EMPIRICAL ANALYSIS OF TOTAL FACTOR PRODUCTIVITY TRENDS IN THE U.S. ELECTRIC DISTRIBUTION INDUSTRY (UPDATED)

Prepared for

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DISCLAIMER

London Economics International LLC ("LEI") was retained by Eversource Energy Services, Company. ("Eversource") on behalf of its operating subsidiary Connecticut Light and Power ("CL&P" or "the Company") to prepare an industry total factor productivity ("TFP") study. LEI has made the qualifications noted below with respect to the information contained in this TFP Study and the circumstances under which the report was prepared.

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Table of contents

ACRONYMS **5**

1 EXECUTIVE SUMMARY **7**

1.1 PBR IS A FORM OF REGULATION THAT ENCOURAGES UTILITIES TO SEEK OUT AND IMPLEMENT EFFICIENCY IMPROVEMENTS 9
1.2 INDUSTRY TFP STUDIES ARE USED TO CALIBRATE ELEMENTS OF A PBR REGIME 10
1.3 TFP TRENDS HAVE BEEN NEGATIVE FOR A MAJORITY OF YEARS IN THE U.S. EDC INDUSTRY OVER THE LAST TWO DECADES 11
1.4 DATA FOR THE TFP STUDY COMES FROM RELIABLE SOURCES 13
1.5 TFP STUDY RESULTS SUGGEST THAT A NEGATIVE X FACTOR IS NEEDED TO ENSURE A SUSTAINABLE PBR REGIME 14

2 PRINCIPLES FOR QUANTIFYING TFP TRENDS **16**

2.1 REGULATORY PRECEDENT FOR USING TFP STUDIES TO CALIBRATE THE X FACTOR IN AN I-X REVENUE ADJUSTMENT MECHANISM ("RAM") 17
2.2 TECHNIQUES TO ESTIMATING A TFP TREND FOR THE INDUSTRY 18
2.3 SELECTING AN INDEXING TECHNIQUE 22
2.4 APPROPRIATE LENGTH OF TFP STUDY 23
2.5 MEASURING TFP GROWTH RATES 24
2.6 PRIMARY SOURCES OF DATA 25

3 MEASURING INPUTS AND OUTPUTS **27**

3.1 OVERVIEW OF INPUTS TO THE TFP MODEL 27
3.2 OM&A INPUT IN THE TFP MODEL 27
3.3 CAPITAL INPUT QUANTITY 30
3.4 SELECTING AN OUTPUT METRIC 38

4 INDUSTRY TFP AND PFP RESULTS **41**

4.1 INDUSTRY INPUT INDEX 41
4.2 INDUSTRY OUTPUT INDEX 44
4.3 DETAILED RESULTS FOR INDUSTRY TFP AND PFP GROWTH 45
4.3.1 Industry total factor productivity *45*
4.3.2 Industry partial factor productivity *47*

5 NORTHEAST REGION TFP AND PFP RESULTS **50**

5.1 NORTHEAST REGION INPUT INDEX 51
5.2 NORTHEAST REGION OUTPUT INDEX 53
5.3 DETAILED RESULTS FOR NORTHEAST REGION TFP AND PFP GROWTH 54
5.3.1 Northeast Region TFP *54*
5.3.2 Northeast Region partial factor productivity *56*

6 CONVERTING THE ESTIMATED U.S. AND NORTHEAST REGION TFP ANNUAL AVERAGE GROWTH RATES INTO AN X FACTOR **59**

7 APPENDIX A: LIST OF EDCS INCLUDED IN THE INDUSTRY TFP STUDY BY BLS REGION **61**

7.1 MIDWEST 61
7.2 NORTHEAST 62
7.3 SOUTH 62

7.4 WEST 63

8 APPENDIX B: SENSITIVITY ANALYSIS - INDUSTRY AND NORTHEAST TFP AND PFP RESULTS USING SALES AS THE OUTPUT METRIC 64

8.1 INDUSTRY AND NORTHEAST REGION INPUT INDEX 67
8.2 INDUSTRY AND NORTHEAST REGION OUTPUT INDEX USING SALES AS THE OUTPUT METRIC 67
8.3 DETAILED RESULTS FOR INDUSTRY AND NORTHEAST REGION TFP AND PFP GROWTH USING SALES AS THE OUTPUT METRIC 68
8.3.1 Industry and Northeast Region total factor productivity using sales as the output metric 68
8.3.2 Industry and Northeast Region partial factor productivity 71
8.4 CONVERTING THE ESTIMATED U.S. INDUSTRY AND NORTHEAST REGION TFP ANNUAL AVERAGE GROWTH RATE INTO AN X FACTOR USING SALES AS THE OUTPUT METRIC 72

9 APPENDIX C: SENSITIVITY ANALYSIS - INDUSTRY AND NORTHEAST REGION TFP AND PFP RESULTS USING HYPERBOLIC DEPRECIATION OF CAPITAL 75

9.1 ASSUMPTIONS REQUIRED UNDER HYPERBOLIC DEPRECIATION 75
9.2 U.S. INDUSTRY AND NORTHEAST REGION INPUT INDEX 77
9.3 INDUSTRY AND NORTHEAST REGION OUTPUT INDEX 79
9.4 DETAILED RESULTS FOR U.S. INDUSTRY AND NORTHEAST TFP AND PFP GROWTH USING HYPERBOLIC DEPRECIATION OF CAPITAL 79
9.4.1 Industry and Northeast Region total factor productivity using hyperbolic depreciation of capital 82
9.4.2 U.S. Industry and Northeast Region partial factor productivity using hyperbolic depreciation of capital 85
9.5 CONVERTING THE ESTIMATED U.S. INDUSTRY AND NORTHEAST REGION TFP ANNUAL AVERAGE GROWTH RATE INTO AN X FACTOR USING HYPERBOLIC DEPRECIATION OF CAPITAL 86

10 APPENDIX D: INTRODUCTION TO LONDON ECONOMICS INTERNATIONAL LLC 89

10.1 BACKGROUND ON THE FIRM 89
10.2 RELEVANT EXPERIENCE 90

11 APPENDIX E: OVERVIEW OF THE EDC INDUSTRY IN THE U.S. 95

11.1.1 CUSTOMER AND SALES GROWTH IN THE U.S. ELECTRIC DISTRIBUTION INDUSTRY 95
11.1.2 CUSTOMER AND SALES GROWTH AMONG ELECTRIC DISTRIBUTION COMPANIES IN THE NORTHEAST REGION 97

12 APPENDIX F: LIST OF SOURCES 100

Table of Figures

FIGURE 1. INDUSTRY TFP, OM&A PFP, AND CAPITAL PFP ANNUAL AVERAGE GROWTH RATES, 2005-2024 8
FIGURE 2. ANNUAL GROWTH RATES FOR INDUSTRY OUTPUT, INPUT, PFP, AND TFP 11
FIGURE 3. ELECTRIC DISTRIBUTION INDUSTRY TFP VS. U.S. PRIVATE BUSINESS SECTOR TFP (2005-2024) 13
FIGURE 4. INDUSTRY X FACTOR RESULTS 2005-2024 15
FIGURE 5. GENERALIZED CONCEPT OF A TFP GROWTH RATE 16
FIGURE 6. EMPIRICAL TECHNIQUES FOR ESTIMATING TFP 19
FIGURE 7. INDEXATION TECHNIQUES 22
FIGURE 8. CALCULATING AVERAGE TFP GROWTH FOR A STUDY PERIOD OF 2005-2024 24
FIGURE 9. REPORTED OM&A COSTS OF THE 88 EDCS IN LEI'S TFP STUDY (NOMINAL $) 29
FIGURE 10. AVERAGE INPUT PRICE INDEX FOR OM&A 1988-2024 OF THE 88 EDCS 30
FIGURE 11. CAPITAL ASSET (WITH USEFUL SERVICE LIFE OF 35 YEARS) DEPRECIATION PROFILES 33
FIGURE 12. NORMALIZED BLS PPI TREND 1988-2024 (1988=1) 35
FIGURE 13. REAL CAPITAL QUANTITY FROM 2005 TO 2024 FOR THE U.S. EDC INDUSTRY, 1988 $000S 36
FIGURE 14. TOTAL NUMBER OF CUSTOMERS SERVED VS. ELECTRICITY SALES (REFLECTING ALL 88 EDCS STUDIED) 39
FIGURE 15. TOTAL NUMBER OF CUSTOMERS SERVED VS. ELECTRICITY SALES GROWTH RATES (REFLECTING ALL 88 EDCS STUDIED) 40
FIGURE 16. CHAINED FISHER IDEAL INDICES FOR INDUSTRY TFP, INPUTS, AND OUTPUT 41
FIGURE 17. CHAINED FISHER IDEAL INDEX FOR INDUSTRY CAPITAL 42
FIGURE 18. CHAINED FISHER IDEAL INDEX FOR INDUSTRY OM&A 43
FIGURE 19. CHAINED FISHER IDEAL INDEX FOR TOTAL INDUSTRY INPUTS (CAPITAL AND OM&A) 44
FIGURE 20. CHAINED FISHER IDEAL INDEX FOR TOTAL INDUSTRY OUTPUT (CUSTOMERS) 45
FIGURE 21. CHAINED FISHER IDEAL INDEX FOR INDUSTRY TFP 46
FIGURE 22. ANNUAL GROWTH RATES FOR INDUSTRY OUTPUT, INPUT, PFP, AND TFP 47
FIGURE 23. CHAINED FISHER IDEAL INDEX FOR INDUSTRY CAPITAL PFP 48
FIGURE 24. CHAINED FISHER IDEAL INDEX FOR INDUSTRY OM&A PFP 49
FIGURE 25. CHAINED FISHER IDEAL INDICES FOR NORTHEAST REGION TFP, INPUTS, AND OUTPUT 50
FIGURE 26. CHAINED FISHER IDEAL INDEX FOR NORTHEAST REGION CAPITAL 51
FIGURE 27. CHAINED FISHER IDEAL INDEX FOR NORTHEAST REGION OM&A 52
FIGURE 28. CHAINED FISHER IDEAL INDEX FOR TOTAL NORTHEAST REGION INPUTS (CAPITAL AND OM&A) 53
FIGURE 29. CHAINED FISHER IDEAL INDEX FOR TOTAL NORTHEAST REGION OUTPUT (CUSTOMERS) 54
FIGURE 30. CHAINED FISHER IDEAL INDEX FOR NORTHEAST REGION TFP 54
FIGURE 31. ANNUAL GROWTH RATES FOR NORTHEAST REGION OUTPUT, INPUT, PFP, AND TFP 56
FIGURE 32. CHAINED FISHER IDEAL INDEX FOR NORTHEAST REGION CAPITAL PFP 57
FIGURE 33. CHAINED FISHER IDEAL INDEX FOR NORTHEAST REGION OM&A PFP 58
FIGURE 34. INDUSTRY X FACTOR RESULTS 2005-2024 60
FIGURE 35. NORTHEAST REGION X FACTOR RESULTS 2005-2024 61
FIGURE 36. CHAINED FISHER IDEAL INDICES FOR INDUSTRY TFP, INPUTS, AND OUTPUT USING SALES AS THE OUTPUT METRIC 65
FIGURE 37. CHAINED FISHER IDEAL INDICES FOR NORTHEAST TFP, INPUTS, AND OUTPUT USING SALES AS THE OUTPUT METRIC 66
FIGURE 38. CHAINED FISHER IDEAL INDEX FOR TOTAL INDUSTRY AND NORTHEAST OUTPUT (SALES) 67

