Capstone Workshop Final Report *Crédit Agricole CIB*

Analysis of Carbon-Reducing Investments that are Supported by the Inflation Reduction Act

May 2, 2024

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Overview of the Inflation Reduction Act (IRA)

- The Inflation Reduction Act of 2022, allocates significant funding and tax incentives to promote clean energy, reduce carbon emissions, and enhance energy efficiency across various sectors in the US.

- **Impact of IRA on energy transition-related investments**

  - **Expansion of technology coverage** to new technologies such as standalone energy storage systems and clean hydrogen production technologies.

  - **Extended tax credits timeline** for both ITC and PTC to encourage long-term investment in clean energy.

  - **Tax Credit Transfers** allow developers to transfer tax credits outside of scarce traditional tax equity investors.

  - **Bonus Credits** for projects meeting domestic content and/or energy communities requirements, potentially increasing the credit by an additional 10% for each criterion met.

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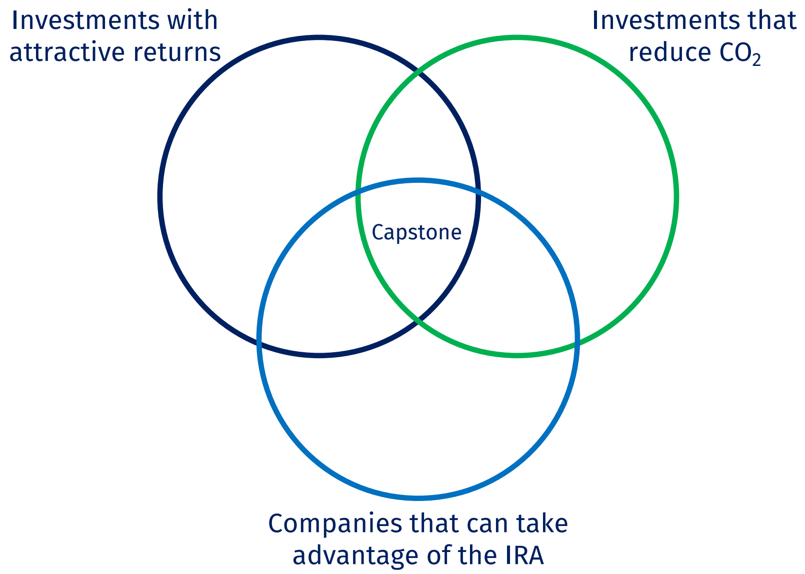
Capstone Objectives

- **Within the context of the Inflation Reduction Act ("IRA"), Crédit Agricole CIB is interested in quantitatively and qualitatively evaluating:**
  - Which regions and technologies offer the most economically attractive renewable investments?
  - Which regions and through which technologies can CACIB's clients achieve the greatest reduction in CO_2 emissions?
  - Who are the developers active in the most advantageous renewable technologies and regions?



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Team and Work Streams

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Scope of Analysis and Methodology

Objectives & Scope

Objectives

- Identify carbon-reducing investments in the U.S. that deliver both attractive returns and carbon - reduction benefits
- Identify industry players with strategic advantages to leverage the IRA when developing new projects

Scope

- Five clean energy technologies: on-shore wind, utility-scale solar, lithium-ion battery storage, “green” hydrogen, and carbon capture, utilization , and storage
- Four U.S. electricity markets: Central MISO, ERCOT, Western PJM, Pacific Northwest (“PNW”)

Project Methodology

Step 1

Technical inputs & Assumptions

- Cost and operating data compilation for each technology and region from secondary sources
- Assumptions setting based on discussions with the CACIB

Step 2

Economic & Environmental Modeling. Three main models

- Levelized Cost (LCOE/LCOS) based on Step 1 data and IRA tax credit impacts
- Project revenue modeling based on LCOE/S analysis and merchant revenue forecast to assess project economics compared to recent PPA transactions
- Environmental analysis calculating the avoided CO_2 emissions over project lifecycle based on generation profile and market carbon intensity

Step 3

Competitive Analysis

- Interviews with industry players to confirm model assumptions and provide market insights
- Mapped the competitive landscape of strategic developers in the four markets and ranked by operating capacity

Step 4

Output

- Economic: identified investments most positively impacted by the IRA
- Environmental: identified the Avoided Carbon per Dollar Invested (ACDI) for each technology and market and the effects of IRA incentives on ACDI
- Competitive: based on the above, identified strategic players in each selected technology and region

Key Findings

- PTC generally reduces LCOEs relative to ITC. PTC favorability ranges widely by region due to capacity factors and underlying costs
- LCOEs are lowest in ERCOT, followed by MISO

Key Metrics	Wind				Solar				Battery			
	PJM	ERCOT	MISO	PNW	PJM	ERCOT	MISO	PNW	PJM	ERCOT	MISO	PNW
Technical drivers	In $/kW				In $/kW				In $/kW			
Overnight capital costs *(Green indicates lower Capex)*	2,290	1,971	2,103	2,100	1,498	1,483	1,694	1,549	1,777	1,759	1,848	1,795
Net capacity factor *(Green indicates higher NCF)*	24%	45%	42%	34%	27%	30%	24%	19%	NA	NA	NA	NA
Economic modeling	LCOE in $/MWh				LCOE in $/MWh				LCOS is $/kW-month			
LCOE/LCOS without tax credits *(Green indicates lower LCOE)*	130.0	59.0	66.0	81.4	75.9	65.9	93.0	103.3	15.9	15.2	16.1	15.4
LCOE/LCOS with fully stacked IRA tax credits *(Green indicates lower LCOE)*	61.0	30.0	30.5	41.1	34.7	32.1	42.6	50.2	8.4	8.0	8.8	8.7
IRA impact on LCOE												
▪ **ITC**												
LCOE reduction with base rate ITC	-6%	-5%	-6%	-5%	-6%	-6%	-6%	-5%	-5%	-5%	-5%	-2%
LCOE reduction with full ITC bonuses	-35%	-32%	-36%	-32%	-36%	-34%	-36%	-34%	-30%	-30%	-29%	-26%
▪ **PTC**												
LCOE reduction with base rate PTC	-8%	-21%	-20%	-14%	-16%	-18%	-12%	-10%				
LCOE reduction with full PTC bonuses	-13%	-32%	-30%	-22%	-24%	-27%	-19%	-16%				

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Key Findings

- Avoided Carbon per Dollar Invested (ACDI) is highest in ERCOT, and lowest in PNW.
- Compared to a pre-IRA tax landscape, the new IRA PTC reduces ACDI by ~13%, while the ITC reduces ACDI by ~2.5%.
- The IRA renders ERCOT Wind w/ PTC, MISO Wind w/PTC and PJM Solar w/ITC the most attractive opportunities.
- Overall, wind provides the highest ACDI due to higher capacity factors and high generation during peak shoulder hours.

Key Metrics	Wind				Solar				Battery			
	PJM	ERCOT	MISO	PNW	PJM	ERCOT	MISO	PNW	PJM	ERCOT	MISO	PNW
Commercial drivers												
Investment Attractiveness Ranking *(LCOE Gap to Market Price)*	8	6	2		1	3	5	7	NA	NA	NA	NA
Environmental drivers	Short tons of CO_2				Short tons of CO_2				Short tons of CO_2			
Short tons of avoided CO_2 per $M invested	9,122	13,453	15,537	6,749	12,281	14,116	10,609	5,294	1,717	2,524	1,924	3,865
Short tons of avoided CO_2 per $M invested *(Subsidized with highest bonus PTC/ITC)*	10,907	19,591	21,595	8,761	16,182	19,499	13,006	6,430	1,997	2,927	2,232	4,476

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Economic Analysis

Identifying investments that offer attractive returns

LCOE: Methodology & Overview

The Economic Modeling Team runs the model mechanics, sets key financial assumptions and evaluates the IRA impact on LCOE

Onshore Wind - PJM West
In USD 000, unless otherwise noted

Pro Forma		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	EUL 2053
Period	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**30**
C. With ITC (Post-IRA)													
Capacity		100	100	100	100	100	100	100	100	100	100	100	100
Capacity Factor		24%	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Total Generation (MWh)		208,339	208,339	208,339	208,339	208,339	208,339	208,339	208,339	208,339	208,339	208,339	208,339
Levelized Energy Cost (LCOE		**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**	**88.48**
Total Revenues		18,434	18,434	18,434	18,434	18,434	18,434	18,434	18,434	18,434	18,434	18,434	18,434
Operating Expense													
Fuel Cost		-	-	-	-	-	-	-	-	-	-	-	-
O&M		(3,218)	(3,299)	(3,381)	(3,466)	(3,552)	(3,641)	(3,732)	(3,825)	(3,921)	(4,019)	(4,120)	(6,586)
Total Operating Costs		(3,218)	(3,299)	(3,381)	(3,466)	(3,552)	(3,641)	(3,732)	(3,825)	(3,921)	(4,019)	(4,120)	(6,586)
EBITDA		15,216	15,135	15,053	14,968	14,882	14,793	14,702	14,608	14,513	14,415	14,314	11,848
Debt Outstanding BoP		151,815	149,048	146,115	143,005	139,710	136,216	132,513	128,588	124,428	120,017	115,342	
Interest Expense		(9,109)	(8,943)	(8,767)	(8,580)	(8,383)	(8,173)	(7,951)	(7,715)	(7,466)	(7,201)	(6,921)	
Amortization		(2,767)	(2,933)	(3,109)	(3,296)	(3,493)	(3,703)	(3,925)	(4,161)	(4,410)	(4,675)	(4,955)	
Debt Outstanding EoP	151,815	149,048	146,115	143,005	139,710	136,216	132,513	128,588	124,428	120,017	115,342	110,387	
Levelized Debt Service		(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	(11,876)	
EBITDA		15,216	15,135	15,053	14,968	14,882	14,793	14,702	14,608	14,513	14,415	14,314	11,848
Less: Depreciation		(36,562)	(58,499)	(35,100)	(21,060)	(21,060)	(10,530)	-	-	-	-	-	-
Less: Interest Expense		(9,109)	(8,943)	(8,767)	(8,580)	(8,383)	(8,173)	(7,951)	(7,715)	(7,466)	(7,201)	(6,921)	-
Taxable Income		(30,455)	(52,307)	(28,814)	(14,672)	(14,561)	(3,910)	6,751	6,893	7,047	7,214	7,394	11,848
Tax Liability (Benefit)		7,839	13,464	7,417	3,777	3,748	1,006	(1,738)	(1,774)	(1,814)	(1,857)	(1,903)	(3,050)
Federal ITC		64,521											
Capex	(101,210)	(151,815)											
After-Tax Net Equity Casl	(101,210)	75,700.2	16,723.1	10,593.5	6,868.8	6,753.6	3,923.3	1,088.1	958.2	822.9	682.0	535.2	8,798.4
IRR After Tax	**12.0%**												

Model Code	Wind PJM
Assumptions	
Onshore Wind	
With ITC (Post-IRA)	**LCOE 88.48**

Capacity MwH	100	Ovn. CapEx ($/kW)	2,290
Capacity Factor %	23.8%	Other Costs ($/kW)	240
Fixed O&M ($/kW-yr)	32	Total CapEx ($/kW)	2,530
Variable O&M	-	Total CapEx ($mm)	253
O&M Escalation Rate	2.5%		

Debt %	60.0%
Cost of Debt	6.0%
Cash Equity %	40.0%
Cost of Equity	12.0%
Tax Equity %	0%
Combined Tax Rate	25.7%
Economic Useful Life	1
MACRS Depreciation Schedule	5
Debt Repayment Year	25
Conversion '000	1000

MACRS Schedule	
1	20%
2	32%
3	19%
4	12%
5	12%
6	6%

Accelerated depreciation on eligible costs (tax basis minus 50% of the ITC)

Capex	253,025
% Eligible for ITC	85%
Base for ITC	215,071
ITC Rate	30%
ITC Rate	**64,521**
Depreciable basis to Capex	85%
For Accelerated Depreciation	182,810

Commercial Team will use LCOE figures as a baseline for the required PPA price

Technical Team provides the cost components by technologies and its cost multiplier based on region

