegar-announces-revenue-for-fiscal-2022-august-state-sales-tax-collections-1662060818986 (accessed Jun. 16, 2023).
[120] "BCG-Executive-Perspectives-US-IRA-Clean-Tech.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://media-publications.bcg.com/BCG-Executive-Perspectives-US-IRA-Clean-Tech.pdf
[121] "Blog: Inflation Reduction Act: A game changer for DERs." https://www.leap.energy/blog/inflation-reduction-act-a-game-changer-for-ders (accessed Jun. 12, 2023).
[122] "🌍 Lessons from Plaid for a future energy unicorn," *Climate Tech VC*, Mar. 11, 2022. https://www.ctvc.co/lessons-from-plaid-for-a-future/ (accessed Jun. 16, 2023).
[123] "Registered Demand Response Providers (DRPs)/Aggregators & FAQ."

https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/registered-demand-response-providers-drps-aggregators-and-faq (accessed Jun. 12, 2023).
[124] K. Poplavskaya and L. de Vries, "Chapter 5 - Aggregators today and tomorrow: from intermediaries to local orchestrators?," in *Behind and Beyond the Meter*, F. Sioshansi, Ed., Academic Press, 2020, pp. 105–135. doi: 10.1016/B978-0-12-819951-0.00005-0.
[125] C. Eid, P. Codani, Y. Chen, Y. Perez, and R. Hakvoort, "Aggregation of demand side flexibility in a smart grid: A review for European market design," in *2015 12th International Conference on the European Energy Market (EEM)*, Lisbon, Portugal: IEEE, May 2015, pp. 1–5. doi: 10.1109/EEM.2015.7216712.
[126] A. Osterwalder and Y. Pigneur, *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons, 2010.
[127] "Texas Demand Response Opportunity as a Load Resource," *Enel X*. https://www.enelx.com/n-a/en/stories/texas-demand-response-opportunity-as-a-load-resource (accessed Jun. 12, 2023).
[128] "2022-ERCOT_Seasonal-Prep.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://cpowerenergy.com/wp-content/uploads/2022/05/2022-ERCOT_Seasonal-Prep.pdf
[129] "52373_336_1180125.pdf." Accessed: Jun. 12, 2023. [Online]. Available: https://interchange.puc.texas.gov/Documents/52373_336_1180125.PDF
[130] "Resource Adequacy in ERCOT: How Long-term Market Design Reforms Could Enhance Reliability | Baker Institute." https://www.bakerinstitute.org/research/resource-adequacy-ercot-how-long-term-market-design-reforms-could-enhance-reliability (accessed Jun. 12, 2023).
[131] "Tyba." https://www.tyba.ai/blog/is-there-value-for-storage-in-ercot-outside-rrs (accessed Jun. 12, 2023).
[132] "Virtual Power Plant (VPP) Software as a Service Market." https://www.transparencymarketresearch.com/vpp-software-as-a-service-market.html (accessed Jun. 12, 2023).
[133] "Virtual Power Plants." https://encyclopedia.pub/entry/3666 (accessed Jun. 12, 2023).
[134] "What is a Virtual Power Plant (VPP)? - AutoGrid." https://blog.auto-grid.com/what-is-virtual-power-plant/ (accessed Jun. 12, 2023).
[135] "Global Virtual Power Plant (VPP) Software as a Service Market Research Report 2023." https://reports.valuates.com/market-reports/QYRE-Auto-37P5783/global-virtual-power-plant-vpp-software-as-a-service (accessed Jun. 12, 2023).
[136] "The Future of Artificial Intelligence in Smart Grid Virtual Power Plants." https://ts2.space/en/the-future-of-artificial-intelligence-in-smart-grid-virtual-power-plants/ (accessed Jun. 12, 2023).
[137] "Virtual power plants one key to controlling enterprise energy costs," *VentureBeat*, Apr. 09, 2023. https://venturebeat.com/data-infrastructure/virtual-power-plants-one-key-controlling-enterprise-energy-costs/ (accessed Jun. 12, 2023).