FIGURE 39. CHAINED FISHER IDEAL INDEX FOR INDUSTRY AND NORTHEAST REGION TFP USING SALES AS THE OUTPUT METRIC 69
FIGURE 40. ANNUAL GROWTH RATES FOR INDUSTRY OUTPUT, INPUT, PFP, AND TFP USING SALES AS THE OUTPUT METRIC 70
FIGURE 41. ANNUAL GROWTH RATES FOR NORTHEAST OUTPUT, INPUT, PFP, AND TFP USING SALES AS THE OUTPUT METRIC 70
FIGURE 42. CHAINED FISHER IDEAL INDEX FOR INDUSTRY AND NORTHEAST CAPITAL PFP USING SALES AS THE OUTPUT METRIC 71
FIGURE 43. CHAINED FISHER IDEAL INDEX FOR INDUSTRY AND NORTHEAST OM&A PFP USING SALES AS THE OUTPUT METRIC 72
FIGURE 44. U.S. INDUSTRY X FACTOR RESULTS 2005-2024 USING SALES AS THE OUTPUT METRIC 74
FIGURE 45. NORTHEAST REGION X FACTOR RESULTS 2005-2024 USING SALES AS THE OUTPUT METRIC 74
FIGURE 46. AVERAGE AGE OF PRIOR 35 YEARS OF REAL CAPITAL ADDITIONS 76
FIGURE 47. CHAINED FISHER IDEAL INDEX FOR U.S. INDUSTRY AND NORTHEAST REGION CAPITAL USING HYPERBOLIC DEPRECIATION OF CAPITAL 78
FIGURE 48. CHAINED FISHER IDEAL INDEX FOR TOTAL INDUSTRY AND NORTHEAST REGION INPUTS (CAPITAL AND OM&A) 79
FIGURE 49. CHAINED FISHER IDEAL INDICES FOR U.S. INDUSTRY TFP, INPUTS, AND OUTPUT USING HYPERBOLIC DEPRECIATION OF CAPITAL 80
FIGURE 50. CHAINED FISHER IDEAL INDICES FOR NORTHEAST REGION TFP, INPUTS, AND OUTPUT USING HYPERBOLIC DEPRECIATION OF CAPITAL 82
FIGURE 51. CHAINED FISHER IDEAL INDEX FOR U.S. INDUSTRY AND NORTHEAST REGION TFP USING HYPERBOLIC DEPRECIATION OF CAPITAL 83
FIGURE 52. ANNUAL GROWTH RATES FOR U.S. INDUSTRY OUTPUT, INPUT, PFP, AND TFP USING HYPERBOLIC DEPRECIATION OF CAPITAL 84
FIGURE 53. ANNUAL GROWTH RATES FOR NORTHEAST REGION OUTPUT, INPUT, PFP, AND TFP USING HYPERBOLIC DEPRECIATION OF CAPITAL 84
FIGURE 54. CHAINED FISHER IDEAL INDEX FOR THE U.S. INDUSTRY AND NORTHEAST REGION CAPITAL PFP USING HYPERBOLIC DEPRECIATION OF CAPITAL 86
FIGURE 55. U.S. INDUSTRY X FACTOR RESULTS 2005-2024 USING HYPERBOLIC DEPRECIATION OF CAPITAL 87
FIGURE 56. NORTHEAST REGION X FACTOR RESULTS 2005-2024 USING HYPERBOLIC DEPRECIATION OF CAPITAL 88
FIGURE 57. SELECTED LEI CLIENTS THROUGHOUT THE WORLD 89
FIGURE 58. AVERAGE CUSTOMER GROWTH AND ELECTRICITY SALES GROWTH IN THE U.S. EDC INDUSTRY 95
FIGURE 59. TOP 5 ELECTRIC DISTRIBUTION UTILITIES IN TERMS OF 2024 TOTAL NUMBER OF CUSTOMERS ACROSS THE U.S. (88 EDCS) 96
FIGURE 60. TOP 5 EDCS IN TERMS OF 2024 TOTAL SALES VOLUME ACROSS THE U.S. (88 EDCS) 97
FIGURE 61. TOP 5 ELECTRIC DISTRIBUTION UTILITIES IN TERMS OF 2024 TOTAL NUMBER OF CUSTOMERS ACROSS THE NORTHEAST REGION 98
FIGURE 62. TOP 5 EDCS IN TERMS OF 2024 TOTAL SALES VOLUME ACROSS THE NORTHEAST REGION 99

Acronyms

A&G	Administrative and General
ASL	Average Service Life
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BLS PPI	Bureau of Labor Statistics Producer Price Index
CAGR	Compound Annual Growth Rate
CL&P	The Connecticut Power and Light Company
CPI	Consumer Price Index
EIA	U.S. Energy Information Administration
ECI	Employment Cost Index
EDC	Electric Distribution Company
EEI	Edison Electric Institute
FERC	Federal Energy Regulatory Commission
FRED	Federal Reserve Economic Data
GDP	Gross Domestic Product
GDP-FSDP	GDP Implied Price Deflator for Final Sales to Domestic Purchasers
HWI	Handy Whitman Index
IOU	Investor-Owned Utility
LBNL	Lawrence Berkeley National Laboratory
LEI	London Economics International LLC
OHS	One-Hoss-Shay
OM&A	Operations, Maintenance, and Administrative
MFP	Multifactor Productivity
NBER	National Bureau of Economic Research
OM&A	Operations, Maintenance, and Administrative Expenses
OPG	Ontario Power Generation
PBR	Performance-Based Regulation
PFP	Partial Factor Productivity
PIM	Performance Incentive Mechanism
PURA	Connecticut Public Utilities Regulatory Authority
RAM	Revenue Adjustment Mechanism
ROE	Return on Equity
SCADA	Supervisory Control and Data Acquisition
TFP	Total Factor Productivity
TIPS	Treasury Inflation-Protected Securities
US	United States

UK	United Kingdom
WACC	Weighted Average Cost of Capital

1 Executive Summary

London Economics International LLC ("LEI") was retained by The Connecticut Light and Power company ("CL&P" or "the Company") to perform an industry total factor productivity ("TFP") study ("Industry TFP Study") for electric distribution companies ("EDCs") operating across the United States ("U.S.") to support the Company's proposed performance-based regulation ("PBR") framework. Under the proposed I-X approach, allowed revenues would be adjusted during the PBR term using an inflation factor ("I Factor") less an X Factor calibrated using productivity evidence. LEI also recommends that the Company's PBR framework rely on the national industry trends.[1]

LEI's Industry TFP Study, which covers 88 EDCs and approximately 90% of the total number of customers served by IOUs in the U.S. as of 2024.[2] LEI's Industry TFP study for EDCs uses customers as the output metric, total inputs are based on a composite of capital costs and operations, maintenance, and administrative ("OM&A") expenses, a One-Hoss-Shay ("OHS") capital depreciation profile, a 35-year average service asset life, and the Bureau of Labor Statistics Producer Price Index ("BLS PPI") as the capital deflator. The study timeframe covers year over year trends over the period of 20 years, from 2005 through 2024.[3]

The 20-year average U.S. industry TFP growth rate is -1.40%. While TFP measures how efficiently the industry uses all inputs collectively—including labor, OM&A, and capital—partial factor productivity ("PFP") provides additional insight by examining each major input separately to help explain what is driving the overall TFP results. For example, the OM&A PFP measures how much utility output is produced for each unit of OM&A used, while the capital PFP measures how much output is produced for each unit of capital deployed. The Industry Study produced 20-year average annual OM&A PFP and capital PFP growth rates of -0.01% and - 2.67%, respectively (see Figure 1). The less negative OM&A PFP relative to the capital PFP suggests that capital input growth was the larger driver of the overall TFP decline. Section 4 provides a discussion on the TFP and PFP Industry results.

[1] LEI also studied the Northeast Region industry trends, and this is discussed in Section 6.

[2] Appendix A (Section 9) provides a list of EDCs included in LEI's Industry TFP Study.

[3] At the time that LEI was performing this study, 2025 annual data was not readily available for all EDCs in the study.

Figure 1. Industry TFP, OM&A PFP, and capital PFP annual average growth rates, 2005-2024

TFP, OM&A PFP, and capital PFP	20-year industry average
TFP	-1.40%
OM&A PFP	-0.01%
Capital PFP	-2.67%

If the I Factor selected for a total revenue cap PBR framework is set to an economy-wide output-based inflation index, then certain computation adjustments would need to be made to convert the industry TFP trends to a theoretically robust X Factor; therefore, this report also documents those computation adjustments.[4] LEI estimated that the 20-year average U.S. industry TFP growth rate of -1.40%, if paired with a national Gross Domestic Product Implicit Price Deflator for Final Sales to Domestic Purchasers ("GDP-FSDP") I Factor, would require an X Factor of -1.95%. If a customized input-based inflation index is selected for the I Factor, then there is no need for adjustment, and the X Factor should be set based on the U.S. industry TFP growth rate. Section 6 discusses the conversion of the average TFP to an X Factor.

LEI also looked at the average TFP trends for the Northeast Region,[5] which is discussed in Section 5 and developed several sensitivity analyses using alternative assumptions, including using sales as the output metric and using a hyperbolic capital depreciation profile, to test the robustness of the results; those are presented in the Appendices B and C to this report.