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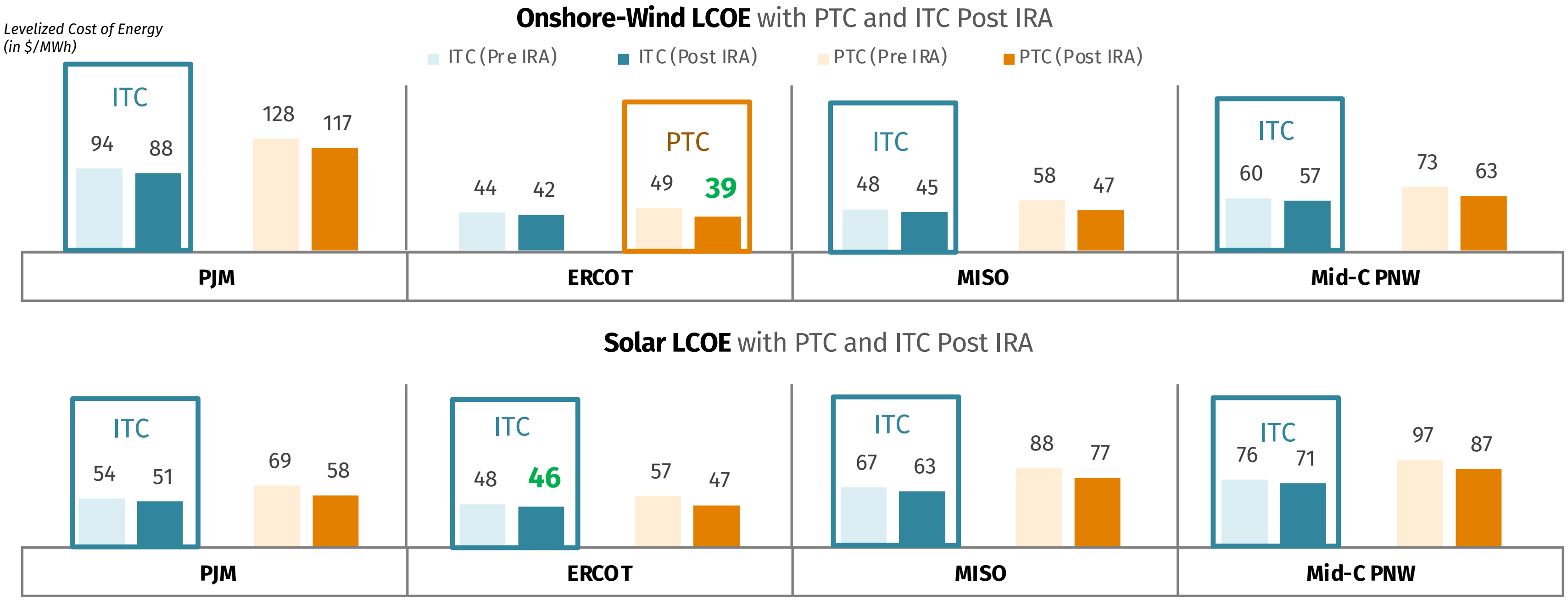
LCOE: PTC vs. ITC at Base Rate

- Among the four regions analyzed, **ERCOT** exhibits the lowest LCOE for both onshore-wind and solar assets
- Apart from onshore wind in ERCOT, electing the ITC will yield a lower LCOE in the current high-cost environment



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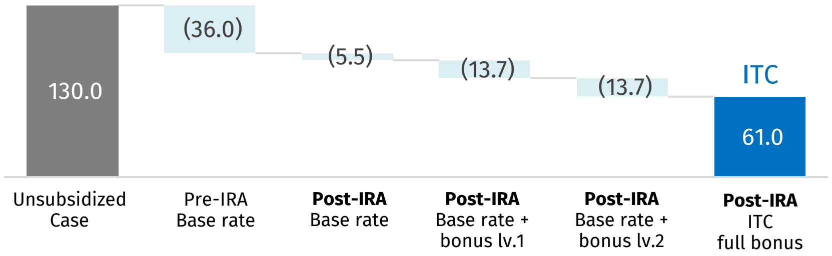
*Note: The figures illustrate the Levelized Cost of Energy in dollars per megawatt-hour

IRA Impact to LCOE: Onshore Wind

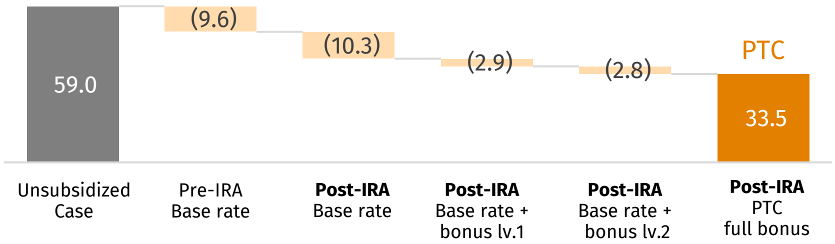
- IRA incentives greatly reduces the LCOE for onshore wind projects, especially if the project qualifies for additional Domestic Content and Energy Community bonuses

Levelized Cost of Energy (in $/MWh)

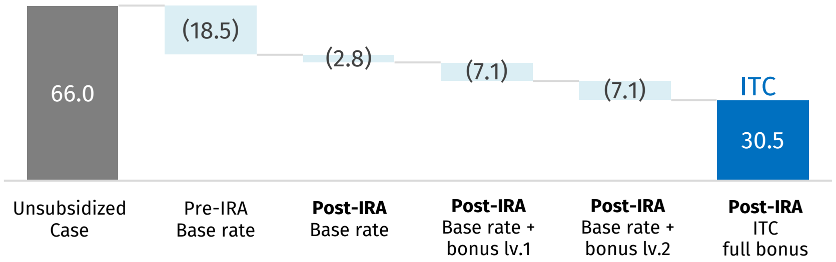
Onshore Wind - **PJM**



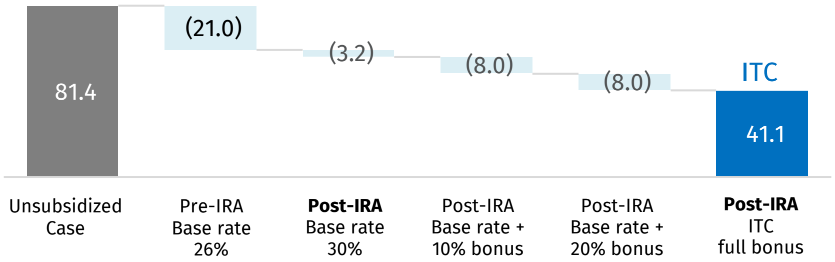
Onshore Wind - **ERCOT**



Onshore Wind - **MISO**



Onshore Wind - **Mid-C PNW**



*Note: :
- The figures illustrate the Levelized Cost of Energy in dollars per megawatt-hour. The lighter shaded bars indicate the dollar amount saved for each tax incentive scenario.
- **Bonus Level 1** is attained when the project is eligible for either the Domestic Content Bonus or the Energy Community Bonus. **Bonus Level 2** is reached when the project qualifies for both bonuses

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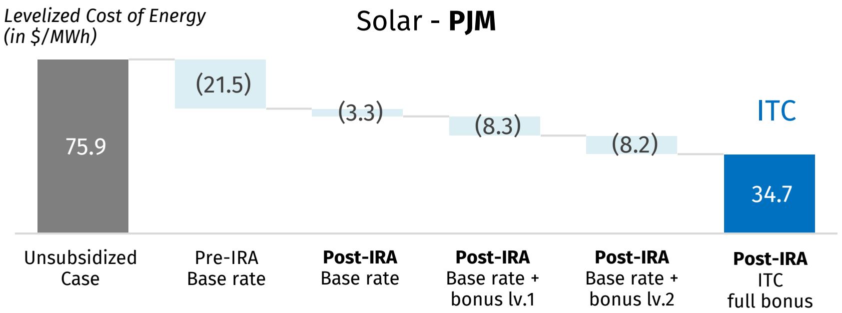
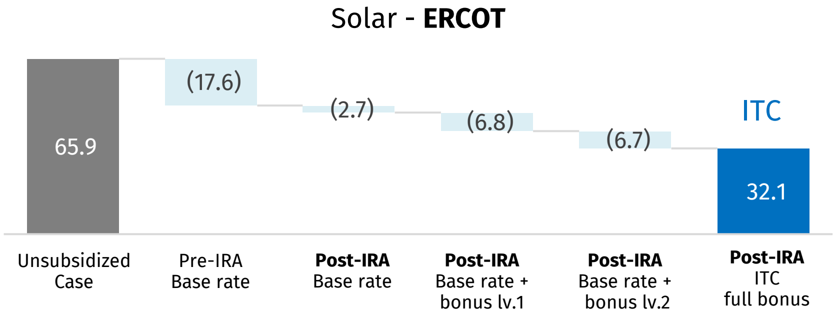
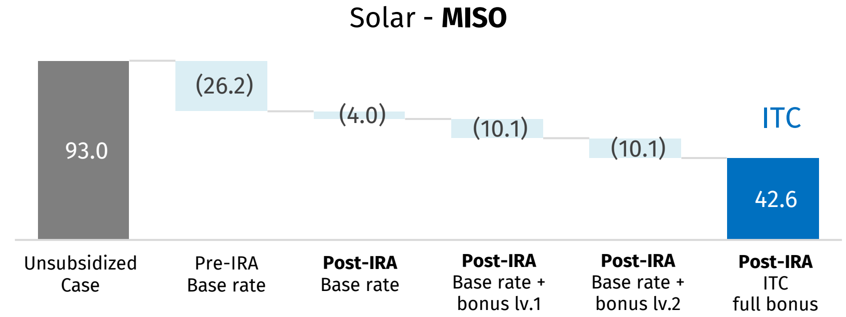
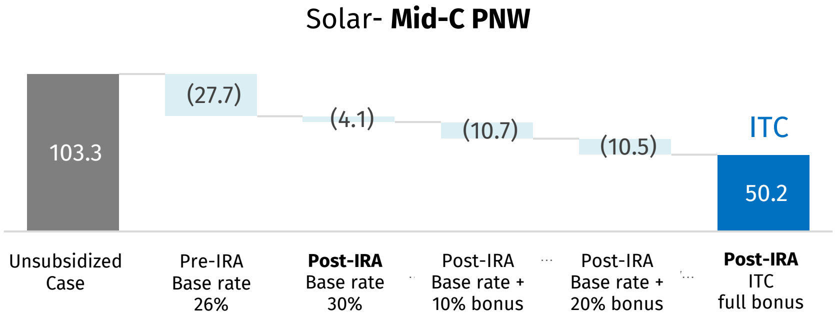
IRA Impact to LCOE: Solar

- The IRA's incentives also significantly reduce solar LCOE, with substantial reductions when projects utilize the full bonus for domestic content and energy community bonus









*Note: :
- The figures illustrate the Levelized Cost of Energy in dollars per megawatt-hour. The lighter shaded bars indicate the dollar amount saved for each tax incentive scenario.
- **Bonus Level 1** is attained when the project is eligible for either the Domestic Content Bonus or the Energy Community Bonus. **Bonus Level 2** is reached when the project qualifies for both bonuses

LCOE Sensitivity: ERCOT Solar

Heatmap of LCOE Differences*: PTC vs. ITC with 10% Bonus
(Domestic Content or Energy Community Bonus)

PTC ADVANTAGE

Capex scenario		30%	32%	34%	36%
20% ↓	1,186	-0.43	-2.01	-3.51	-4.85
15% ↓	1,260	1.09	-0.68	-2.23	-3.65
10% ↓	1,334	2.63	0.68	-0.88	-2.52
	1,483	5.51	3.41	1.62	0.03

ITC ADVANTAGE

NCF scenario

In our base case scenario LCOE with **ITC** will be **$ 5.51/MWh** lower than with PTC

Base Case
Overnight Capex: $ 1,483/kWh
NCF: 30%

When Overnight CAPEX is 15% lower with higher NCF at 34% **PTC** becomes more favorable with an LCOE that is **$2.23/MWh** lower than ITC

*Note: The displayed numbers represent the difference in LCOE when subtracting ITC LCOE values from PTC LCOE values
Positive numbers indicate scenarios where the ITC is more cost-effective, while negative numbers favor the PTC.

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LCOE Sensitivity: ERCOT Wind

Heatmap of LCOE Differences*: PTC vs. ITC with Full Bonus
(Domestic Content & Energy Community Bonus)

PTC ADVANTAGE

Capex scenario		NCF scenario: 43%	45%	47%	49%
20% ↓	1,576	(1.55)	(2.70)	(3.86)	(4.94)
15% ↓	1,675	0.10	(1.22)	(2.45)	(3.56)
10% ↓	1,774	1.75	0.29	(0.91)	(2.08)
	1,971	4.93	3.44	2.06	0.76

ITC ADVANTAGE

In our base case scenario
The LCOE with **ITC** will be
$ 3.44/MWh lower than with PTC

Base Case
Overnight Capex: $ 1,971/kWh
NCF: 45%

When Overnight CAPEX is 15% lower, **PTC** becomes more favorable with an LCOE that is **$1.22/MWh** lower than ITC

*Note: The displayed numbers represent the difference (delta) in LCOE when subtracting PTC LCOE values from ITC LCOE values
Positive numbers indicate scenarios where the ITC is more cost-effective, while negative numbers favor the PTC.