[138] F.-C. Gu, S.-D. Lu, J.-X. Wu, C.-L. Kuo, C.-H. Lin, and S.-J. Chen, "Interruptible Power Estimation and Auxiliary Service Allocation Using Contract Theory and Dynamic Game for Demand Response in Aggregator Business Model," *IEEE Access*, vol. 7, pp. 129975–129987, 2019, doi: 10.1109/ACCESS.2019.2940628.
[139] K. T. Ponds, A. Arefi, A. Sayigh, and G. Ledwich, "Aggregator of Demand Response for Renewable Integration and Customer Engagement: Strengths, Weaknesses, Opportunities, and Threats," *Energies*, vol. 11, no. 9, Art. no. 9, Sep. 2018, doi: 10.3390/en11092391.
[140] "About Us | OhmConnect - Team and Company Information." https://www.ohmconnect.com/about-us (accessed Jun. 12, 2023).
[141] O. Energy, "First-of-its-Kind Texas Energy Provider, OhmConnect Energy, to Pay Customers to Save Electricity." https://www.prnewswire.com/news-releases/first-of-its-kind-texas-energy-provider-ohmconnect-energy-to-pay-customers-to-save-electricity-301476659.html (accessed Jun. 12, 2023).
[142] "Evolution of Demand Response: A Historical Analysis of Legislation and Research Trends | IEEE Conference Publication | IEEE Xplore." https://ieeexplore.ieee.org/document/8635264 (accessed Jun. 12, 2023).
[143] Z. Peterson, "Overcoming Challenges for DER Interconnection - Spotlight on Energy

Storage”.
[144] R. Valova and G. Brown, “Distributed energy resource interconnection: An overview of challenges and opportunities in the United States,” *Sol. Compass*, vol. 2, p. 100021, Aug. 2022, doi: 10.1016/j.solcom.2022.100021.
[145] “The Challenges and Opportunities Facing Power Companies Today.” https://www.powermag.com/the-challenges-and-opportunities-facing-power-companies-today/ (accessed Jun. 12, 2023).
[146] B. Hargreaves, “Everything You Need to Know About Electric Vehicle Charging in Multifamily.” https://www.thesisdriven.com/p/everything-you-need-to-know-about (accessed Jun. 12, 2023).
[147] “As IRA drives renewables investment, attention turns to transmission upgrades.” https://www.spglobal.com/marketintelligence/en/news-insights/research/as-ira-drives-renewables-investment-attention-turns-to-transmission-upgrades (accessed Jun. 12, 2023).
[148] H. S. Das, M. M. Rahman, S. Li, and C. W. Tan, “Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review,” *Renew. Sustain. Energy Rev.*, vol. 120, p. 109618, Mar. 2020, doi: 10.1016/j.rser.2019.109618.
[149] M. Chang, “IEEE Standards for the Evolving Distributed Energy Resources (DER) Ecosystem,” *IEEE Standards Association*, Nov. 09, 2021. https://standards.ieee.org/beyond-standards/ieee-standards-for-the-evolving-distributed-energy-resources-der-ecosystem/ (accessed Jun. 12, 2023).
[150] Z. Pei, Y. Ma, M. Wu, and J. Yang, “Study on Load-Participated Demand Response Model Based on Load Aggregator,” *Front. Energy Res.*, vol. 9, 2021, Accessed: Jun. 12, 2023. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fenrg.2021.797979
[151] D. Feldman, K. Dummit, J. Zuboy, and R. Margolis, “Winter 2023 Solar Industry Update,” NREL/PR-7A40-85291, 1959948, MainId:86064, Feb. 2023. doi: 10.2172/1959948.
[152] “한국전력거래소_신재생연계ESS 설비용량 자료_20220930 | 공공데이터포털.” https://www.data.go.kr/data/15080672/fileData.do (accessed Jun. 13, 2023).
[153] S. Cummings, “Focusing on Energy Storage Safety,” *Nexceris*, Jun. 14, 2019. https://nexceris.com/2019/06/14/south-korea-identifies-top-4-causes-that-led-to-ess-fires/ (accessed Jun. 13, 2023).