LEI has extensive experience advising electric and gas utilities, regulators, and other market participants on the design and implementation of PBR plans in the United States, Canada, and internationally. LEI's work has included developing and defending TFP studies, evaluating inflation factors, assessing X Factors, advising on stretch factors, and analyzing other PBR design features such as earnings sharing mechanisms, efficiency carryover mechanisms, capital trackers, revenue adjustment mechanisms, and incremental capital funding mechanisms. LEI has advised

[4] Under this framework, the X Factor is calibrated to reflect both the productivity growth differential between the electric distribution industry and the broader economy, and the input price differential between the broader economy and the industry. This ensures that the I-X formula is aligned with the theoretical foundation of index-based ratemaking and reflects expected cost trends for electric distribution utilities relative to the broader economy.

[5] The Northeast Region, according to the BLS, includes the states of New England (namely Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont), New Jersey, New York, and Pennsylvania. Source: Bureau of Labor Statistics. N*ortheast Census Region*, < https://www.bls.gov/regions/northeast/northeast.htm>

on formulaic I-X approaches, building-block approaches historically used in the United Kingdom ("UK") and Australia, and the RIIO model currently used in the UK. LEI has also testified in PBR proceedings for regulated utilities in various jurisdictions in North America (see Appendix D for further details).

1.1 PBR is a form of regulation that encourages utilities to seek out and implement efficiency improvements

PBR encourages utilities to seek and implement efficiency improvements primarily through financial incentives and accountability mechanisms. PBR decouples a utility's revenue from its actual costs, creating a structure where utility earnings are influenced by performance, not just by covering expenses. This setup inherently incentivizes the utility to improve efficiency and reduce costs to maintain profitability. In addition, because rates are typically set formulaically for a multi-year period and accompanied by "stay-out" provisions that limit frequent rebasing, PBR can create further incentives for efficiency while also reducing administrative burden and promoting regulatory efficiency for the utility, regulator, and other stakeholders.

PBR's elements that encourage efficiency include the following:

- The use of a **formulaic rate adjustment mechanism**, such as an I-X formula, creates an external benchmark for annual rate changes rather than allowing rates to automatically track the utility's actual costs. If the utility can manage its costs below the revenue path established by the formula, it may retain some of the resulting savings during the PBR term. Conversely, if its costs grow faster than the formula allows, the utility bears greater financial pressure. This creates a stronger incentive to control costs than traditional cost-of-service regulation. By adjusting allowed revenues for inflation less an industry productivity factor, PBR seeks to replicate the incentives for cost control and efficiency improvements found in competitive markets, while operating within a regulatory framework appropriate for a natural monopoly.

- The **X Factor** embeds an expected level of productivity improvement into the rate-setting formula. By reducing the inflation adjustment to reflect expected productivity gains, the X Factor ensures that customers receive a share of efficiency improvements over time. At the same time, utilities have an incentive to outperform the productivity benchmark because they can benefit financially from efficiency gains achieved during the plan term.

- **Multi-year rate periods** strengthen efficiency incentives by reducing the frequency with which cost savings are reset through rebasing. Under traditional regulation, efficiency gains may be passed back to customers relatively quickly in the next rate case. Under PBR, the utility has a defined period during which it can retain a portion of the benefits from improved performance, making cost control and operational efficiency more financially meaningful. This can also reduce administrative burden for the utility, regulator, and

intervenors by limiting the need for repeated full cost-of-service rate cases during the PBR term.

- The **Stretch Factor** ("S Factor"), also referred to as the **customer dividend**, is intended to promote operational efficiency and sharing of those efficiency benefits with customers. It recognizes that some utilities may be less efficient than their peers and creates an incentive for those utilities to improve their performance and move toward industry best practice. At the same time, the S Factor provides customers with an immediate share of the expected efficiency gains during the PBR term, rather than requiring them to wait until the next rate case, where regulators and the utility would identify efficiency gains and their impact on costs of service through re-basing process.

- **Performance metrics, scorecards, and incentive mechanisms** help ensure that cost reductions are not achieved at the expense of service quality, reliability, safety, or customer outcomes. This is particularly important in Connecticut, where CL&P already operates within a regulatory framework that includes service quality and reliability oversight, and annual reliability reporting. These existing requirements reduce the risk that a multi-year rate plan would encourage cost containment at the expense of core utility obligations.

- **Capital funding mechanisms** can help ensure that a multi-year PBR framework remains sustainable where CL&P expects capital investment needs during the plan term to differ materially from historical trends. A properly designed capital funding mechanism can provide a mechanism for addressing qualifying capital-related revenue requirements within the PBR term, while preserving the broader efficiency incentives created by the I-X formula and stay-out provisions. This helps distinguish between costs that should be managed through efficiency improvements and capital investment needs that may warrant separate treatment.

1.2 Industry TFP studies are used to calibrate elements of a PBR regime

PURA and stakeholders have been studying how to implement PBR for regulated utilities for a number of years. The discussions in Docket No. 21-05-15RE01 (Investigation into Revenue Adjustment Mechanisms for a Performance-Based Regulation Framework) supported an evidence-based and transparent approach to developing a PBR revenue cap formula, including the determination of the X Factor. Throughout the proceeding, stakeholders and PURA staff discussed the use of a TFP study submitted as part of a utility's rate application to inform the determination of the X Factor, recognizing that the X Factor is intended to reflect industry productivity trends and refine the inflation-based I Factor within the revenue cap formula.

LEI's independent analysis of industry TFP trends for U.S. EDCs was conducted in a manner consistent with the principles discussed in Docket 21-05-15RE01.[6] Specifically, the LEI's Industry TFP study is transparent, based on credible data, reproducible, evidence-based, implemented using an open-source Excel model, and includes alternative scenarios to facilitate review and evaluation.

Furthermore, LEI's Industry TFP study is similar to other industry TFP reports and analyses that have been used by regulators around the world to calibrate the parameters of formulaic-based price cap or revenue cap regimes, as well as other forms of PBR. Regulators have chosen to move to PBR in other jurisdictions to balance the need for operational efficiency, the achievement of public policy goals, and utility's financial stability, all while providing customer benefits like improved service and cost control.[7] Section 2 explains the theoretical foundation for PBR and the role of a TFP study.

1.3 TFP trends have been negative for a majority of years in the U.S. EDC industry over the last two decades

Based on LEI's index-based analysis of the U.S. EDC industry, the industry experienced an annual average TFP trend of -1.40% over the period 2005 to 2024. A negative TFP growth rate means that the quantity of inputs (capital and OM&A) grew faster than the quantity of outputs (number of customers served). Figure 2 below shows that the total inputs served grew at a higher rate on average (at 2.18% per year) compared to the growth in the quantity of output measured across U.S. EDCs (at 0.78% per year) over the period.

Figure 2. Annual growth rates for industry output, input, PFP, and TFP

[6] Connecticut Public Utilities Regulatory Authority. *PURA Investigation into Revenue Adjustment Mechanisms for a Performance-Based Regulation Framework*. July 14, 2025.

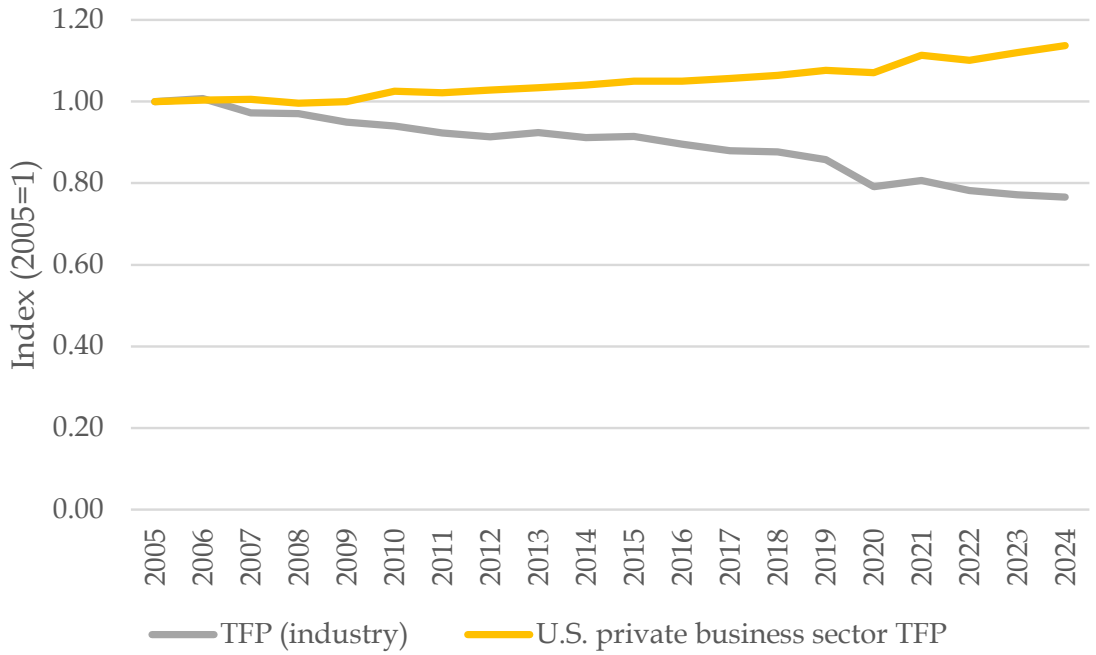
[7] For example, Hawaii decided to transition to PBR to support its renewable energy transition, improve customer experience and affordability, encourage utility efficiency, reduce regulatory burden, promote innovation and flexibility, and maintain utility's financial stability. See Hawaii Public Utilities Commission. *Performance-Based Regulation for the Hawaiian Electric Companies*. 2026.