LCOS: Methodology & Overview to the Model

Economic Modeling Team: runs the model mechanics, sets key financial assumptions and compare IRA impacts to LCOS

LCOS

In USD 000, unless otherwise noted

Pro Forma		2024	2025	2026	2027	2028	2029	2037	2038	2039	2040	2041	2042	2043
Period	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C. With ITC Post-IRA														
Capacity (MW)		100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
LCOS $/kW-month		**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**	**$11**
Total Revenues ($ million)		13,726	13,726	13,726	13,726	13,726	13,726	13,726	13,726	13,726	13,726	13,726	13,726	13,726
Operating Expense														
Total Charging Cost		-	-	-	-	-	-	-	-	-	-	-	-	-
Total O&M		(5,600)	(5,740)	(5,884)	(6,031)	(6,181)	(6,336)	(7,720)	(7,913)	(8,110)	(8,313)	(8,521)	(8,734)	(8,952)
Other cost														
Total Warranty				(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)
Total Operating Costs		(5,600)	(5,740)	(7,084)	(7,231)	(7,381)	(7,536)	(8,920)	(9,113)	(9,311)	(9,513)	(9,721)	(9,934)	(10,153)
EBITDA		8,126	7,986	6,642	6,495	6,344	6,190	4,806	4,613	4,415	4,212	4,005	3,792	3,573
Debt Outstanding BoP		80,680	78,487	76,162	73,698	71,085	68,316	39,267	34,589	29,630	24,374	18,802	12,896	6,636
Interest Expense		(4,841)	(4,709)	(4,570)	(4,422)	(4,265)	(4,099)	(2,356)	(2,075)	(1,778)	(1,462)	(1,128)	(774)	(398)
Amortization		(2,193)	(2,325)	(2,464)	(2,612)	(2,769)	(2,935)	(4,678)	(4,959)	(5,256)	(5,572)	(5,906)	(6,260)	(6,636)
Debt Outstanding EoP	80,680.0	78,487	76,162	73,698	71,085	68,316	65,381	34,589	29,630	24,374	18,802	12,896	6,636	0
Levelized Debt Service		(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)	(7,034)
EBITDA		8,126	7,986	6,642	6,495	6,344	6,190	4,806	4,613	4,415	4,212	4,005	3,792	3,573
Less: Depreciation		(29,146)	(46,633)	(27,980)	(16,788)	(16,788)	(8,394)	-	-	-	-	-	-	-
Less: Interest Expense		(4,841)	(4,709)	(4,570)	(4,422)	(4,265)	(4,099)	(2,356)	(2,075)	(1,778)	(1,462)	(1,128)	(774)	(398)
Taxable Income		(25,861)	(43,356)	(25,907)	(14,715)	(14,709)	(6,303)	2,450	2,538	2,637	2,750	2,877	3,018	3,175
Tax Liability (Benefit)		6,982	11,706	6,995	3,973	3,971	1,702	(662)	(685)	(712)	(743)	(777)	(815)	(857)
Federal ITC		51,434	-	-	-	-	-	-	-	-	-	-	-	-
Capex	(121,020)	(80,680)	-	-	-	-	-	-	-	-	-	-	-	-
After-Tax Net Equity Cash	(121,020)	59,508	3,314	6,681	9,556	9,407	11,522	12,502	12,332	12,161	11,989	11,815	11,641	11,465
After-Tax IRR to Equi	**12.0%**													

Commercial Diligence Team will use LCOS as a baseline for PPA price

Model Code Battery PJM

Assumptions

Battery

Without Tax Equity Benefit — LCOS, $/kW-mo **11.44**

Power Rating (MW)	100	Fixed O&M Cost ($/kwh)	$56.00
Duration (Hours)	4	Fixed O&M Escalator (%)	2.5%
Depth of Discharge	90%	Charging Cost Escalator	2.5%
90% Depth of Discharge Cycles/Day	1	Efficiency	91%
Operating Days/Year	350	Extended Warranty (% of capex/equip	0.70%
Charging Cost ($/kwH)	$0.000	Extended Warranty start year	3

Capital Structure	
Debt %	40.0%
Cost of Debt	6.0%
Equity %	60.0%
Cost of Equity	12.0%
Tax Equity %	-

Capex	
Ovn. CapEx ($/kW)	1777
Other Costs ($/kW)	240
Total CapEx ($mm)	201.7

Conversion to 000	1,000
Base Year	2024
Combined Tax Rate	27.0%
Debt Repayment Year	20
Economic Useful Life	20
MACRS Depreciation Schedule	5
Federal ITC - BESS	30%

MACRS Schedule	
1	20.0%
2	32.0%
3	19.2%
4	11.5%
5	11.5%
6	5.8%

Capex	201,700
% Eligible for Accelerated Depreciation	85.0%
Base for ITC	171,445
ITC Rate	30%
ITC Rate	**51,434**
Depreciable basis to Capex	85%
For Accelerated Depreciation	145,728

Goal Seek: **LCOE** (yellow) calculated to set the After-tax IRR to Equity

Technical Diligence Team provides the cost components by technologies and its cost multiplier based on region

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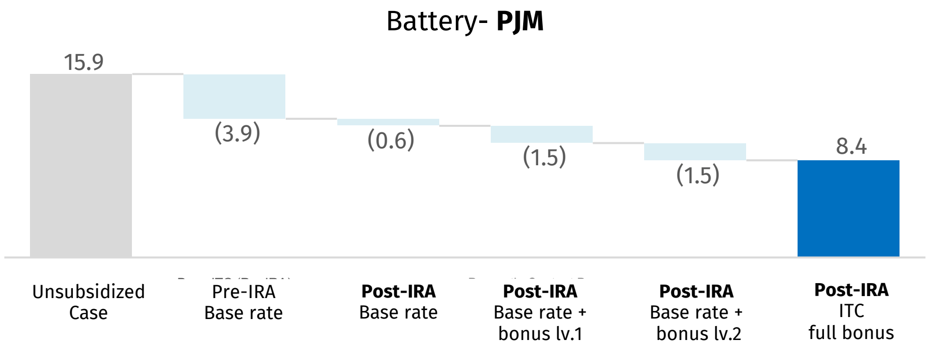
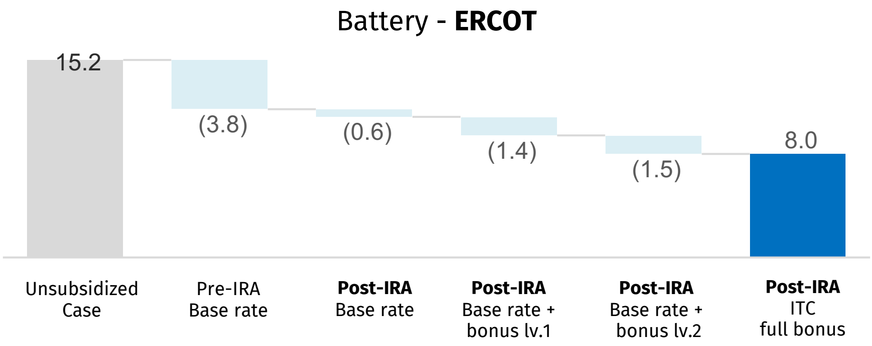
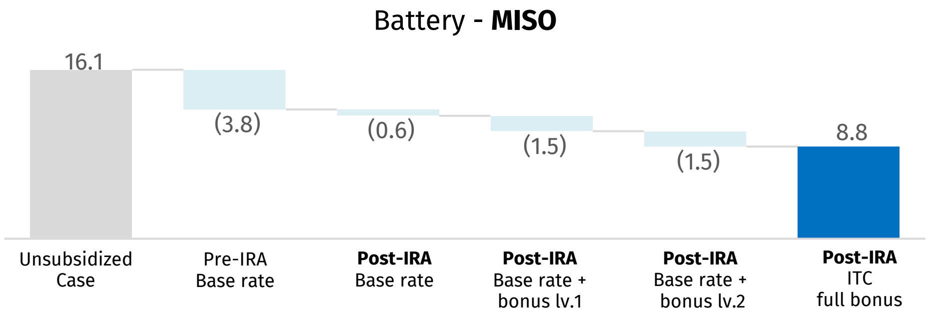
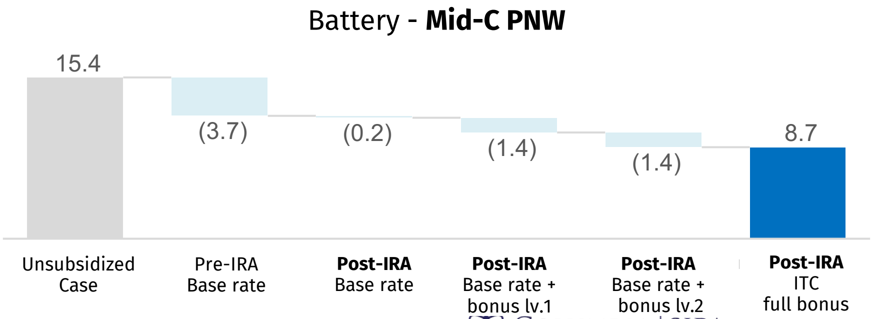
IRA Impact to LCOS: Storage

- ERCOT stands out as having the most competitive Levelized Cost of Electricity (LCOS) among the four regions analyzed









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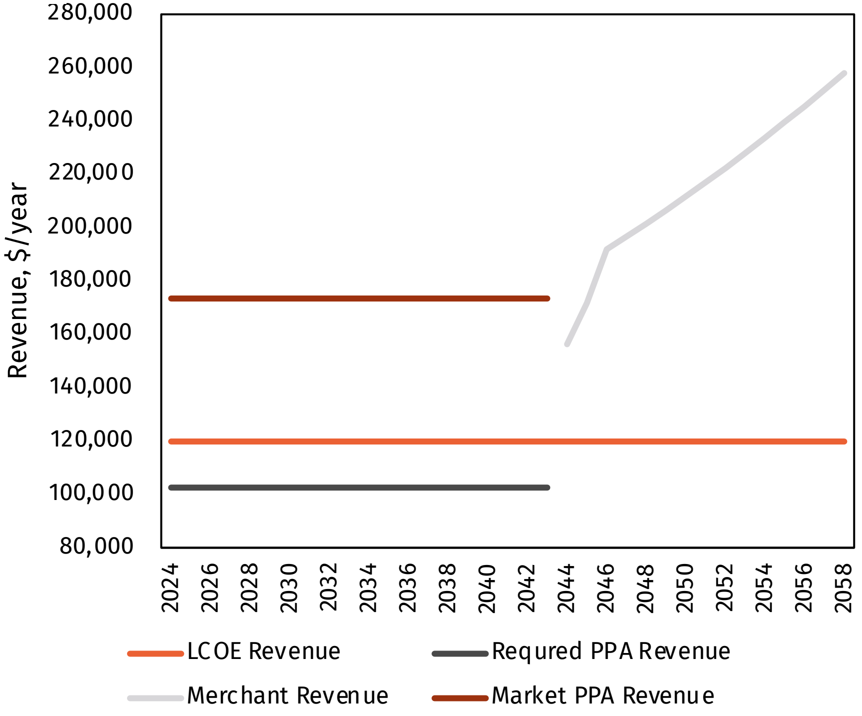
*Note: :
- The figures illustrate the Levelized Cost of Storage in dollars per kilowatt-month, with the lighter shaded bar segments representing savings achieved under various tax incentive scenarios.
- **Bonus Level 1** is attained when the project is eligible for either the Domestic Content Bonus or the Energy Community Bonus. **Bonus Level 2** is reached when the project qualifies for both bonuses

Commercial Analysis Methodology

Illustrative Example: Proxy Solar Project



Methodology

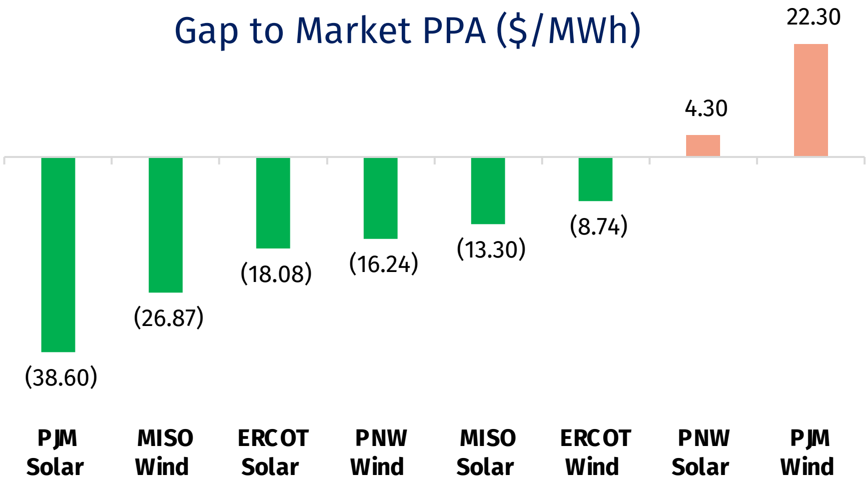
- The levelized cost analysis calculates the LCOE for projects over its full useful life
- To better reflect the commercial reality of renewable projects currently in development, we split the operating life into a PPA period (20 years) and a merchant period (reminder of operating life). The projects’ revenues, therefore, are the sum of their PPA revenue during the PPA period and merchant revenue during the merchant tail.
- Merchant revenues are based on third-party commercially available curves that are modified based on industry feedback. Based on this merchant revenue forecast, we then calculate the minimum required PPA price that would yield an NPV of revenues that is equivalent to the LCOE.
- The required PPAs are then compared to actual C&I PPA prices observed in the market to assess the relative attractiveness of each technology in each market
- The graph on the left illustrates this methodology: high merchant revenue results in low required PPA prices, compared to both LCOE and market PPA.