[154] “Apple files with FERC to sell energy in wholesale markets,” *Utility Dive*. https://www.utilitydive.com/news/apple-files-with-ferc-to-sell-energy-in-wholesale-markets/420747/ (accessed Jun. 13, 2023).
[155] “Apple Energy deeper dive: Is this Apple running its own microgrids or more? | Electrek.” https://electrek.co/2016/06/10/apple-energy-deeper-dive-is-this-apple-running-its-own-microgrids-or-more/ (accessed Jun. 13, 2023).
[156] “24/7 Clean Energy – Data Centers – Google,” *Google Data Centers*. https://www.google.com/about/datacenters/cleanenergy/ (accessed Jun. 13, 2023).
[157] M. Kanellos, “It’s Official: Google Can Sell Power Like a Utility,” *Wired*. Accessed: Jun. 13, 2023. [Online]. Available: https://www.wired.com/2010/02/google-can-sell-power-like-a-utility/
[158] Z. Ullah, M. Baseer, and Arshad, “Demand Response Strategy of a Virtual Power Plant for Internal Electricity Market,” in *2022 IEEE 10th International Conference on Smart Energy Grid Engineering (SEGE)*, Aug. 2022, pp. 100–104. doi: 10.1109/SEGE55279.2022.9889759.
[159] R. R. Labastida and M. Kelly, “Peter Asmus Research Director”.
[160] E. Nokandi, M. Vahedipour Dahraie, S. R. Goldani, and P. Siano, “A Three-Stage Bi-Level Model for Joint Energy and Reserve Scheduling of Vpp Considering Local Intraday Demand Response Exchange Market.” Rochester, NY, Jul. 27, 2022. doi: 10.2139/ssrn.4173987.
[161] “Virtual Power Plants: new energy systems will generate green revenues for real estate. But the sector will need to build capacity for Open Innovation. Here’s how. | by MICHELE.SCATAGLINI. | Medium.” https://medium.com/@MicheleScatta/virtual-power-plants-how-innovative-energy-systems-will-generate-green-revenues-for-real-estate-66c55c9ab8d0 (accessed Jun. 13, 2023).
[162] D. Hammell, “Incentives and Innovation Charge Up Battery Projects in New England,” *CPower Energy*, Dec. 05, 2022. https://cpowerenergy.com/incentives-and-innovation-charge-up-

battery-projects-in-new-england/ (accessed Jun. 13, 2023).
[163] A. Ramos, “Aggregators and Retailers in Electricity Markets: Roles and Conflicts.” Rochester, NY, Oct. 30, 2020. doi: 10.2139/ssrn.3980492.
[164] “Let’s talk about Texas,” *EnergyHub*. https://www.energyhub.com/blog/lets-talk-about-texas/ (accessed Jun. 13, 2023).
[165] L. Kolodny, “Tesla files to become an electricity provider in Texas,” *CNBC*, Aug. 26, 2021. https://www.cnbc.com/2021/08/26/tesla-files-to-become-an-electricity-provider-in-texas.html (accessed Jun. 13, 2023).
[166] F. B. Insights, “Virtual Power Plant Market Size worth USD 6.47 Billion by 2028 | Fortune Business Insights,” *GlobeNewswire News Room*, Apr. 18, 2023. https://www.globenewswire.com/news-release/2023/04/18/2648865/0/en/Virtual-Power-Plant-Market-Size-worth-USD-6-47-Billion-by-2028-Fortune-Business-Insights.html (accessed Jun. 13, 2023).
[167] I. Service, “Power/Interest Grid,” *Improvement Service*, Jan. 30, 2020. https://www.improvementservice.org.uk/business-analysis-framework/consider-perspectives/powerinterest-grid (accessed Jun. 13, 2023).
[168] R. Barrington, “What Is Mendelow’s Matrix And How Is It Useful?,” *Oxford College of Marketing Blog*, Apr. 23, 2018. https://blog.oxfordcollegeofmarketing.com/2018/04/23/what-is-mendelows-matrix-and-how-is-it-useful/ (accessed Jun. 13, 2023).