	Output	Input			Productivity		
Year	Customers	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	1.25%	2.01%	-0.77%	0.48%	-0.76%	2.02%	0.77%
2006-2007	1.12%	2.11%	6.78%	4.68%	-0.99%	-5.66%	-3.56%
2007-2008	0.68%	2.40%	-0.37%	0.89%	-1.72%	1.06%	-0.21%
2008-2009	0.10%	2.99%	1.62%	2.25%	-2.88%	-1.51%	-2.15%
2009-2010	0.39%	1.86%	0.97%	1.38%	-1.47%	-0.58%	-0.99%
2010-2011	0.19%	2.34%	1.87%	2.09%	-2.15%	-1.68%	-1.90%
2011-2012	0.45%	3.09%	-0.05%	1.41%	-2.64%	0.50%	-0.96%
2012-2013	0.56%	3.18%	-4.01%	-0.56%	-2.62%	4.56%	1.12%
2013-2014	0.61%	3.53%	0.58%	2.03%	-2.92%	0.03%	-1.42%
2014-2015	0.78%	3.87%	-3.10%	0.41%	-3.10%	3.87%	0.36%
2015-2016	0.90%	4.23%	1.72%	3.00%	-3.33%	-0.82%	-2.11%
2016-2017	0.92%	4.27%	1.07%	2.73%	-3.35%	-0.15%	-1.81%
2017-2018	0.75%	4.23%	-2.40%	1.09%	-3.48%	3.15%	-0.34%
2018-2019	0.92%	4.49%	1.41%	3.04%	-3.57%	-0.49%	-2.12%
2019-2020	0.98%	4.89%	13.70%	9.12%	-3.91%	-12.72%	-8.14%
2020-2021	0.97%	3.39%	-6.24%	-0.97%	-2.42%	7.21%	1.94%
2021-2022	1.40%	3.27%	6.23%	4.49%	-1.88%	-4.83%	-3.09%
2022-2023	0.80%	4.42%	-1.03%	2.20%	-3.62%	1.84%	-1.39%
2023-2024	1.02%	4.90%	-3.02%	1.69%	-3.88%	4.04%	-0.67%
Annual average 2005-2024	**0.78%**	**3.44%**	**0.79%**	**2.18%**	**-2.67%**	**-0.01%**	**-1.40%**

Increases in the quantity of inputs involve more OM&A spending and more capital deployment. A negative TFP result does not, by itself, demonstrate poor operating decisions or inefficiency. It is simply the mathematical consequence of investment cycles, increasing requirements for businesses to provide their services. This is true for the electric distribution business as well as other industries.

Notably, LEI's estimate of electric distribution industry TFP index declined over the study period, while U.S. private business sector TFP increased as indicated by BLS' calculations. Since 2005, the EDC TFP index fell from the starting point of 1.00 in 2005 to roughly 0.77 by 2024, whereas the U.S. private business sector TFP index rose to approximately 1.14 (Figure 3). This divergence indicates that the EDC sector experienced a difference set of drivers of TFP trends as compared to the broader U.S. economy over this period, which is reflected in the TFP differential used to calculate the X Factor (if the I Factor is set at US GDP-FSDP).

Figure 3. Electric distribution industry TFP vs. U.S. private business sector TFP (2005-2024)



Source: BLS. *Private Business Sector: Total Factor Productivity*. 2026.

1.4 Data for the TFP study comes from reliable sources

Operational and financial data were required to measure the quantities of inputs used by EDCs, including labor, non-labor OM&A expenses, and capital, as well as the quantity of output produced, proxied by the number of customers served.[8] To support this analysis, LEI collected 37 years of operational and financial data for EDCs, covering the period from 1988 through 2024, from FERC Form 1, as well as customer data from Electricity Information Administration ("EIA") 861. Section 2.6 discusses the data used in LEI's Industry TFP Study.

LEI's Industry TFP Study covers 88 EDCs and represents approximately 90% of the total number of customers served by investor-owned utilities ("IOUs") in the U.S as of 2024. A large sample ensures that the Study accurately represents the whole national EDC sector.[9] EDCs can vary widely in size, efficiency, and operational practices. By covering a significant portion, the TFP analysis becomes more representative and captures the diversity of the EDC industry, leading to

[8] In Appendix B (Section 8), LEI also presents the detailed results of the TFP calculations using electricity sales, rather than number of customers. The directional and relative trends are similar under the alternative output metric.

[9] Appendix E (Section 11) provides an overview of the EDC sector.

more reliable conclusions around industry trends. For the theoretical underpinnings of a formula-based (I-X) PBR framework to hold, the X Factor needs to rely on industry average trends.

1.5 TFP Study results suggest that a negative X Factor is needed to ensure a sustainable PBR regime

If the I Factor is based on an inflation index that measures price changes for the inputs used by the electric distribution industry, then the X Factor can be based directly on the industry's TFP trend estimated in the TFP analysis. As discussed in Section 1.3, LEI's TFP study estimates a 20-year average TFP growth rate of -1.40%. Accordingly, under an input price-based I Factor, the corresponding X Factor would also be negative, reflecting the industry's observed decline in productivity over the study period. The study likewise estimates negative PFP growth rates for both OM&A and capital.

If CL&P proposes using BEA's economy-wide implicit GDP Implicit Price Deflator for Final Sales to Domestic Purchasers ("GDP-FSDP") as the I Factor, this I Factor would reflect economy-wide inflation in the prices of final goods and services purchased by U.S. residents, rather than inflation specific to the electric utility industry. Unlike industry-specific input price indices, the GDP-FSDP provides a broad measure of domestic inflation across the economy over a given period.[10,11] More specifically, the GDP-FSDP measures changes of prices of all final goods and services produced domestically.[12] Because the GDP-FSDP reflects economy-wide inflation rather than consumer prices alone, it can be used as the inflation component of an I-X revenue cap and paired with a productivity-based X Factor. The estimated TFP trend of -1.40%, if paired with an I Factor that relies on GDP-FSDP, would require an X factor of -1.95% in order to ensure a sustainable regulatory environment consistent with the theory of PBR (see Figure 4 for the detailed calculation). Section 6 explains further the adjustments that are made to convert a TFP growth rate into an X Factor estimate if the I Factor is set based on GDP-FSDP.

As discussed earlier, a negative X Factor does not imply that the PBR plan lacks incentives for efficiency or productivity improvements. Instead, it recognizes that the industry's historical

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[10] Bureau of Economic Analysis. *Prices & Inflation*. 2026.; Bureau of Economic Analysis. *Concepts and Methods of the U.S. National Income and Product Accounts*. 2024.

[11] Bureau of Labor Statistics. *Comparing the Consumer Price Index with the gross domestic product price index and gross domestic product implicit price deflator*. 2024.; Bureau of Economic Analysis. *Measuring the Economy; A Primer on GDP and the National Income and Product Accounts*. Web. December 2015. P.2.

[12] In contrast, the Consumer Price Index ("CPI") measures changes in the prices paid by households for a representative basket of consumer goods and services and is intended to measure changes in the cost of living. This may suggest it is less suitable from a relevancy perspective at capturing inflationary pressures impacting the electric distribution industry. Nevertheless, if CPI is used as I Factor, there would need to similar adjustments as GDP-FSDP to get to X Factor.

productivity growth has been negative, reflecting that the quantity of inputs required to provide electric distribution services has increased faster than the growth in output over the study period. Incorporating this observed productivity trend into the I-X formula allows the revenue cap to better reflect the industry's efficient cost trajectory while continuing to ensure that the utilities provide reliable services to their customers and preserve incentives for utilities to improve productivity beyond the level assumed in the revenue cap formula.

Figure 4. Industry X Factor results 2005-2024

Year	TFP differential			Input price differential			X-factor
	Calculated industry TFP	National TFP	Difference	GDP FDD + National TFP	Weighted average of OM&A price and capital price	Difference	
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	0.77%	0.32%	0.4%	3.6%	6.1%	-2.5%	-2.08%
2006-2007	-3.56%	0.27%	-3.8%	3.0%	0.4%	2.6%	-1.22%
2007-2008	-0.21%	-0.97%	0.8%	1.9%	5.0%	-3.1%	-2.35%
2008-2009	-2.15%	0.41%	-2.6%	0.0%	-1.4%	1.4%	-1.19%
2009-2010	-0.99%	2.51%	-3.5%	4.0%	2.9%	1.1%	-2.36%
2010-2011	-1.90%	-0.40%	-1.5%	2.0%	3.0%	-1.0%	-2.45%
2011-2012	-0.96%	0.68%	-1.6%	2.4%	2.1%	0.4%	-1.29%
2012-2013	1.12%	0.58%	0.5%	2.0%	1.8%	0.2%	0.75%
2013-2014	-1.42%	0.60%	-2.0%	2.2%	2.0%	0.2%	-1.84%
2014-2015	0.36%	0.91%	-0.5%	1.1%	0.6%	0.6%	0.05%
2015-2016	-2.11%	0.01%	-2.1%	0.7%	0.7%	0.0%	-2.09%
2016-2017	-1.81%	0.64%	-2.4%	2.4%	2.7%	-0.3%	-2.72%
2017-2018	-0.34%	0.71%	-1.0%	2.9%	-0.3%	3.2%	2.18%
2018-2019	-2.12%	1.21%	-3.3%	2.6%	1.0%	1.6%	-1.68%
2019-2020	-8.14%	-0.56%	-7.6%	0.8%	0.6%	0.1%	-7.46%
2020-2021	1.94%	3.94%	-2.0%	8.2%	15.6%	-7.5%	-9.46%
2021-2022	-3.09%	-1.04%	-2.1%	5.9%	8.8%	-2.9%	-4.99%
2022-2023	-1.39%	1.66%	-3.1%	5.2%	0.0%	5.2%	2.12%
2023-2024	-0.67%	1.58%	-2.2%	4.0%	0.7%	3.3%	1.02%
Annual average 2005-2024	**-1.40%**	**0.69%**	**-2.09%**	**2.89%**	**2.75%**	**0.14%**	**-1.95%**

Note: National TFP is added to GDP-FSDP to approximate economy-wide input price growth. This is because GDP-FSDP is an output price index that measures changes in the prices of final goods and services purchased by domestic users. Because economy-wide productivity growth allows a given bundle of inputs to produce more output over time, output price inflation generally understates the growth in input prices. Adding national TFP growth to GDP-FSDP therefore provides an approximation of economy-wide input price growth, making it more comparable to the input price inflation faced by electric distribution utilities.

2 Principles for quantifying TFP trends

TFP is used to calibrate a formulaic approach to PBR because, in theory, it lets the regulator set rates as if the utility were operating under competitive market pressure.

TFP measures the total quantity of output(s) produced by a firm (or group of firms) relative to the quantity of inputs employed. As implied in the name, a **total** factor productivity metric should cover all inputs to the production process. For purposes of ratemaking and specifically for input to a comprehensive price cap or revenue cap plan under PBR, an industry TFP study is needed that reports the growth rate or year-over-year rate of change in TFP levels. Moreover, TFP trends should be based on **quantities** of inputs and outputs, not simply annual operating costs.[13] In this way, the industry TFP study captures the changes in the overall physical productivity of firms within the industry over time. Figure 5 shows the generalized formula for measuring TFP growth over time.