Required PPA Price vs Market PPA Price

- PJM Solar, MISO Wind, and ERCOT Solar Top the Investment Attractiveness Ranking

	PJM Solar	MISO Wind	ERCOT Solar	PNW Wind	MISO Solar	ERCOT Wind	PNW Solar	PJM Wind
Investment Attractiveness Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Required PPA, Mid-Point Case	33.41	32.33	28.57	49.76	44.41	30.47	64.30	72.30
Market PPA	72.01	59.20	46.65	66.00	57.71	39.21	60.00	50.00
Gap to Market Price	(38.60)	(26.87)	(18.08)	(16.24)	(13.30)	(8.74)	4.30	22.30

Gap to Market PPA ($/MWh)



Notes

- The table above displays results for investment attractiveness for generic wind and solar projects in PJM, MISO, PNW, and ERCOT.
- Mid-Point Case presents the average of Pre-IRA and Max-IRA results, after optimizing ITC/PTC selection.
- In the Mid-Point Case, required PPAs are lower than market PPAs for all regions/technologies other than PNW Solar and PJM Wind, highlighting ample investment opportunities in wind and solar.
- It is, however, worth nothing that the analysis is for generic wind and solar projects and does not include ad-hoc project-specific costs (e.g. basis).

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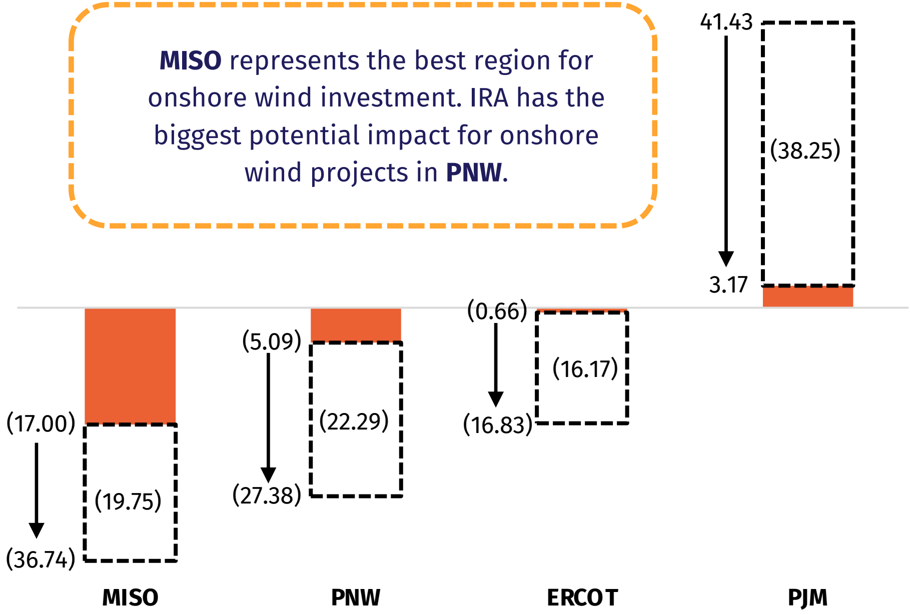
Onshore Wind Results

Market and Required PPA Gap (Pre-IRA vs Max IRA), $/MWh

MISO represents the best region for onshore wind investment. IRA has the biggest potential impact for onshore wind projects in **PNW**.



	Onshore Wind: Required PPA ($/MWh)			
	PJM	ERCOT	MISO	PNW
ITC Pre-IRA @26%	91.43	38.55	42.20	60.91
ITC Post-IRA @30%	85.05	35.78	38.95	57.10
ITC Post-IRA @40%	69.06	29.08	30.70	47.86
ITC Post-IRA @50%	53.17	22.38	22.46	38.62
PTC Pre-IRA @$15/MWh	130.49	44.79	54.40	75.81
PTC Post-IRA @$26/MWh	118.09	32.89	41.04	63.80
PTC Post-IRA @$29/MWh	114.61	29.54	37.56	60.56
PTC Post-IRA @$32/MWh	111.13	26.42	33.96	57.21
Market PPA	**50.0**	**39.2**	**59.2**	**66.0**

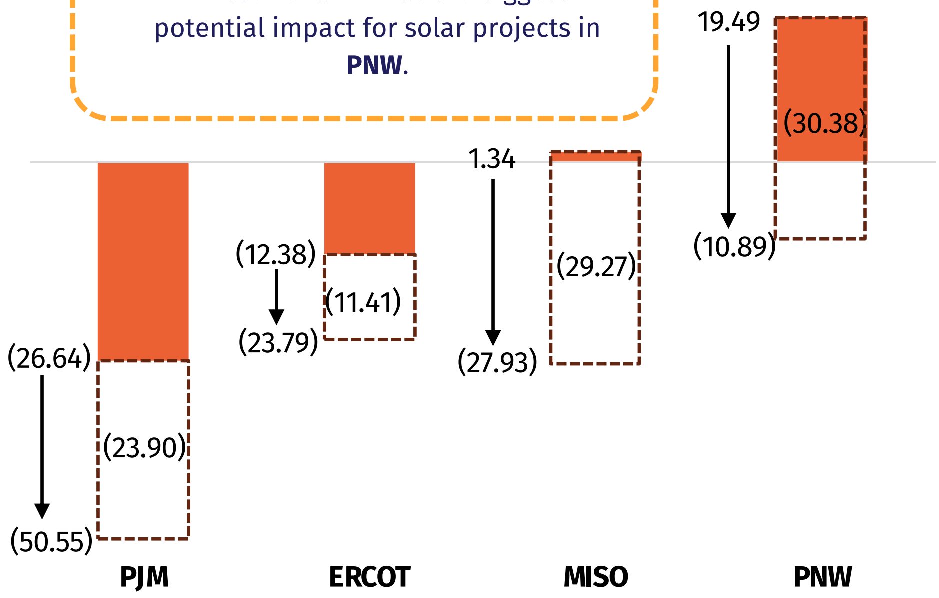
Key Takeaways

- MISO, PNW, and ERCOT are seeing negative gaps between required PPAs and market PPAs, highlighting favorable investment opportunities. PJM's required PPAs for onshore wind, however, are higher than the market PPA in all cases.
- High required PPA in PJM is partly because the capacity factor for wind in the state we chose (Virginia) is low. This result could differ in other regions in PJM, for example, Ohio. However, PJM in general lacks wind resources.
- For Q2 and Q3 2023, market price data for PJM wind was unavailable in the Level 10 report because data volume did not hit the minimum threshold, indicating weak market appetite for wind investments in PJM.

Solar Results

Market and Required PPA Gap (Pre-IRA vs Max IRA), $/MWh

PJM represents the best region for solar investment. IRA has the biggest potential impact for solar projects in **PNW**.



Solar: Required PPA ($/MWh)	PJM	ERCOT	MISO	PNW
ITC Pre-IRA @26%	45.37	34.27	59.05	79.49
ITC Post-IRA @30%	41.37	39.02	54.23	74.56
ITC Post-IRA @40%	31.38	30.86	42.01	61.75
ITC Post-IRA @50%	21.46	22.86	29.78	49.11
PTC Pre-IRA @$15/MWh	62.88	52.87	85.24	105.53
PTC Post-IRA @$26/MWh	49.74	40.80	71.90	93.58
PTC Post-IRA @$29/MWh	46.44	37.47	68.19	90.21
PTC Post-IRA @$32/MWh	42.87	34.13	64.48	86.77
Market PPA	**72.0**	**46.7**	**57.7**	**60.0**

Key Takeaways

- PJM, ERCOT, and MISO are seeing negative gaps between required PPAs and market PPAs in ITC cases, indicating favorable investment opportunities. Investing in solar projects in PNW, however, does not generate satisfactory returns unless with full IRA ITC benefits.
- Solar projects favor ITC in all cases.

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Environmental Analysis

Identifying Investments that reduce CO_2

Environmental Methodology

1. Rank historical hourly load (8760 hours) in each region from highest to lowest
2. Assign a heat rate to each hour of load. Hourly heat rates are based on data from Wood Mackenzie on the % of hours each technology type (combined cycle, gas peaker, coal, etc) is marginal. The highest load hours are assumed to correspond with the highest heat rate technology type. The % of hours marginal changes annual based on the change in the fuel mix over time
3. Overlay the hourly (8760) generation profile of wind, solar, and storage in each region against the hourly load and hourly heat rate
4. Multiply the heat rate by the emissions rate to calculate the avoided lbs of CO_2 emissions per MWh
5. Multiply the MWh of generation from solar, wind, and storage by the avoided CO_2 emissions to estimate how much CO2 is avoided in hour. Sum up the total avoided CO_2 emissions for each year

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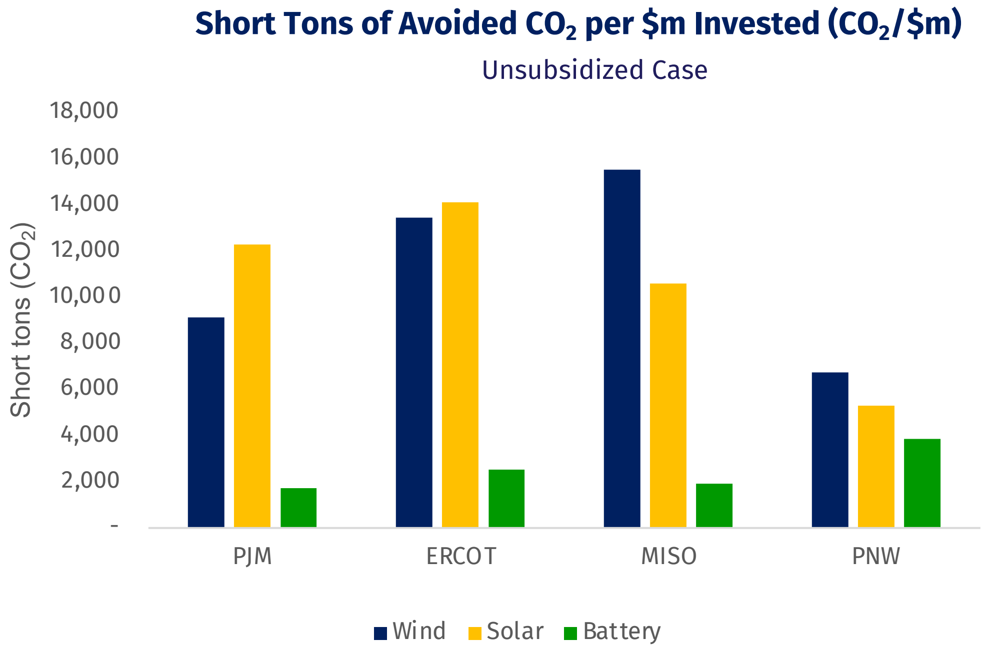
Avoided CO_2 per Dollar Invested (ACDI)



Key Takeaways

- MISO wind yields the highest ACDI of all resource types and regions studied, followed by ERCOT solar, ERCOT wind, and PJM solar
- PNW generally has the lowest ACDI of the regions studied, due primarily to the high levels of hydro, which is often marginal during the shoulder months
- Storage generally has a smaller ACDI due to the fact that there is round trip efficiency losses and due to the fact that the total output is generally much lower than a solar or wind resource
- Key drivers include generation both seasonal and intraday generation profiles, the net capacity factor, projected GHG intensity of the power grid in each region, and the total cost of the project.

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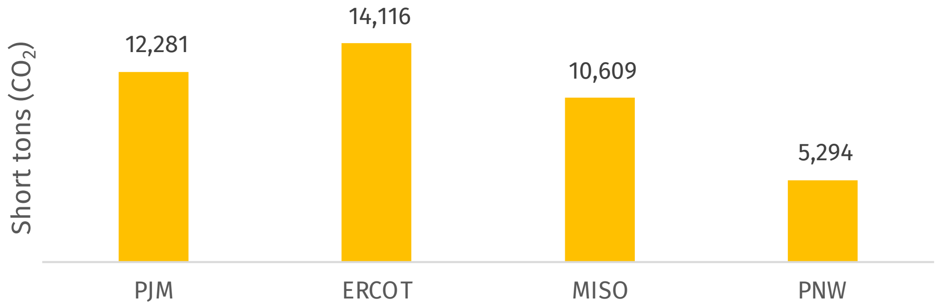
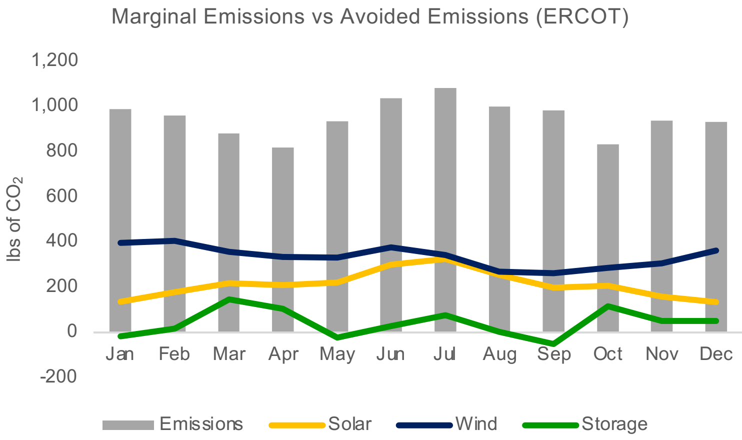
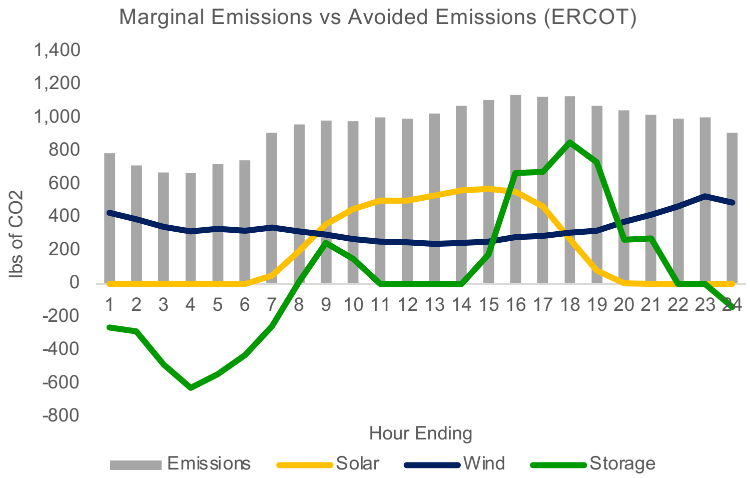
Highest Solar ACDI