[169] M. Eurich and M. Burtscher, “The Business-to-Consumer Lock in Effect”.
[170] “The-Debate-About-Demand-Response-Final-10.28.15.pdf.” Accessed: Jun. 13, 2023. [Online]. Available: https://eepartnership.org/wp-content/uploads/2015/10/The-Debate-About-Demand-Response-Final-10.28.15.pdf
[171] “epijJepic2022.pdf.” Accessed: Jun. 13, 2023. [Online]. Available: https://www.jepic.or.jp/pub/pdf/epijJepic2022.pdf
[172] “27706_397_1004614.pdf.” Accessed: Jun. 13, 2023. [Online]. Available: https://interchange.puc.texas.gov/Documents/27706_397_1004614.PDF
[173] M. Hourihan, “How to hedge against Load Resource proration in ERCOT,” *CPower Energy*, Apr. 10, 2019. https://cpowerenergy.com/how-to-hedge-against-load-resource-proration-in-ercot/ (accessed Jun. 13, 2023).
[174] “2019 Utility Demand Response Market Snapshot,” *SEPA*. https://sepapower.org/resource/2019-utility-demand-response-market-snapshot/ (accessed Jun. 13, 2023).
[175] “Long-Range Weather Forecast for 2022 | The Old Farmer’s Almanac.” https://www.almanac.com/weather/longrange/region/us/11 (accessed Jun. 13, 2023).
[176] “Lessons from the 2021 Texas electricity crisis,” *Utility Dive*. https://www.utilitydive.com/news/lessons-from-the-2021-texas-electricity-crisis/596998/ (accessed Jun. 13, 2023).
[177] “Leap gets about 45% of California’s latest demand response auction award,” *Utility Dive*. https://www.utilitydive.com/news/leap-energy-gets-about-45-of-californias-latest-demand-response-auction-a/526479/ (accessed Jun. 13, 2023).
[178] E. Breed, “Texas Winter Blackout Analysis Sheds Light on ERCOT’s Summer Warnings,” *UT News*, Jun. 17, 2021. https://news.utexas.edu/2021/06/17/texas-winter-blackout-analysis-sheds-light-on-ercots-summer-warnings/ (accessed Jun. 13, 2023).
[179] “Google Cites Requirement For Aggregated Load To Participate In ERCOT Market Through Same QSE (REP) As ‘Biggest’ Limitation Facing DERs -- EnergyChoiceMatters.com.” http://www.energychoicematters.com/stories/20220615b.html (accessed Jun. 13, 2023).
[180] “UnlockingthePotentialofDERs_Powersystemopportunitiesandbestpractices.pdf.” Accessed: Jun. 13, 2023. [Online]. Available: https://iea.blob.core.windows.net/assets/3520710c-c828-4001-911c-ae78b645ce67/UnlockingthePotentialofDERs_Powersystemopportunitiesandbestpractices.pdf
[181] “AGG - Aggregator - Registration and Reporting.” https://www.puc.texas.gov/industry/electric/business/agg/agg.aspx (accessed Jun. 13, 2023).
[182] “Energy Brokers in Texas: What Do They Do? | Energy Ogre.” https://www.energyogre.com/ (accessed Jun. 13, 2023).
[183] B. L. Weinstein, “THE POTENTIAL OF DISTRIBUTED ENERGY RESOURCES IN

ERCOT, AND THE IMPORTANCE OF GETTING IT RIGHT".
[184] "How Inflation Reduction Act reforms U.S. energy storage market?-Industry-InfoLink Consulting." https://www.infolink-group.com/energy-article/energy-storage-topic-impact-of-ira-on-us-energy-storage-market (accessed Jun. 13, 2023).
[185] "Electricity storage and renewables: Costs and markets to 2030," 2030.