Figure 5. Generalized concept of a TFP growth rate

$$TFP\ growth\ rate = \frac{\%\Delta\ weighted\ sum\ of\ the\ quantities\ of\ all\ outputs}{\%\Delta\ weighted\ sum\ of\ the\ quantities\ of\ all\ inputs}$$

If a business uses many inputs, then there are many types of productivity that could be measured. For example, to assess labor productivity, one would look at the ratio that represents the quantity of output relative to the quantity of labor inputs used. Capital productivity would be measured as a ratio of the quantity of output relative to the quantity of capital deployed. A single input, such as labor or capital, is a partial measure of productivity (also known as PFP). In contrast, a TFP measure covers output(s) relative to all inputs.[14] The distinction between the TFP measure and the PFP measure, therefore, lies in the number of inputs analyzed.

An industry TFP study measures the changes in overall productivity over time for the industry as whole. A TFP study is not a benchmarking study, as it does not report relative efficiency levels at a given point in time. Also, it is important to keep in mind that a TFP study, by its nature, is not a forecast of future productivity. Rather, an industry TFP study relies on historical data and reports historical trends. An industry TFP study will not focus on any single regulated firm. The premise of PBR rests on the idea that firms in the same industry will face similar pressures for

[13] LEI commenced the data collection process with identification of operating expenses and other financial data. LEI then deflated the data by an appropriate input price index to estimate a proxy for a physical quantity. Prices are also needed to form input weights; this is described further in Section 4.

[14] Organization for Economic Co-operation and Development. *Measuring Productivity: Measurement of aggregate and industry-level productivity growth*. 2001.

costs and output growth, and therefore an industry TFP growth trend is a reasonable target to impose on a regulated firm operating within the industry.

When the initial conceptual model for a PBR framework was proposed by economists in the 1980s, the theory drew from observations in competitive industries around how prices are set and how firms operate. No single firm in a competitive market can unilaterally set prices or shield itself from the inflationary pressures all firms face for their inputs; instead, firms are under continuous pressure to manage costs and compete for customers. By aligning a regulated firm's rate trajectory with industry-wide TFP growth and general inflation trends, regulators aim to simulate these same competitive pressures, using industry TFP as a proxy for the incentives that competitive markets naturally produce. The long-run[15] average productivity growth rate achieved by the industry therefore informs regulators on the choice of an explicit productivity target or X Factor under an "I-X" price cap or revenue cap regulatory regime. Under this framework, I represents an inflation index, typically a broad economy-wide measure such as the Consumer Price Index ("CPI") or a sector-specific input price index, that captures changes in the cost of inputs the utility uses to deliver service. X is the productivity offset, reflecting the rate at which the utility is expected to improve its efficiency. Together, the I-X formula determines the annual change in a utility's allowed prices or revenues: prices may rise by the rate of inflation (I) less the expected productivity gain (X), ensuring customers share in efficiency improvements over time. Nevertheless, a TFP study, while grounded in historical data, is crucial for the development of an evidence-based formula for the I-X structure. Without this empirical foundation, setting the X Factor risks being arbitrary and unsustainable.

2.1 Regulatory precedent for using TFP studies to calibrate the X Factor in an I-X revenue adjustment mechanism ("RAM")

TFP studies have been used in other jurisdictions pursuing a form of PBR. Jurisdictions in North America that have performed a TFP Study to inform and calibrate an I-X RAM include Alberta

(Canada),[15] British Columbia (Canada),[16] Hawaii,[17] Massachusetts,[18] New Hampshire,[19] and Ontario (Canada).[20] Although the TFP levels and parameters for the X may differ from electricity and gas industries, the structure of a formulaic (I-X) RAM and the importance of having an evidence-based assessment of TFP trends to support decision-making around the X Factor, is equally applicable.

2.2 Techniques to estimating a TFP trend for the industry

There are a number of methods that can be used to estimate a TFP trend for an industry. TFP methods can be broadly categorized into deterministic methodologies, which "calculate" TFP, and econometric methodologies, which "estimate" TFP. Econometric approaches can either measure the typical level of productivity across firms or identify best-practice performance and assess how far individual firms fall short of it, the latter commonly referred to as an efficiency frontier analysis. Figure 6 below and Section 2.3 give an overview of some of the methods for conducting a TFP study, including the numerical techniques known as the index method, data envelopment analysis, and Stochastic Frontier Analysis.

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[15] National Economic Research Associates, Inc. *In the Matter of AUC Proceeding 27388 Independent Evidence of Jeff D. Makholm*. January 19, 2023; Alberta Utilities Commission. *2024-2028 Performance-Based Regulation Plan for Alberta Electric and Gas Distribution Utilities, Decision 27388-D01-2023*. October 4, 2023.

[16] FortisBC Energy Inc. and FortisBC Inc. *Application for Approval of a Rate Setting Framework for 2025 through 2027*. British Columbia Utilities Commission. April 8, 2024.

[17] Pacific Economics Group Research LLC. *New X Factor Research for HECO*. Hawaii Public Utilities Commission Docket No. 2018-0088. May 13, 2020. Available as Exhibit A in Filing No. F-168221 (Companies' Correction to their Second Updated Comprehensive Proposal, filed May 14, 2020), Document 00012C3E.PDF.

[18] National Grid. *Direct Testimony of Mark E. Mietzen, Ph.D and Nicolas A. Crowley, MS (Performance-Based Ratemaking Panel)*. Massachusetts D.P.U. 20-120. November 13, 2020; NSTAR Gas Company, *NSTAR Gas Company. Direct Testimony of Julia Frayer and Marie Fagan* (London Economics International LLC). Massachusetts D.P.U. 19-120. November 8, 2019; *Direct Testimony of Mark E. Meitzen, PhD (Christensen Associates)*. Massachusetts D.P.U. 17-05. January 17, 2017; Meitzen, Mark E. and Crowley, Nicholas A. *Pre-Filed Direct Testimony of Mark E. Meitzen, Ph.D. and Nicholas A. Crowley, MS*. Exhibit ES-PBR/TFP-1. Massachusetts Department of Public Utilities Docket No. D.P.U. 22-22. January 14, 2022.

[19] Mark B. Kolesar, Kolesar Buchanan & Associates Limited. *Principle Report on Behalf of Public Service Company of New Hampshire d/b/a Eversource Energy, Docket No. DE 24-070, New Hampshire Public Utilities Commission*. June 10, 2024.

[20] Pacific Economics Group Research LLC. *Rate Setting in Ontario: Report to the Ontario Energy Board*. May 2013. Ontario Energy Board. *Partial Decision and Order, Toronto Hydro-Electric System Ltd., Application for Electricity Distribution Rates Beginning January 1, 2025, EB-2023-0195*. November 12, 2024.

Figure 6. Empirical techniques for estimating TFP

	Non-frontier technique	Frontier technique	
Parameters	**TFP Index**	**Data Envelopment Analysis ("DEA")**	**Stochastic Frontier Analysis ("SFA")**
Description	Index number measures the ratio of all outputs (weighted by revenue shares) to all inputs (weighted by cost shares)	Linear programming technique which identifies best practice within a sample by fitting a frontier over the top of the data points and measures relative inefficiencies	Same as DEA but following econometric methods to estimate the efficiency frontier
Data Needs	Quantity and price data on inputs and outputs for 2 or more firms	Quantity data on inputs and outputs for a sample of firms	Quantity data on inputs and outputs for a sample of firms
Advantages	Relatively simple and robust technique. Can incorporate many inputs and outputs with few observations.	Can decompose cost efficiency into component parts, breaking down allocative and technical efficiencies. Can be used without the need for price data. Can easily handle multiple outputs.	Can decompose cost efficiency into component parts, breaking down allocative and technical efficiencies. Accounts for "data noise" (data errors, omitted variables, etc.) and allows for the use of standard statistic tests
Drawbacks	It does not allow for identification of various factors of TFP change such as technical efficiency, scale efficiency, etc.	Requires a large dataset. Sensitive to the way outputs and inputs specified. Can be difficult to explain in a regulatory setting.	Requires large sample size for robust estimates. Require specification of production or cost function. Can be difficult to explain in a regulatory setting.

Source: Coelli et al. *A Primer on Efficiency Measurement for Utilities and Transport Regulators.* 2003.

LEI chose to use an index method. The index method is deterministic and the most straightforward technique for estimating TFP growth over time. Firm-level data is aggregated into an industry-level number representing the quantity of inputs and outputs. Chained indices are formed based on these numbers, and the growth of the input and output indices over time allow for the estimation of the growth rate of TFP.

The index method will not measure performance relative to a hypothetical efficiency frontier[21]; instead, it will measure the actual industry average productivity over time. It is also important to note that an index method, because it is a numerical technique as opposed to a statistical technique, does not give a forecast error measure. Therefore, interpreting changes in index values requires qualitative considerations. Moreover, with an index-based approach, the resulting TFP cannot be segregated into different drivers (e.g., technology versus economies of scale). Also, index methods cannot take into account other business factors affecting productivity, and those must be considered in the selection of the peer grouping for the industry and the input and output data itself.

The benefits of the index method include relative simplicity in calculation and ease of communication. Index methods are more transparent when dealing with outliers, unlike DEA and SFA methods, and require significantly fewer data points/observations to reach a robust conclusion. For these reasons, index methods are often used for informing regulators in ratemaking proceedings.

Index-based approaches have been used by regulators in other jurisdictions to calibrate their PBR plans.

- In Massachusetts, the Department of Public Utilities ("D.P.U.") has relied on TFP studies for several years to set rates for electric and gas distributors, ensuring alignment with industry productivity trends.[22]

- In New Hampshire, Public Service Company of New Hampshire d/b/a Eversource Energy employed an index-based TFP approach in its 2024 PBR filing before the New Hampshire Public Utilities Commission to calculate the X Factor for its proposed revenue-cap PBR plan.[23]

[21] Deterministic methodologies "calculate" TFP values, as opposed to econometric methodologies which "estimate" TFP values.

[22] In Massachusetts D.P.U. 17-05-B, the regulator, the Massachusetts D.P.U. stated that it "has determined that the goals of designing utility rate structures are to achieve efficiency and simplicity as well as to ensure continuity of rates, fairness between rate classes, and corporate earnings stability. The Department has determined that a rate structure achieves the goal of simplicity if it is easily understood by consumers." Massachusetts Department of Public Utilities. *Order Establishing Eversource's Rate Structure, D.P.U. 17-05-B*. January 5, 2018.