Solar: Avoided Short Tons of CO_2/$m

Unsubsidized Case



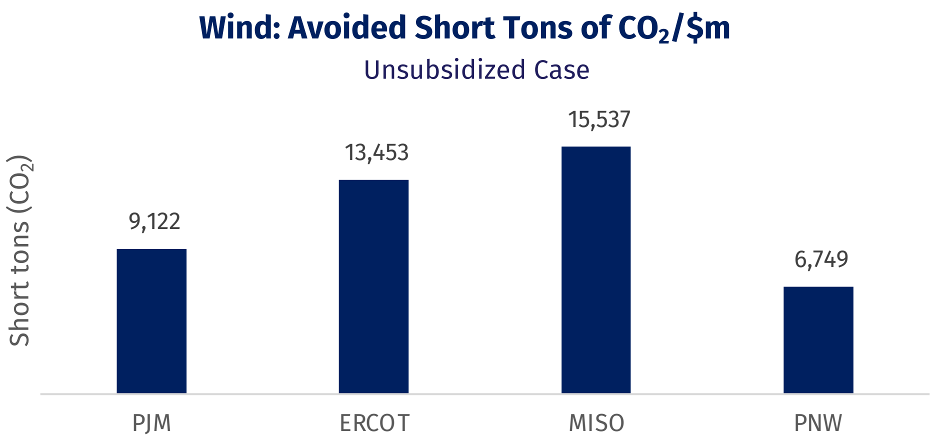


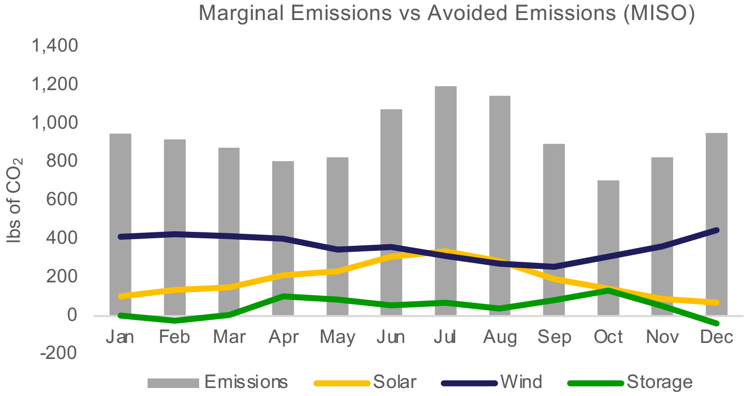


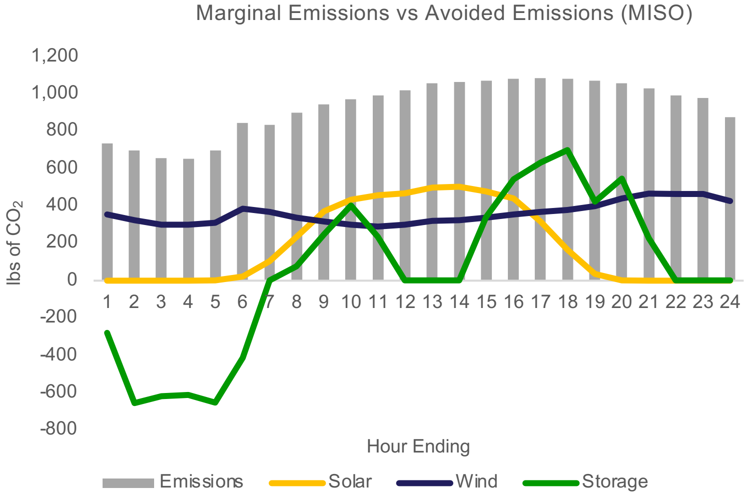
Key Takeaways: ERCOT

- ERCOT is a summer peaking system. This means the least fuel-efficient resources will be operating in the summer during the evening ramp, followed by winter. This is supported by the observation that the highest CO_2 emissions occur in Jun - Aug.
- Conversely, PNW solar is the lowest, due to the low capacity factor and the fact that it will often miss the evening ramp, when emissions are generally highest.

Highest Wind ACDI



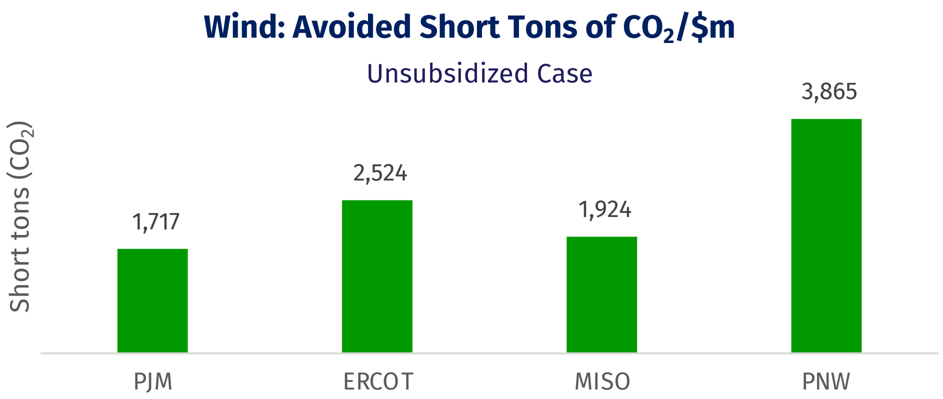




Key Takeaways: MISO

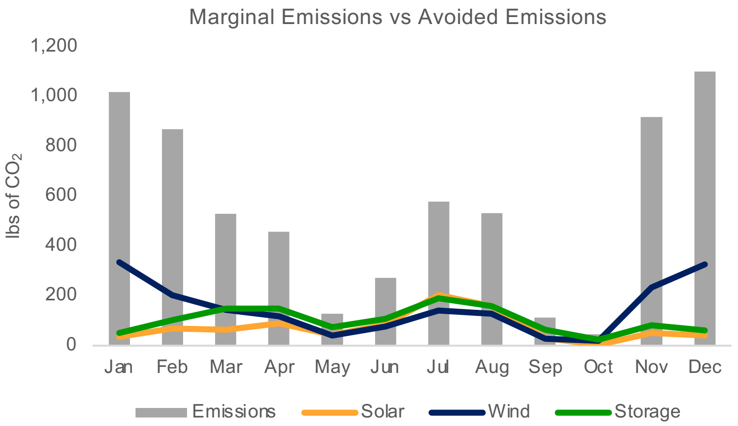
- MISO is a summer peaking system. This means the least fuel-efficient resources will be operating in the summer, followed by winter. This is supported by the observation that the highest CO_2 emissions occur in Jun - Aug.
- Wind and solar have similar capacity factors in the summer, resulting in similar avoided emissions during the peak summer months. However, wind's generation profile is higher in the winter, meaning it reduces emissions more over the course of the year, while solar generation declines in the winter.

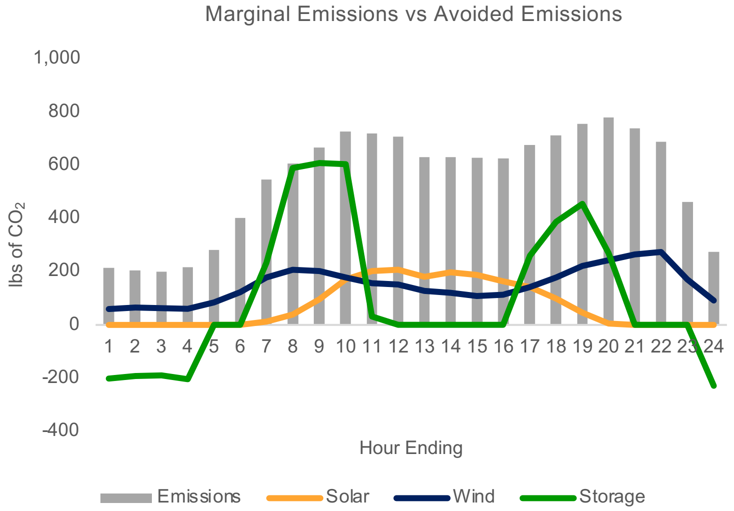
Highest Storage ACDI



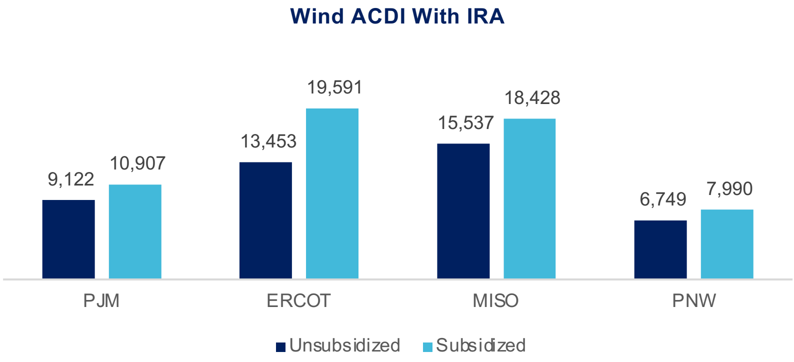
Key Takeaways: PNW

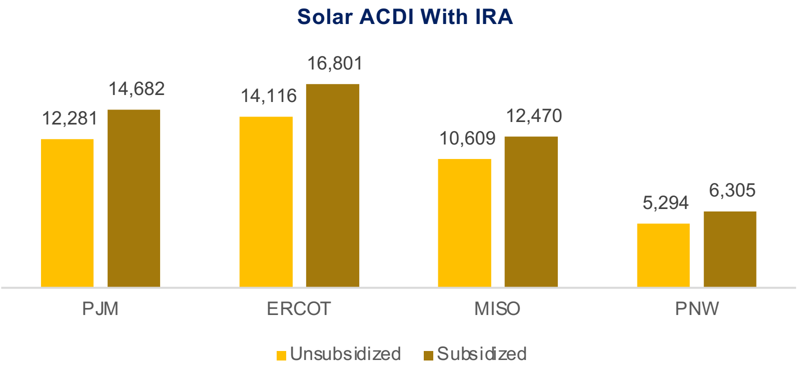
- PNW is a winter peaking system. This means the least fuel-efficient resources will be operating in the winter during the morning ramp, followed by summer. This is supported by the observation that the highest CO_2 emissions occur in Nov - Feb.
- We observe that storage is dispatching during the morning and evening ramps, when marginal emissions are highest (500-700 lbs/MWh), while charging during the lowest marginal emissions (200-300 lbs/MWh). Therefore, even after accounting for round-trip efficiency loss, storage in the PNW appears to be reducing CO2 emissions the most relative to other regions.

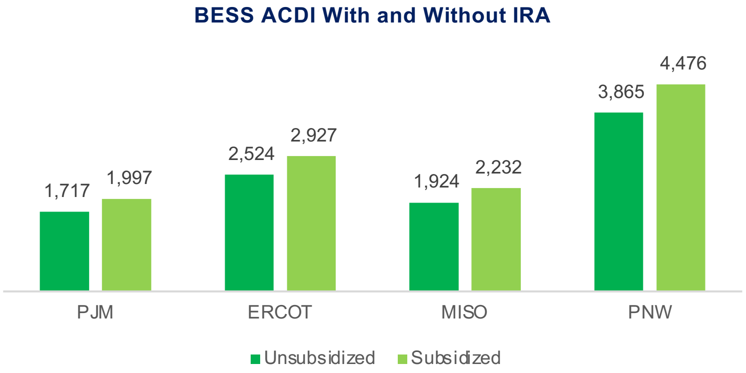




Tax Incentives and Environmental Impact







Key Takeaways

- Relatively high capacity factors for ERCOT wind and MISO wind result in high tax incentive impacts on the ACDI.
- Capex costs represent a relatively large percentage of total costs underlying MISO wind LCOEs. Thus, tax incentive reduce a proportionally higher share of costs relative to revenues.
- MISO and ERCOT wind facilities pre-IRA already had some of the lowest LCOEs, so relatively small reduction in absolute terms results in relatively large reduction percentages.