[186] admin, "Eolian claims the 200-MW energy storage project in Texas is the first to apply the IRA tax credit for independent energy storage.," *POMCube*, Feb. 24, 2023. https://www.pomcube.com/eolian-claims-the-200-mw-energy-storage-project-in-texas-is-the-first-to-apply-the-ira-tax-credit-for-independent-energy-storage/ (accessed Jun. 13, 2023).
[187] "Battery stampede spurs sunny storage economics in ERCOT | S&P Global Market Intelligence." https://www.spglobal.com/marketintelligence/en/news-insights/research/battery-stampede-spurs-sunny-storage-economics-in-ercot (accessed Jun. 13, 2023).
[188] F. Ramos *et al.*, "Development of Operation Strategy for Battery Energy Storage System into Hybrid AC Microgrids," *Sustainability*, vol. 14, no. 21, Art. no. 21, Jan. 2022, doi: 10.3390/su142113765.
[189] Y. T. Akoda, "Analysis of Customer Perception and Satisfaction for Behind-the-meter Battery Energy Storage Systems (BESS) for Commercial and Industrial Users in California".
[190] "BESS: Energy Saving Solutions for Efficient Energy Management." https://www.integrasources.com/blog/energy-management-and-energy-saving-bess/ (accessed Jun. 13, 2023).
[191] "Storage + efficiency for C&I demand management," *Utility Dive*. https://www.utilitydive.com/spons/storage-efficiency-for-ci-demand-management/548508/ (accessed Jun. 13, 2023).
[192] "Commercial & industrial energy storage market shows signs of life." https://www.energy-storage.news/commercial-and-industrial-energy-storage-fresh-moves-in-a-slow-moving-market-segment/ (accessed Jun. 16, 2023).
[193] C. Xie, D. Wang, C. S. Lai, R. Wu, X. Wu, and L. L. Lai, "Optimal sizing of battery energy storage system in smart microgrid considering virtual energy storage system and high photovoltaic penetration," *J. Clean. Prod.*, vol. 281, p. 125308, Jan. 2021, doi: 10.1016/j.jclepro.2020.125308.
[194] "Supercharged: Challenges and opportunities in global battery storage markets." Accessed: Jun. 13, 2023. [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/bg/Documents/energy-resources/gx-er-challenges-opportunities-global-battery-storage-markets.pdf
[195] "Inflation Reduction Act: A Boon for VPP Industry - AutoGrid," Aug. 29, 2022. https://blog.auto-grid.com/inflation-reduction-act-a-boon-for-vpp-industry/ (accessed Jun. 13, 2023).
[196] V. Ahlqvist, P. Holmberg, and T. Tangerås, "A survey comparing centralized and decentralized electricity markets," *Energy Strategy Rev.*, vol. 40, p. 100812, Mar. 2022, doi: 10.1016/j.esr.2022.100812.
[197] "ercot.com/mktrules/pilots/ader." Accessed: Jun. 13, 2023. [Online]. Available: https://www.ercot.com/mktrules/pilots/ader
[198] "Texans can now sign up for virtual power plant to help grid, make…," *Canary Media*, Jan. 27, 2023. https://www.canarymedia.com/articles/grid-edge/texans-can-now-sign-up-for-virtual-power-plant-to-help-grid-make-money (accessed Jun. 13, 2023).
[199] "Registration Form for Aggregate Distributed Energy Resource (ADER)." Accessed: Jun. 16, 2023. [Online]. Available: https://www.puc.texas.gov/industry/electric/forms/ader/aderregistrationform.pdf
[200] G. Post, "EnergyTech: ERCOT moves forward on pilot to evaluate DERs in wholesale markets," *Microgrid Knowledge*, Oct. 2022. https://www.microgridknowledge.com/distributed-energy/article/11436845/energytech-ercot-moves-forward-on-pilot-to-evaluate-ders-in-wholesale-markets (accessed Jun. 13, 2023).
[201] "Texas PUCT Project No . 53911 | Aggregated Distributed Energy Resources (ADER) ERCOT Pilot | Texas Solar Energy Society." https://txses.org/texas-puct-project-no-53911-aggregated-distributed-energy-resources-der-ercot-pilot/, https://txses.org/texas-puct-project-no-53911-aggregated-distributed-energy-resources-der-ercot-pilot/ (accessed Jun. 13, 2023).