[23] Mark B. Kolesar, Kolesar Buchanan & Associates Limited. *Principle Report on Behalf of Public Service Company of New Hampshire d/b/a Eversource Energy, Docket No. DE 24-070, New Hampshire Public Utilities Commission*. June 10, 2024.

- Hawaiian Electric used an index-based TFP approach for its first PBR rate case.[24]

- In Connecticut, Docket No. 21-05-15RE01 discussed the adoption of a TFP study as the basis for the X Factor in its Revenue Cap Formula. PURA described the TFP study as reflecting "average historical trends in multifactor productivity of a group of peer utilities." PURA retained discretion to set the X Factor value, including at zero, based on the evidence presented in each rate proceeding.

- In Alberta, the third generation of PBR included comprehensive TFP studies by consulting firms, covering both the electric and gas distribution sectors.[25]

- In New Hampshire, Eversource Energy's 2024 PBR filing employed an index-based TFP model drawing on FERC and EIA data from 87 electric distribution companies to derive the X Factor.[26]

- In British Columbia, the Utilities Commission approved the continuation of an index-based approach for FortisBC, applying a formula that adjusts unit O&M costs annually by an inflation factor minus an approved productivity factor.[27]

- In Ontario, the Ontario Energy Board ("OEB") has used an index-based TFP approach since its 3rd Generation Incentive Rate-setting (3rd Gen IR) plan in 2008. The subsequent 4th Gen IR built on this foundation, introducing a more Ontario-specific inflation measure and using an index-based TFP study to more precisely calibrate the X Factor for the Province's electricity distribution sector.[28]

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[24] Pacific Economics Group Research LLC. *New X Factor Research for HECO*. Hawaii Public Utilities Commission Docket No. 2018-0088. May 13, 2020. Available as Exhibit A in Filing No. F-168221 (Companies' Correction to their Second Updated Comprehensive Proposal, filed May 14, 2020), Document 00012C3E.PDF.

[25] National Economic Research Associates, Inc. *In the Matter of AUC Proceeding 27388 Independent Evidence of Jeff D. Makholm*. 2023; Alberta Utilities Commission. *2024-2028 Performance-Based Regulation Plan for Alberta Electric and Gas Distribution Utilities, Decision 27388-D01-2023*. 2023.

[26] Mark B. Kolesar, Kolesar Buchanan & Associates Limited. *Principle Report on Behalf of Public Service Company of New Hampshire d/b/a Eversource Energy, Docket No. DE 24-070, New Hampshire Public Utilities Commission*. June 10, 2024.

[27] British Columbia Utilities Commission. *FortisBC Energy Inc. and FortisBC Inc. 2025 to 2027 Rate Setting Framework, Order No. G-70-25*. 2025.

[28] Pacific Economics Group Research LLC. *Rate Setting in Ontario: Report to the Ontario Energy Board*. 2013.

2.3 Selecting an indexing technique

Under the index method, one needs to choose the type of indexing technique. There are several well-known number indexation techniques and resulting index formulations: Laspeyres index, Paasche index, Fisher Ideal index, and Törnqvist index, as shown in Figure 7.

Figure 7. Indexation techniques

$$\text{Laspeyres index} = \frac{P_t * Q_{t-1}}{P_{t-1} * Q_{t-1}} * 100$$

$$\text{Paasche index} = \frac{P_t * Q_t}{P_{t-1} * Q_t} * 100$$

$$\text{Fisher Ideal index} = \sqrt{\text{Laspeyres index} * \text{Paasche index}}$$

Where:

P = price

Q = quantity

t = time

LEI selected the Fisher Ideal index, which is a geometric mean of the Laspeyres and the Paasche indices. The Fisher Ideal index has been shown to have the most reasonable numerical index properties, based on an axiomatic approach by which a set of axioms determined which index would provide the most accurate representation of TFP.[29] These axioms were:

- **Constant quantities test**: if quantities are the same in two periods, then the output index should be the same in both periods irrespective of the price of the goods in both periods;
- **Constant basket test**: if prices are constant over two periods, then the level of output in period 1 compared to period 0 is equal to the value of output in period 1 divided by the value of output in period 0;
- **Proportional increase in outputs test**: if all outputs in period t are multiplied by a common factor, l, then the output index in period t compared to period 0 should also increase by l; and
- **Time reversal test**: if the prices and quantities in period 0 and t are interchanged, then the resulting output index should be the reciprocal of the original index.

[29] Walter E. Diewert. *The Measurement of Productivity: A Survey*. 1993.

When the widely used Laspeyres, Paasche, Tornqvist, and Fisher Ideal indices were evaluated against these tests, only the Fisher Ideal passed all four tests. The Laspeyres and Paasche index failed the time reversal test while the Tornqvist index failed the constant basket test. On the basis of this analysis, Walter E. Diewert (the author of the study which tested the indices) recommended that the Fisher Ideal index be used for TFP work. The Fisher Ideal index is commonly used by government statistical agencies such as the U.S. Bureau of Economic Analysis ("BEA"), in its national income and product accounts.[30]

The Fisher Ideal index can be formed as a chained or unchained index.[31] LEI used the chained Fisher Ideal index because it avoids the index number problem, which arises with fixed weights. The chained Fisher Ideal index overcomes this common "index number problem" by changing the base annually - in each period, the base is the previous period's observation. This allows for the most representative weights possible for each observation.

2.4 Appropriate length of TFP study

The main purpose of conducting a TFP study of this nature is to establish industry trends, which are inherently long term. Logically, the best method of creating a trend is by looking at multiple years of data and performance. The use of multiple years of data limits bias that can be caused by numerical outliers or one-off events that affect performance in any single year. Therefore, a productivity trend should cover a period that extends through a sufficiently long timeframe to limit exposure to one-off circumstances with respect to factors like weather, consumption, lumpy capital spending, and fluctuations in labor costs. However, if the range of data is too long, the estimated average trend may be irrelevant for the purposes of informing future ratemaking initiatives. The timeframe should ideally incorporate more recent data that captures the latest trends in the industry while eliminating earlier time periods with productivity growth drivers that are no longer relevant.

Given data availability and quality (*see* Section 2.6 for further details) and best practices for TFP analysis for regulatory decision-making, LEI believes that the 20-year timeframe of 2005-2024 is appropriate for this study of the U.S. EDC industry. The last 20 years reflect the changing business circumstances in the electric distribution industry, which are also going to continue to drive productivity in the next several years. According to the EIA, these changing business conditions include utilities significantly increasing capital investment to replace aging equipment and install new lines, transformers, and other infrastructure to withstand extreme weather events and manage the intermittency of renewable resources, with distribution capital investment rising

[30] Bureau of Economic Analysis. *Glossary*. 2026.

[31] Indexes are chained by comparing data for each year to the data from the year immediately preceding it (except for the base year). This method provides a more accurate portrayal of year over year growth.

160% from 2003 to 2023.[32],[33] U.S. electricity generation rose 3% in 2024, the largest annual jump in five years, driven by AI data center expansion, industrial electrification, and transportation electrification.[34]

In addition, the Edison Electric Institute ("EEI"), the association representing all U.S. investor-owned electric companies, reported that its member companies invested a record $178.2 billion in 2024 to make the energy grid smarter, stronger, more dynamic, and more secure, marking the 13th consecutive year of record-setting investment. Looking ahead, EEI member companies are projected to invest more than $1.1 trillion between 2025 and 2029.[35]

In summary, the 20-year study period overcomes the high variability of year-on-year trends but is also not so long term as to capture "stale" industry trends that would not likely repeat themselves in the future.

2.5 Measuring TFP growth rates

The key finding of an industry TFP study is a numerical estimate of the TFP growth rate over the study period. LEI calculated the growth rates using natural logs, which calculate the year-on-year changes in the TFP Index. LEI then reported the average of the resulting year-on-year growth rates throughout the study period. As further outlined in Figure 8, a mathematical equivalent can be calculated by (i) taking the natural logarithm of the ratio of the last TFP index value divided by the first TFP index value, and (ii) dividing the resulting value by the number of annual year-on-year observations between the start and end year.[36]

Figure 8. Calculating average TFP growth for a study period of 2005-2024

$$\text{Average industry TFP growth} = \ln\left(\frac{\text{2024 industry TFP index}}{\text{2005 industry TFP index}}\right)/19$$

[32] U.S. Energy Information Administration. *Grid infrastructure investments drive increase in utility spending over last two decades*. 2024.

[33] It should be noted that the period covered by this EIA report differs from the period used in LEI's Industry TFP Study.

[34] Utility Dive. *Investor-owned utilities could spend $1.1T between 2025 and 2029: EEI*. 2025.

[35] Edison Electric Institute. *U.S. Electric Companies Projected to Invest More Than $1.1 Trillion Over the Next Five Years to Power America's Economic and Energy Security*. 2025.

[36] The number of annual changes can be calculated as the number of years for which data is collected as part of the TFP study period minus one. In the example, a study period of 2005-2024 has 20 years of data and (20 – 1 = 19) annual changes over that period.

Average growth is the more common method of measuring the study-period TFP growth rate and has been used in previous studies presented before the Massachusetts Department of Public Utilities.[37] The preference for this method can be attributed to the fact that it calculates the annual growth rates for the TFP index values throughout the study period.

2.6 Primary sources of data

The data gathering process was a fundamental and critical step that required a significant amount of effort in conducting an industry TFP study. The primary data source for this TFP Study included the Federal Energy Regulatory Commission ("FERC") Form 1. LEI also relied on data from the US Bureau of Economic Analysis ("BEA"), the BLS, the Federal Reserve Economic Data ("FRED"), Moody's, Institute of Taxation and Economic Policy, U.S. Department of the Treasury, S&P Capital IQ, and the Internal Revenue Service.