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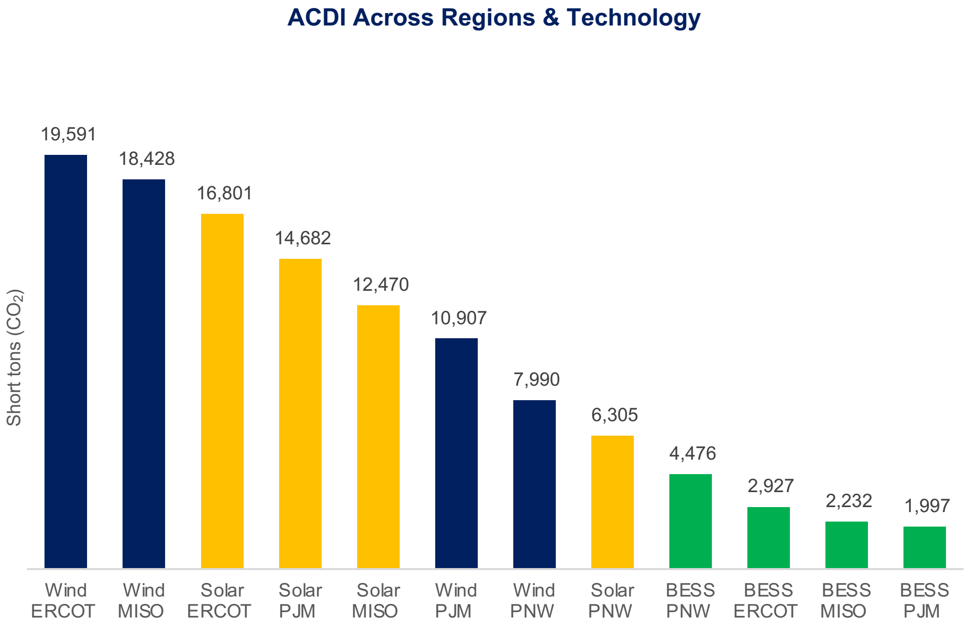
*Note: subsidized scenario based on PTC and ITC elect suggestion in segment LCOE

Tax Incentives Across Regions & Technologies



Key Takeaways

- The underlying grid GHG intensity (both seasonal and intraday) have a meaningful impact on the ACDI. For example, the grid in the PNW is already partially GHG-free at the margin due to large hydro resources, particularly in the shoulder months.
- The MISO's grid is relatively dirty at the margin in most hours and seasons. As a result, GHG reductions are relatively high across all hours. As such, the higher the capacity factor, the higher the ACDI regardless of the seasonal or intraday profile.
- ERCOT experiences the highest capacity factor for wind and comes in a close second for highest solar capacity factor, resulting in a high ACDI impact. However, the ACDI does not account for curtailment, which may occur more frequently in West Texas due to covariance of wind generation and LMP.
- BESS unsurprisingly offers the lowest ACDI due to round trip efficiency losses.

Competitive Analysis

Key developers for each technology and in each region

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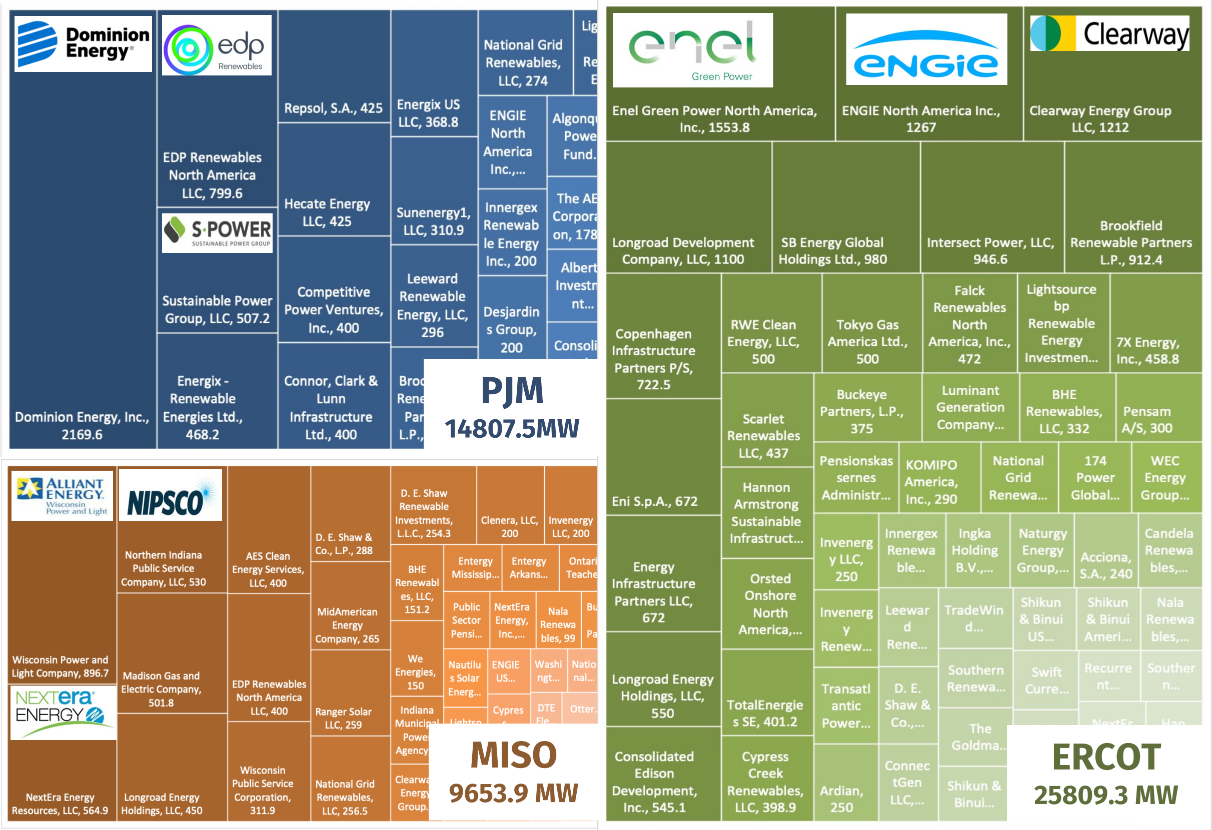
Solar



- **Scale:** ERCOT has an operating capacity of 25,809 MW for solar, larger than the other two regions combined. Enel, Engie, and Clearway lead the solar development in ERCOT.
- **Market concentration:** MISO has the highest level of market concentration, with top 10 developers accounting for nearly half of the total market share (47%). In comparison, this number is roughly 42% and 39% for PJM and ERCOT. PJM has the highest number of developers across three regions.
- **Investment attractiveness:** Regardless of relatively low PPA price, ERCOT is still seeing active solar developments.

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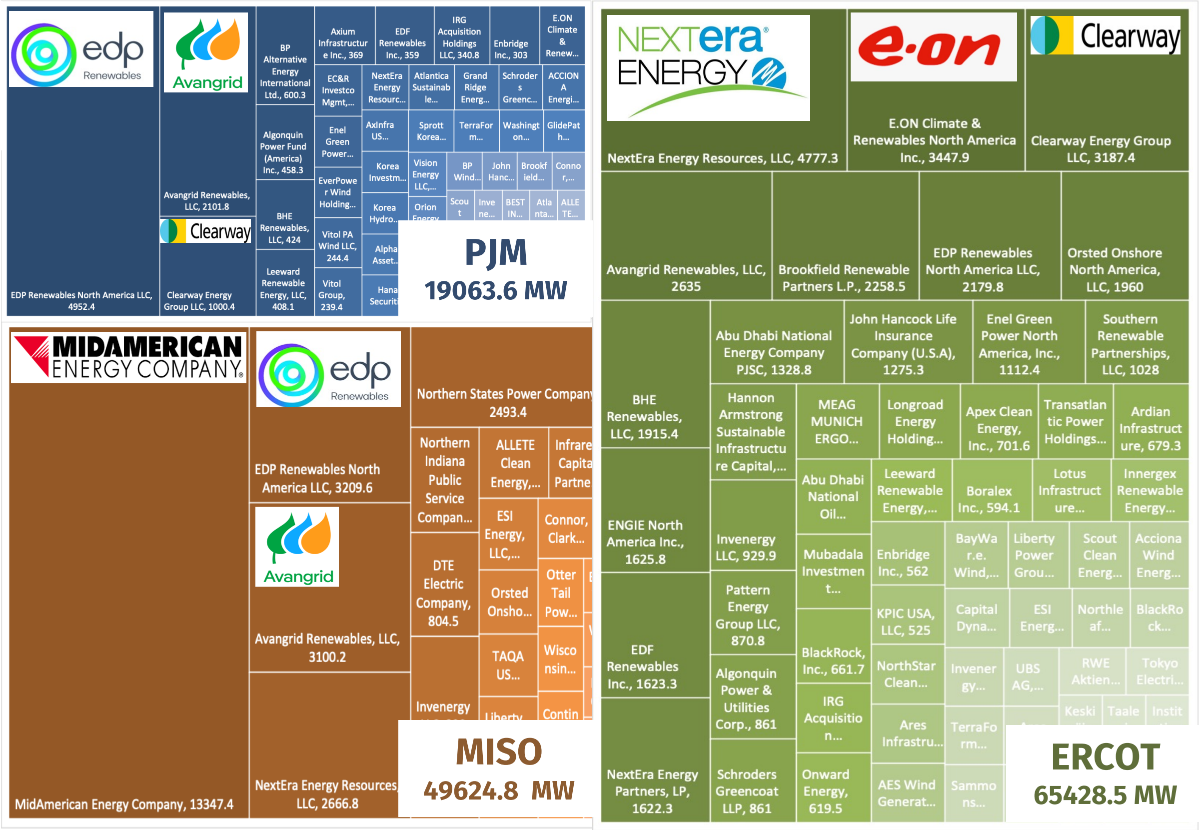
Wind



- **Scale**: The total wind operating capacity in ERCOT is 65,428 MW, larger than the combined solar capacity from PJM, MISO, and ERCOT (50,270 MW).
- **Market concentration:** Wind has an overall higher market concentration compared to solar. The top 10 wind developers in MISO and PJM account for roughly 60% and 58% of the market share, respectively. However, the wind developer concentration is much lower in ERCOT, with the top 10 developers making up roughly 40% of the market share. ERCOT also has the largest number of wind developers among the three regions.
- **Major developers:** EDP and Avangrid have a major presence in both PJM and MISO. Clearway has a dominant role in both PJM and ERCOT.

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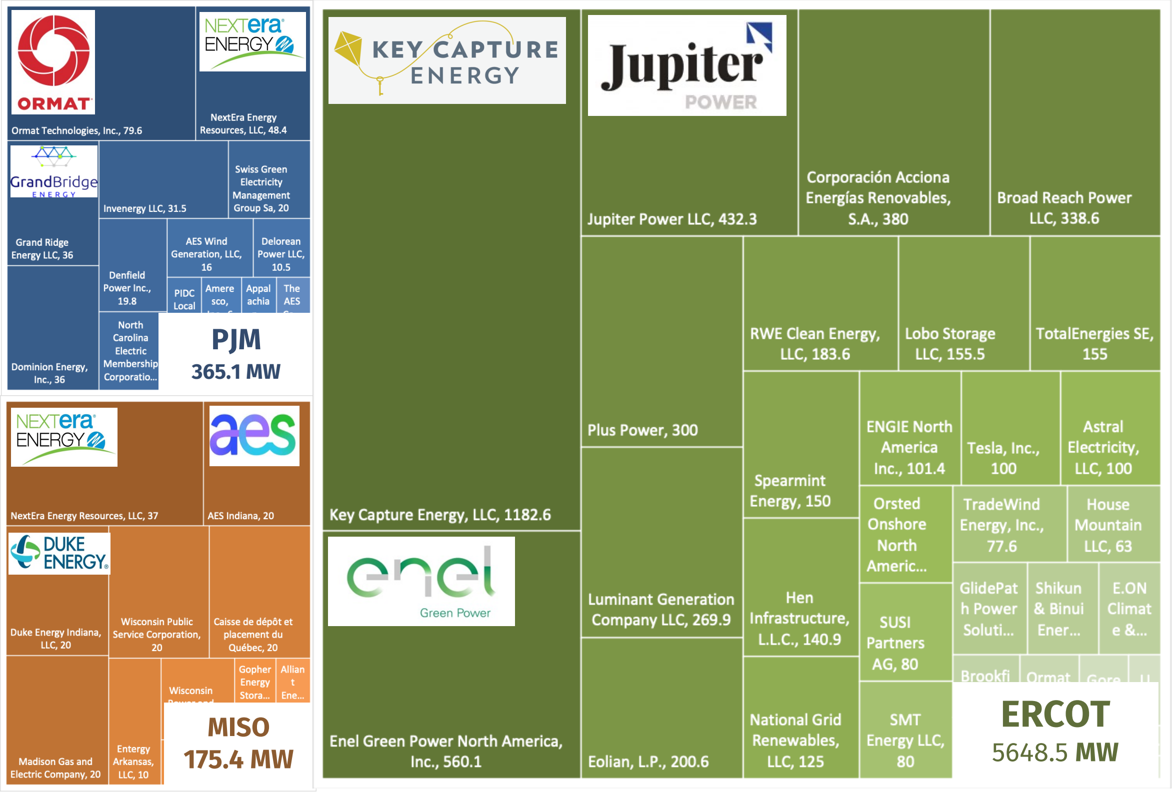
BESS



- **Scale:** ERCOT is ramping up its battery energy storage, boasting an operational capacity of 5,648 MW, partially driven by persistent grid reliability issues. The battery storage market in ERCOT is roughly ten times that of PJM and MISO combined.
- **Market concentration:** Battery storage projects have a much higher market concentration compared to wind and solar, largely because there are fewer players in the field. The top 5 battery storage project developers account for 63% and 66% of the market share in PJM and MISO, respectively. The number stands at 51% for ERCOT.
- **Major developers:** Key Capture Energy, Enel, and Jupiter Power lead the battery storage deployment in ERCOT.