[202] "ERCOT must prioritize new ancillary services for electric reliability: Texas PUC | S&P

Global Commodity Insights." https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/011822-ercot-must-prioritize-new-ancillary-services-for-electric-reliability-texas-puc (accessed Jun. 16, 2023).
[203] "Texas expands industrial demand response program as grid goes to the brink of rolling outages," *Utility Dive*. https://www.utilitydive.com/news/texas-expands-industrial-demand-response-program-as-grid-goes-to-the-brink/627358/ (accessed Jun. 13, 2023).
[204] "What the Inflation Reduction Act Means for Real Estate." https://www.aquicore.com/blog/inflation-reduction-act-real-estate (accessed Jun. 13, 2023).
[205] "Presentation-Energy-Transition-Series-Real-Estate-Opportunities-in-the-Energy-Transition-May-11-2022.pdf." Accessed: Jun. 13, 2023. [Online]. Available: https://media.velaw.com/wp-content/uploads/2022/04/24164036/Presentation-Energy-Transition-Series-Real-Estate-Opportunities-in-the-Energy-Transition-May-11-2022.pdf
[206] "The Inflation Reduction Act: Key Provisions Regarding the ITC and PTC | Foley & Lardner LLP." https://www.foley.com/en/insights/publications/2022/08/inflation-reduction-act-key-provisions-itc-ptc (accessed Jun. 13, 2023).
[207] "Inflation Reduction Act Shines a Bright Light on Renewable Energy, but Guidance is Needed," Oct. 31, 2022. https://www.novoco.com/periodicals/articles/inflation-reduction-act-shines-bright-light-renewable-energy-guidance-needed (accessed Jun. 13, 2023).
[208] D. Costley • •, "Biden Administration Announces Nearly $11 Billion for Renewable Energy in Rural Communities," *NBC 5 Dallas-Fort Worth*, May 16, 2023. https://www.nbcdfw.com/news/national-international/biden-administration-announces-nearly-11-billion-for-renewable-energy-in-rural-communities/3259009/ (accessed Jun. 13, 2023).
[209] "The Inflation Reduction Act: An Overview of Clean Energy Provisions and Their Impact on Affordable Housing," Jan. 13, 2023. https://www.novoco.com/notes-from-novogradac/inflation-reduction-act-overview-clean-energy-provisions-and-their-impact-affordable-housing (accessed Jun. 13, 2023).
[210] "New IRA Investments Will Help Rural America Thrive in Clean Energy Economic Boom | E2." https://e2.org/releases/new-ira-investments-will-help-rural-america-thrive-in-clean-energy-economic-boom/ (accessed Jun. 13, 2023).
[211] "EnergyHub and EvoCharge Announce Integration with EnergyHub EV," *Utility Dive*. https://www.utilitydive.com/press-release/20230602-energyhub-and-evocharge-announce-integration-with-energyhub-ev/ (accessed Jun. 13, 2023).
[212] K. R. T. last updated, "EV Charger Tax Credit 2023: What You Need to Know," *Kiplinger.com*, Sep. 12, 2022. https://www.kiplinger.com/taxes/605201/federal-tax-credit-for-electric-vehicle-chargers (accessed Jun. 13, 2023).
[213] "Home," *VP3*. https://vp3.io/ (accessed Jun. 13, 2023).
[214] "RMI partners with General Motors, Google Nest for initiative to promote and support virtual power plants," *Utility Dive*. https://www.utilitydive.com/news/rmi-general-motors-google-nest-virtual-power-plants/640131/ (accessed Jun. 13, 2023).
[215] "Understanding the Inflation Reduction Act - The Council of State Governments," *The Council of State Governments* -, Aug. 16, 2022. https://www.csg.org/2022/08/16/understanding-the-inflation-reduction-act/ (accessed Jul. 04, 2023).