For this Industry TFP Study, LEI sought to include as many electric distribution companies ("EDCs") as possible, subject to the availability and quality of data over the entire study period. Beginning with a population of 144 investor-owned EDCs operating in the United States as of 2024, LEI selected those EDCs with sufficiently complete and reliable data spanning 1988 through 2024. Although the TFP growth analysis covers the period from 2005 through 2024, the benchmark year was established as 1988 to enable the estimation of capital input quantities, which requires historical investment data dating back to the benchmark year. Where appropriate, LEI interpolated isolated missing observations when data were unavailable for a single year but were available for the immediately preceding and following years. Applying these selection criteria resulted in a final sample of 88 EDCs across 48 states.[38] This sample provides a robust representation of the U.S. electric distribution industry, encompassing both small and large

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[37] For example, the average growth approach was used in the TFP study for National Grid in both D.P.U. 23-150 and D.P.U. 26-50 in Massachusetts. Mark E. Meitzen, Ph.D. and Nicholas A. Crowley, MS, Christensen Associates. *Pre-Filed Direct Testimony of Mark E. Meitzen, Ph.D. and Nicholas A. Crowley, MS, Performance-Based Ratemaking Panel, Massachusetts Electric Company and Nantucket Electric Company each d/b/a National Grid, D.P.U. 23-150, Exhibit NG-MM-NC-1*. November 16, 2023. Nicholas A. Crowley and Daniel P. McLeod, Christensen Associates Energy Consulting. *Pre-Filed Joint Direct Testimony of Nicholas A. Crowley, CFA and Daniel P. McLeod, Ph.D., Total Factor Productivity Study, Cost Benchmarking Study, and Performance-Based Regulation Framework Evaluation, Boston Gas Company d/b/a National Grid, D.P.U. 26-50, Exhibit NG-CAEC-1*. January 16, 2026.

[38] A sample of 88 firms is consistent with other TFP studies for U.S. electric distribution sector. For instance, Public Service Company of New Hampshire (DE 24-070) used 87 utilities and NSTAR Electric and Western Massachusetts Electric Company (MA DPU 22-22) used 65 utilities. [Sources: Mark B. Kolesar, Kolesar Buchanan & Associates Limited. *Principle Report on Behalf of Public Service Company of New Hampshire d/b/a Eversource Energy, Docket No. DE 24-070, New Hampshire Public Utilities Commission*. June 10, 2024. Meitzen, Mark E. and Crowley, Nicholas A. *Pre-Filed Direct Testimony of Mark E. Meitzen, Ph.D. and Nicholas A. Crowley, MS*. Exhibit ES-PBR/TFP-1. Massachusetts Department of Public Utilities Docket No. D.P.U. 22-22. January 14, 2022.]

utilities, diverse customer compositions, urban, suburban, and rural service territories, and all BLS regions.[39]

[39] A list of utilities included in LEI's Industry TFP Study is shown in Appendix A (Section 7).

3 Measuring inputs and outputs

Selecting the appropriate inputs and outputs is a crucial part of a TFP study. Intuitively, selected inputs and outputs would be those that most accurately represent the physical process behind the distribution of electricity. At the most basic level, inputs to a TFP study should reflect the quantity of capital deployed[40] and the quantity of OM&A costs. In other words, all major inputs that impact the cost of providing electric distribution service. Together, these inputs form a two-input model formulation. Output should reflect key products or services. For this TFP Study, LEI determined it would be best to use a single output metric, namely the total number of customers served by the distribution network of each EDC, as discussed further below. For comprehensiveness, LEI also tested electricity sales as an alternative output metric, as discussed further in Appendix B (see Section 8).

3.1 Overview of Inputs to the TFP model

The inputs were estimated based on monetary data taken from the annual financial reports and regulatory filings. LEI primarily relied on data at the operating subsidiary level from FERC Form 1 filings, which is compiled by a third-party data provider (S&P Global Market Intelligence). When data was missing and not available directly through the S&P Global Market Intelligence database, LEI conducted additional research (including outreach to state regulatory bodies and/or the EDCs and manually inputted the data from FERC Form 1). The conversion of financial asset data and OM&A cost data into capital quantities and OM&A quantities, respectively, involved several steps that are described further below.

3.2 OM&A input in the TFP model

OM&A inputs reflect the non-capital related expenses that apply to the electric distribution business and associated with sales, distribution customer service, customer account, and administration and general ("A&G") expense categories reported in EDCs' FERC Form 1.[41] A&G expenses are reported on a corporate basis and not solely for the distribution business, so for the purposes of this Study, LEI considered only a proportion of A&G expenses. This proportion was determined for each EDC and year by calculating the share of distribution assets relative to total plant in service.

Cost categories that are not directly relevant to physical productivity of the distribution function of EDCs were excluded. For example, supply costs and/or fuel procurement is generally treated as a pass-through cost, and not part of the distribution PBR rate contemplated by PURA. In

[40] LEI used a monetary approach for estimating capital quantities and have assumed a One Hoss Shay physical depreciation profile. A detailed discussion of this is found in Section 4.1.3.2.

[41] FERC Form 1. Line No. 46. Title of Schedule Electric Operation and Maintenance Expenses. Reference Page No. 320.

addition, LEI excluded FERC Account 908 (Customer Assistance Expenses) from the Industry TFP Study because the objective of the analysis is to measure productivity in the provision of electric distribution service. Account 908 primarily includes expenditures associated with customer assistance and public policy programs, including energy efficiency, demand-side management, customer education, and related activities. These expenditures are largely driven by legislative or regulatory requirements rather than the utility's efficiency in operating and maintaining the electric distribution system. Moreover, the level of these expenditures varies considerably across jurisdictions due to differences in state policy objectives rather than differences in distribution productivity. Including Account 908 would therefore introduce policy-driven variation into the TFP analysis and could bias measured productivity trends downward as customer assistance programs have expanded over time.

Distribution expenses are the largest share of total OM&A expenses, averaging 46% per year, followed by the allocated A&G expenses, which account for another 31% of total OM&A costs at the industry aggregate level. Figure 9 shows the breakdown of the OM&A expense categories recorded across all 88 EDCs in the TFP Study from 2005 to 2024. The aggregate total of OM&A costs in nominal terms (not yet converted to input quantities) for the 88 EDCs in the sample grew at an average rate of 3.01% per year over the TFPs study period (2005-2024).

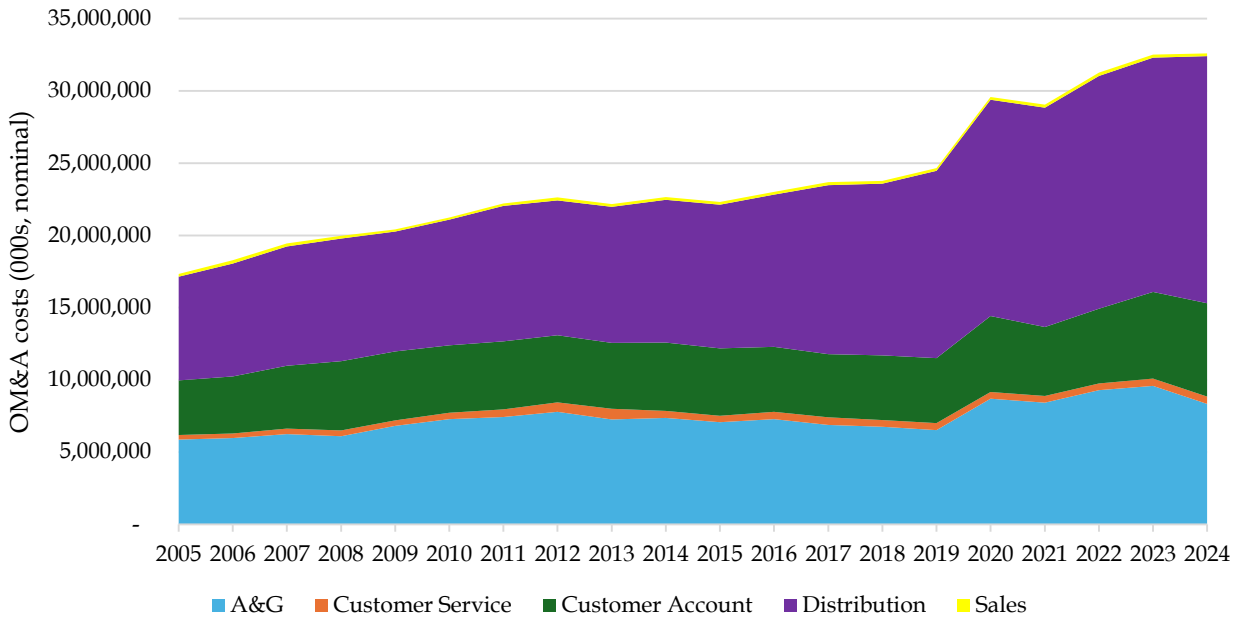
LEI recognizes that OM&A expenditures will include labor as well as non-labor inputs. Therefore, OM&A expenditures will be affected by different inflation pressures; LEI constructed a customized price index that accounts for both labor costs and non-labor costs for purposes of deflating the OM&A expenditures and converting the spending levels into unit measures of input. LEI used the BLS Utilities Employment Cost Index ("ECI") for Total Compensation[42] as the labor cost index and the BEA's economy-wide GDP-FSDP as the non-labor cost index.[43] The BEA explains that GDP-FSDP measures prices paid by domestic purchasers across all economic sectors of the economy. Electric distribution utilities procure both domestically produced and imported materials, equipment, and services to support their operations, the GDP-FSDP provides a more representative measure of the inflation experienced in utility input purchases than other variations of inflation measures based on GDP. The ECI and GDP-FSDP indices are combined based on the non-labor and labor cost shares for each individual EDC. The cost shares for each EDC were determined by dividing the salaries and wages reported in FERC Form 1 for sales,

[42] Bureau of Labor Statistics. *ECI, total compensation, private industry workers, by occupation and industry group, seasonally adjusted, current dollar index - Utilities (CIS20144000000001)*. 2026.

[43] The BEA NIPA Handbook (Chapter 8 on Net Exports) explains that final sales of domestic product less net exports represents the market value of final goods and services purchased by U.S. firms, regardless of where those goods and services are produced. Sources: U.S. Bureau of Economic Analysis. *Final Sales to Domestic Purchasers (Glossary)*. <https://www.bea.gov/help/glossary/final-sales-domestic-purchasers>, and U.S. Bureau of Economic Analysis. *NIPA Handbook*. Chapter 8, "Net Exports of Goods and Services," pp. 8-2 to 8-3 <https://www.bea.gov/resources/methodologies/nipa-handbook/pdf/chapter-08.pdf>

distribution customer service, customer account, and A&G expense categories[44] by the OM&A expenses for the same respective expense categories.