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Green Hydrogen Industry

Key Takeaways:

- Green hydrogen industry still in its nascent phase, rendering the sector **difficult to invest** in from a **lender perspective**.
- **Low demand** and end-use capability leads to **limited offtake opportunity** resulting in projects that only offer uncontracted revenue with only asset value to collateralize any debt investments.
- Fossil fuels and other alternative renewable energy sources provide a clear substitutable option at lower cost. The **key cost driver is the cost of renewable energy**.
- Current LCOH in the U.S. around **$4.5-6.5/kg**, even with IRA tax incentives - **$2/kg** is the production cost threshold where green hydrogen could displace alternatives. **40 to 60%** of production costs **depend** on the **electricity price for renewables.**

Opportunities for CACIB:

- **Low competitive rivalry** and **low threat of new entry** could provide **significant first-mover advantage** for firms able to establish strong presence in the industry, that is highly likely to grow (i.e. project demand to grow 4 to 6x by 2050).

Key Companies

- **Air Liquide**
- **Air Products**
- **Bloom Energy**
- **Acciona**
- **Engie**
- **Linde**
- **Nel ASA**
- **Enel Spa**
- **Iberdola Group**
- **Uniper SE**

Porter's Five Forces Ranking

- ***Supplier Power*** – High
- ***Buyer Power*** – High
- ***Threat of New Entrants*** – Low
- ***Threat of Substitution*** – High
- ***Competitive Rivalry*** – Low

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Carbon Capture Industry

Key Takeaways:

- Carbon Capture industry and associated projects still struggle from **high failure rates (up to 70%)**, heightening the lending risk.
- Capital intensity, site-specific challenges, and insufficient scale **bar new entrants and burden existing ones.**
- Multiple potential revenue streams exist for captured carbon emissions, but **limited viable end-use cases**, and **lack of successful monetization** weaken the business case.
- Higher uptake of low-carbon alternatives like green steel and general grid decarbonization, coupled with higher costs, lead to higher switching costs to CCS technology.
- Policy and tax incentives while significant ($50-&180/ton), **don't translate to standalone cost competitiveness** – both retrofits and new plant CCS facilities are significantly more expensive.

Opportunities for CACIB:

- Capitalization of one or more revenue streams: Voluntary Carbon Market Offset, Enhanced Oil Recovery, and low-carbon feedstock usage opportunity could precipitate a distinct advantage for a firm.

Key Companies

- **CarbFix**
- **Carbon Free**
- **Quest CCS**
- **Carbon Engineering**
- **Aker Carbon Capture**
- **Carbon Clean**
- **Lanza Tech**
- **SAIPEM**
- **Climeworks**
- Global Thermostat

Porter's Five Forces Ranking

- ***Supplier Power*** – High
- ***Buyer Power*** – High
- ***Threat of New Entrants*** – Low
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Appendix

Additional information on the Inflation Reduction Act, renewable technology costs, market fundamentals, and compitative analysis

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IRA Incentives

Production Tax Credit

Before the IRA

- The PTC provided a credit per kilowatt-hour (kWh) of electricity produced by eligible renewable energy sources like wind, biomass, and hydropower. The credit was subject to phase-down schedules similar to the ITC. For wind projects, the PTC had decreased to 60% of its original value by 2021.

After the IRA

- The PTC has been restored to its full rate of 2.6 cents per kilowatt-hour (adjusted annually for inflation) for projects that begin construction before 2025.
- The PTC can also benefit from bonus credits for domestic content and location in energy communities, potentially increasing the credit by an additional 10% for each criterion met.

Investment Tax Credit

Before the IRA

- The ITC for eligible technologies was set to step down over time. In 2021, the rate was 26% for projects that began construction, scheduled to drop to 22% in 2022, and then to 10% permanently for large-scale projects

After the IRA

- The IRA resets the ITC to 30% for projects that begin construction before 2025.
- The IRA also introduces the possibility to qualify for bonus credits. For example, projects can earn an additional 10% if they meet domestic content requirements and another 10% if they are situated in energy communities, potentially raising the ITC to as high as 50%.

Bonus Credits Eligibility requirements

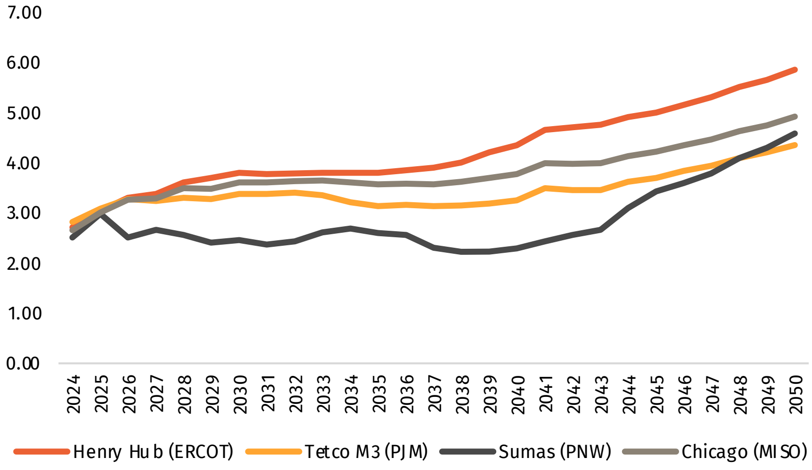
- **Domestic Content Requirement:** To receive the domestic content bonus credit of 10%, projects typically need to demonstrate that a significant portion of their construction and operational materials and equipment are sourced from within the United States.
- **Energy Community Requirement:** Projects located in energy communities qualify for an additional 10% bonus.
- Energy communities are defined as areas that meet one or more of the following criteria:
- Areas with a significant number of coal, oil, or natural gas jobs, including counties with retired or retiring coal power plants.
- Areas historically reliant on fossil fuel-related industries, including regions economically impacted by job losses in fossil fuel sectors.

Cost and Net Capacity Factors

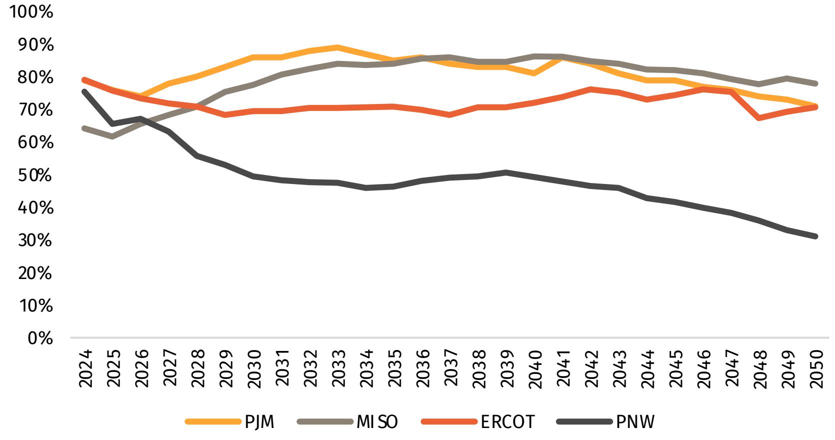
Technology		Onshore Wind	Solar Tracking	Lithium-Ion
Overnight Capex ($/kW)	*PJM*	2,290	1,498	1,777
	ERCOT	1,971	1,483	1,759
	MISO	2,103	1,694	1,848
	PNW	2,100	1,549	1,795
Fixed O&M ($/kW-yr)	*PJM*	32.18	17.79	56.00
	ERCOT		17.79	55.54
	MISO		23.98	57.84
	PNW		17.79	56.46
Capacity Factor, %	*PJM*	24%	27%	N/A
	ERCOT	45%	30%	
	MISO	42%	24%	
	PNW	34%	19%	
Interconnection Cost, $/kW	*PJM*	240		
	ERCOT	150		
	MISO	156		
	PNW	100		

Natural Gas and Energy Prices

Gas Basis Prices (real 2023 $/mmBtu)



Gas Percent of Hours Marginal (%)



- Natural gas-fired generation is expected to remain on the margin in PJM West, Central MISO and ERCOT. Therefore, gas prices is expected to continue to be highly correlated to energy prices
- PNW is expected to deviate somewhat from natural gas prices (Sumas) due to large hydro baseload resources, which increasingly operate on the margin during the shoulder months
- Natural gas prices overall are supported by increased LNG exports in the early 2030s, as well as decreasing supply long-term

PJM

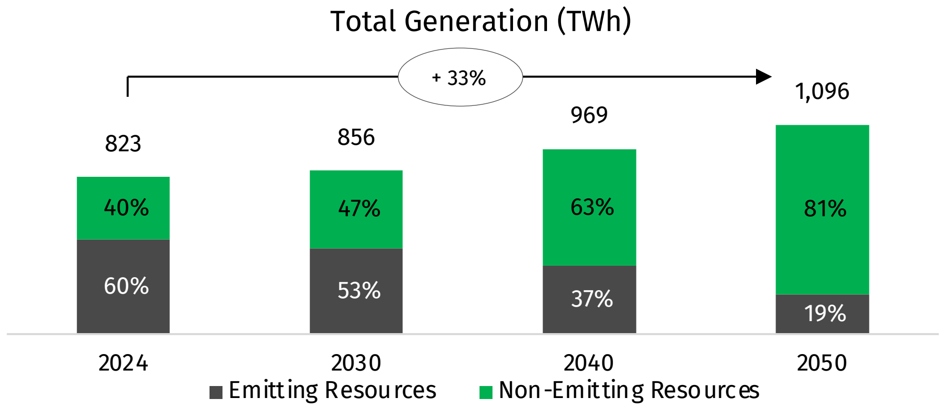
PJM Interconnection is an RTO that coordinates the movement of wholesale electricity in all or parts of DE, IL, IN, KY, MD, MI, NJ, NC, OH, PA, TN, VA, WV, and DC.

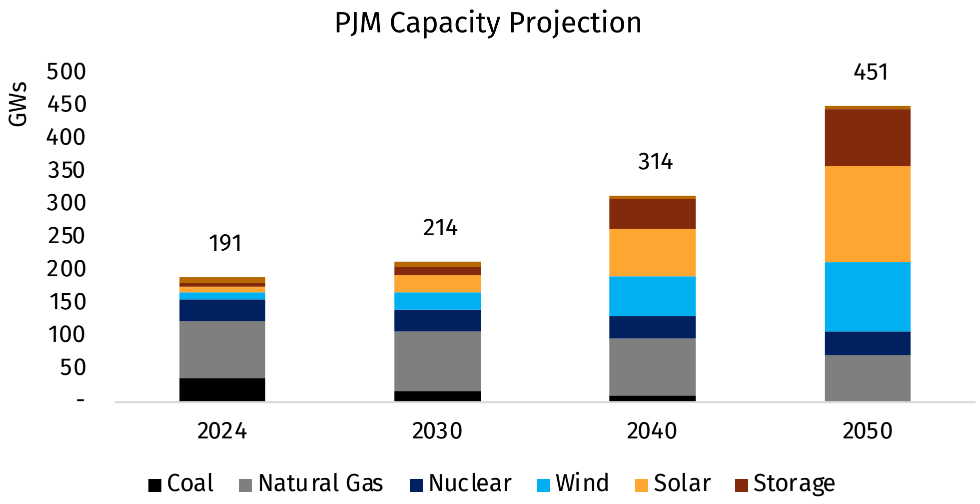
Clean Energy: Driven by the phase-out of coal and solar/wind expansion, PJM's clean energy generation will expand substantially over the next decades. In the short-to-medium term, however, natural gas will still account for a significant portion of PJM's installed capacity.

Policy: Eastern States generally have more robust clean energy policies – for example, DC and NJ have goals of 100% electricity by 2032 and 2035. DE, MD, NJ, and PA have joined the Regional Greenhouse Gas Initiative (RGGI), a "cap-and-invest" program for emissions reduction.

C&I Demand: Data centers are driving growing C&I demand in PJM. Virginia, specifically Northern Virginia, is considered a top location in the US for data centers, due to its high-density fiber optic cable networks. The region has witnessed a 25% CAGR in data centers from 2014 to 2021.

Merchant: Gas will largely continue to be the marginal unit for PJM over the next decades. Merchant electricity prices in PJM will be dependent on gas prices.





MISO

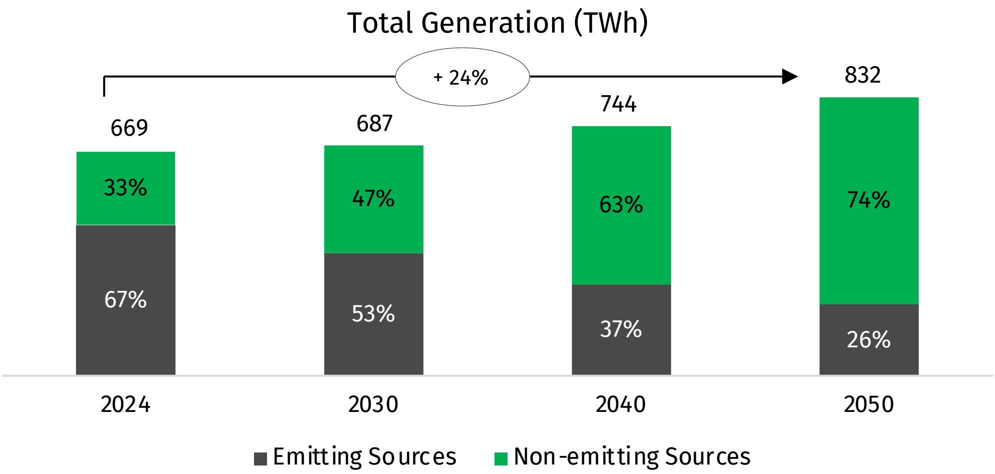
MISO is an independent system operator that operates in 15 states from Minnesota to Louisiana. It has about 60 participating electric distribution utilities.

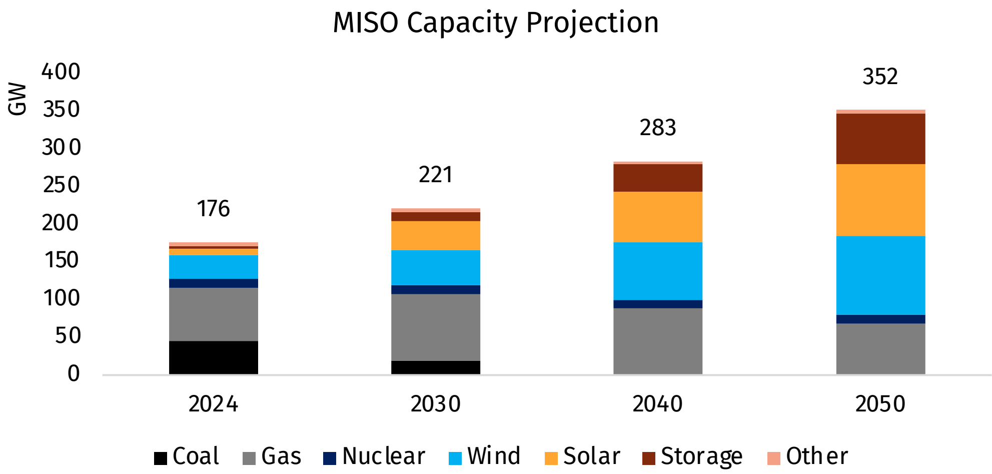
Clean Energy: MISO has a relatively dirty grid but is aiming to transition into a more decarbonized grid. Non-emitting sources are expected to expand from 33% to 74% of total generation from 2024 to 2050.

Policy: MN and MI represent states with progressive clean energy policies, with targets of 100% clean energy by 2040. States in MISO South have less progressive clean energy policies.

C&I Demand: C&I demand for PPAs in MISO is also driven by data center growth, as well as the manufacturing and industrial load in MI and IN.

Merchant: Gas will largely continue to be the marginal unit for MISO over the next decades. Merchant electricity prices in MISO will be dependent on gas prices.





Pacific Northwest

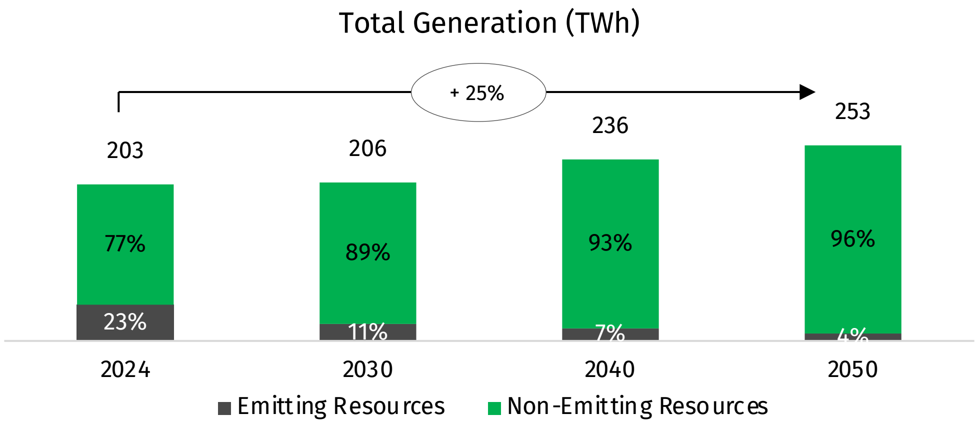
The Pacific Northwest has no single regional transmission operator (RTO) or independent system operator (ISO), but instead uses multiple balancing authorities (BAs) to manage supply/demand.

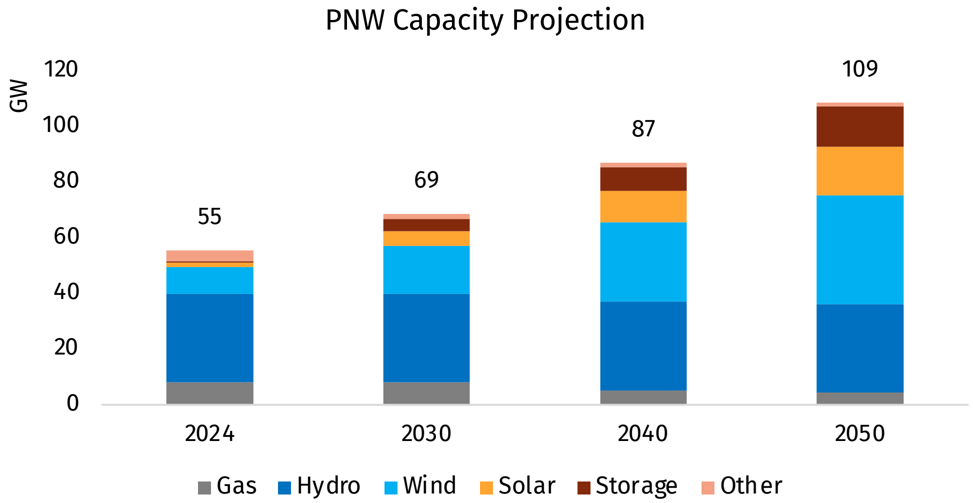
Clean Energy: PNW has a relatively clean grid with large hydro penetration. Non-emitting sources will further expand from 77% to 96% of total generation from 2024 to 2050.

Policy: Large hydro penetration simplifies PNW's decarbonization efforts. Also, starting from Jan. 2023, WA has implemented a cap-and-investment program known as the Climate Commitment Act, setting a limit on overall emissions.

C&I Demand: PNW has a health base of C&I demand for corporate PPAs.

Merchant: PNW will have more hydro plants on the margin in the coming decades, impacting profitability in shoulder months. However, most PNW BAs are planning on joining the Western Resource Adequacy Program (WRAP) and the region is generally expected to be tight on winter capacity. Therefore, even though the region is long on energy supply in the shoulder, PNW is still in needs clean energy with high reliability value in the winter (BESS can fill that gap).





ERCOT

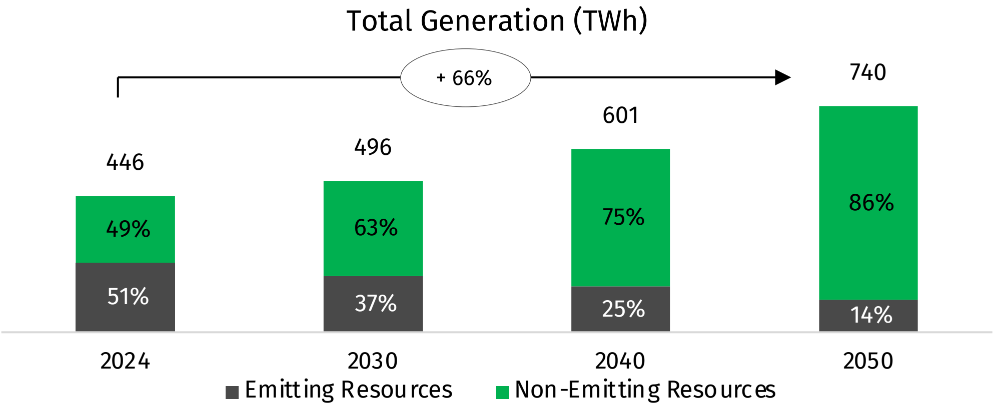
ERCOT serves as an independent system operator, managing the flow of electricity to over 26 million customers and overseeing Texas's competitive wholesale power market, which accounts for approximately 90% of the state's electric load.

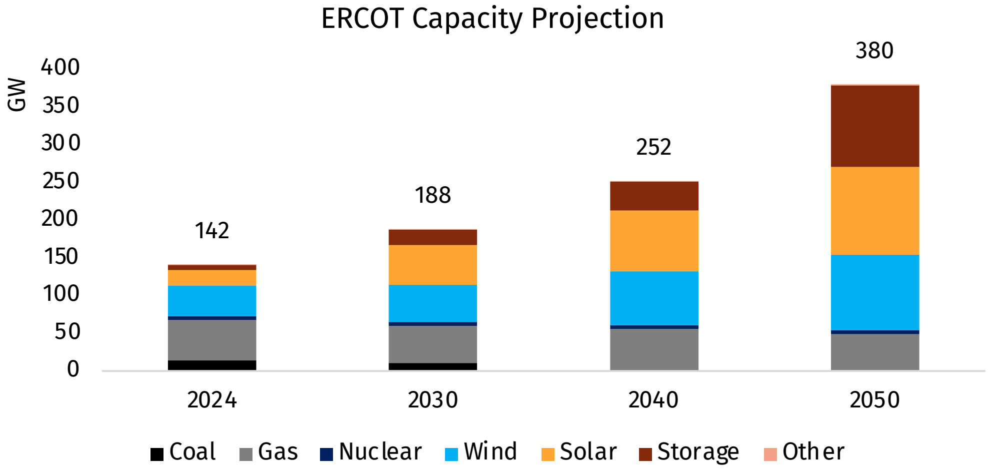
Clean Energy: ERCOT is expected to satisfy its growing electricity demand in the coming decades with non-emitting resources, which will expand from 49% to 86% of total generation from 2024 to 2050. ERCOT’s low barrier to entry has resulted in a huge pipeline of renewable projects in development.

Policy: ERCOT does not have very progressive clean energy policies. ERCOT acts as the program administrator of the Renewable Energy Credit (REC) trading program established by the Public Utility Commission of Texas. However, Texas has no Renewable Portfolio Standard requirements.

C&I Demand: Dallas, Huston, and Austin are well positioned for data centers, driving C&I demand in ERCOT. ERCOT’s Generic Transmission Constraint (GTC) increases the demand to reduce price volatility and risk via corporate PPAs.

Merchant: Gas will largely continue to be the marginal unit for ERCOT over the next decades. Merchant prices in ERCOT will depend on gas prices. GCT in ERCOT can lead to price volatility.





Competitive Analysis – Carbon Capture

Supplier Power:

- Each project is unique, requiring unique components – no out-of-the-box solutions
- Concentrated market of suppliers since CCS project are highly specialized

Buyer Power:

- High change costs associated with Carbon Capture
- U.S. responsible for 60% global industrial emissions - many buyers
- Products with lower carbon footprint have proven higher WTP from consumers, which could provide potential cost pass-through opportunity

Threat of New Entry:

- Extremely onerous permitting process, esp. safety and env. regulations
- Projects are capital-intensive for both new builds and retrofits
- Section 45Q IRA Tax Credit improves economics ($50-180 pt captured and sequestered), but hard to utilize

Threat of Substitution:

- High uptake of other low-emissions technologies (e.g. green steel)
- Less efficient than other renewables
- CCUS Tech like pipelines and compression already bespoke

Competitive Rivalry:

- 121 CCS projects currently in development in North America
- Projects have 70% failure rate
- Limited viable end-use options of captured carbon

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Competitive Analysis - Green Hydrogen

Supplier Power:

- Economics highly dependent on electricity price for renewables (40-60% of cost)
- Feedstock and equipment supply inadequate to satisfy acute spikes in demand
- Costs and expectations have risen substantially (LCOH is about $4.5 - 6.5 per kg), up by 30% to 65%.

Buyer Power:

- High degree of price uncertainty – WTP will be impacted by future policies (e.g. carbon tax)
- Lack of long-term offtake agreements and associated risk cited as the major concern for financing GH projects
- Customers less willing to pay green premium

Threat of New Entry:

- By 2050, green hydrogen demand forecasted at 73-100% (125 to 585 Mtpa) of total hydrogen demand
- Sections 45V and 45Q IRA Tax Credits improve economics cutting LCOH by 40-66%

Threat of Substitution:

- Green hydrogen is not competitive today compared to fossil fuel alternatives
- Less efficient than other renewables
- Wider availability of more mature and proven renewable energy storage solutions (i.e. Li-Ion Battery)

Competitive Rivalry:

- Over 248 projects announced across North America
- 1,400 projects announced globally equaling USD 570 billion of investment and 45 million tons per annum through 2030

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