Figure 9. Reported OM&A costs of the 88 EDCs in LEI's TFP study (nominal $)

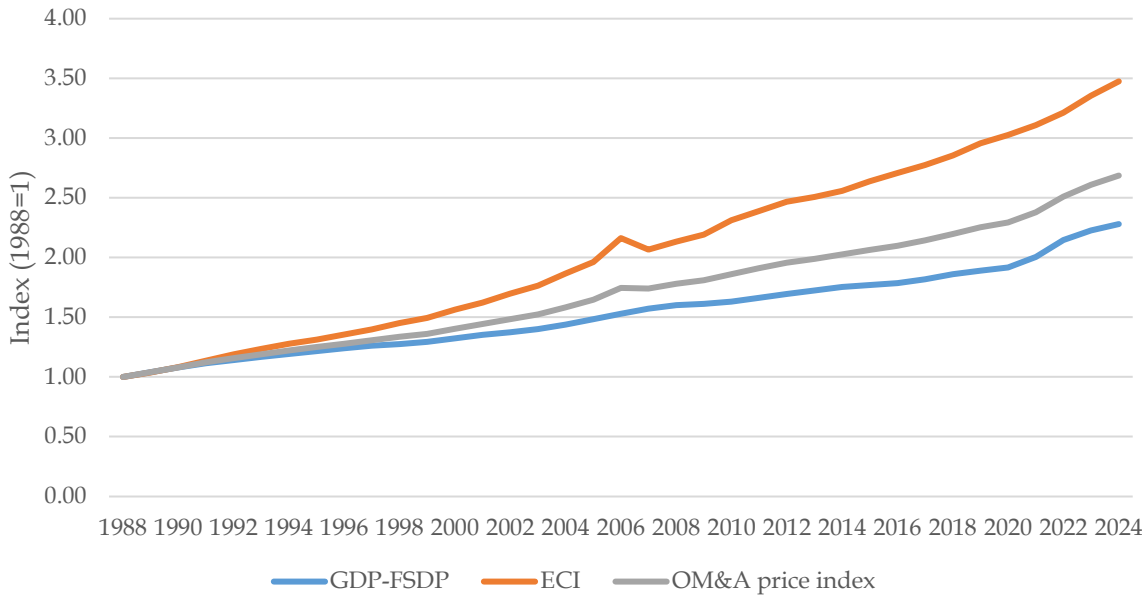


Source: FERC Form 1. Line No. 46. Title of Schedule Electric Operation and Maintenance Expenses. Reference Page No. 320.

Figure 10 shows that labor costs, measured by the ECI, have grown much faster than general prices measured by the GDP-FSDP since 1988. Because the customized OM&A price index blends the two based on each individual utilities labor share, it sits between them: the higher the labor share of OM&A costs, the more closely the customized index tracks the faster-growing ECI. The sharp rise after 2020 reflects the post-pandemic acceleration in both labor costs and broader inflation, with the customized index increasing especially where labor makes up a meaningful share of OM&A.

[44] FERC Form 1. Line No. 55. Title of Schedule Distribution of Salaries and Wages. Reference Page No. 354.

Figure 10. Average input price index for OM&A 1988-2024 of the 88 EDCs



Source: Bureau of Labor Statistics. *ECI, total compensation, private industry workers, by occupation and industry group, seasonally adjusted, current dollar index - Utilities (CIS20144000000000I)*. 2026.

FRED. *Implicit price deflator for final sales to domestic purchasers*. 2026

Note: This is illustrative because individual price indices were used for each of the 88 companies in the sample based on their unique labor and non-labor proportions.

3.3 Capital input quantity

LEI employed the monetary approach for calculating the capital input quantity for the EDCs. The calculation of the capital input quantity under a monetary approach centers around an estimate of the real capital stock of each EDC. This capital stock equals $257 billion (1988 $) in 2024 and includes a mix of electric distribution assets classified under the following categories reported in EDCs' FERC Form 1:[45] structures and improvements, station equipment, computer hardware, computer software, communication equipment, poles, towers, and fixtures, overhead conductors and devices, underground conduit, underground conductors and devices, line transformers, services, meters, installations on customer premises, leased property on customer premises, and street lighting and signal systems, asset retirement costs for distribution plant.

[45] FERC Form 1. Line No. 16. Title of Schedule Electric Plant in Service. Reference Page No. 204.

For properly measuring the capital input quantity for a TFP study, it is not possible to simply take capital expenditures from financial data and use that as proxy. Capital expenditures may be incurred in a specific year but by definition the associated asset or piece of equipment will provide services for multiple years. Moving from financial to physical capital expenditure data is discussed in the subsections below.

3.3.1 Method for estimating the capital input quantity

There are two approaches for calculating the capital input quantity: (i) a physical or direct approach, and (ii) a monetary or indirect approach. The advantage of the monetary approach is that the monetary value of the utility's capital equipment is aggregated using monetary values from the financial records of the firms as the unifying element. Thus, the monetary approach allows for consideration of various capital assets into one capital input quantity. The monetary method also directly accounts for the magnitude of improvements made to capital assets from time to time.

The shortcoming of the monetary method is that financial data on capital spending is typically not reported on a disaggregated basis, for each piece of equipment. EDCs normally only report the change in asset value (gross book value) for their entire stock of assets. The values of the new asset are added (or subtracted, when an asset is retired) based on its original historical cost at the time of the acquisition, and therefore the gross book value mixes assets acquired over different time periods (which makes it challenging to ascertain a "real dollar" value). Furthermore, the financial data typically does not get adjusted for the physical condition of the capital equipment, which is important to capture in a TFP study. Thus, one must apply exogenous assumptions regarding the physical deterioration of the capital stock over time under the monetary approach.

The physical approach has several advantages if a metric could be identified that comprehensively and accurately describes the capital assets of an EDC and the services that such capital assets provide in relation to the distribution business of the EDC. If such a measure were available, it would not need to be further manipulated (for example, one would not need to deflate/inflate historical asset value) and presumably, it could reflect the physical capability directly (so then no further assumptions would need to be made as to physical deterioration or depreciation of the capital employed).

However, such a measure does not exist for EDCs in the U.S., as there is no single measure reported by EDCs that uniformly and comprehensively estimates how different capital pieces of equipment and assets that an EDC may deploy contributes to the distribution services that an EDC provides for its customers. For this reason, LEI relied on the monetary approach.

3.3.2 Physical depreciation of capital under the monetary approach

The monetary approach requires assumptions regarding the physical depreciation of the capital stock over time. Practitioners use three physical deprecation or decay profiles most frequently: geometric, hyperbolic, and OHS (these are illustrated in Figure 11).

It is helpful to understand the basic characteristics of each profile:

- **One-Hoss Shay**: An asset is assumed to retain its full efficiency over its entire lifetime. In other words, its productive capability is not correlated with time. The assets' productive capability drops to zero at the end of its lifetime (it is fully consumed at the end of its last service year). An incandescent lightbulb is a good example of the OHS pattern of capital consumption—it is equally bright every single time it is turned on, except the last time when it is burnt out. Distribution poles are broadly analogous: once installed, a pole generally performs the same basic function of supporting conductors and associated equipment throughout its service life, until it is replaced because it is no longer considered sufficiently reliable or safe. The OHS approach assumes the asset's physical ability to provide services does not deteriorate with age. However, the OHS approach does not preclude including retirement of assets, if an asset is damaged or no longer providing its intended services even if it has not reached the end of its useful life.[46, 47]

- **Hyperbolic depreciation**: The asset's loss of productive efficiency is gradual at first but accelerates as the asset ages, producing a concave age-efficiency profile. The shape of the profile is governed by the beta parameter: a higher beta places more weight on later-life efficiency retention and therefore approaches an OHS pattern, while a lower beta implies faster efficiency loss earlier in the asset's life. OHS can be viewed as a limiting or special case of the hyperbolic family, where the asset retains full productive efficiency until the end of its service life and then drops to zero. Hyperbolic depreciation does not use retirements data and instead uses the hyperbolic profile to depreciate capital assets over time.

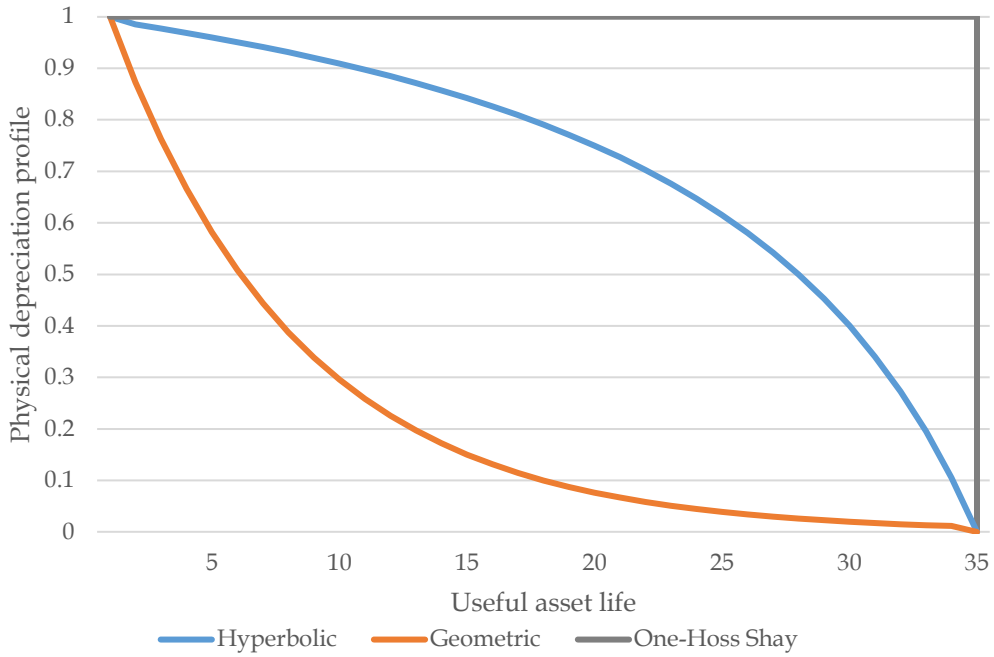
- **Geometric decay**: Under this profile, for each period of time, the asset is assumed to lose a fixed percentage of the productivity of the previous period. The assets therefore experience substantial losses of efficiency early in its lifetime but retains a long tail of low levels of efficiency toward the end of its life (a convex profile). A mailing list of customers

[46] Retirements are the original book cost of utility plant taken out of service and removed from plant-in-service, not the cash cost of removing it or the replacement cost of the new asset. FERC separately defines cost of removal as the cost of demolishing, dismantling, tearing down, or otherwise removing electric plant.

[47] ECFR. *PART 101 – UNIFORM SYSTEM OF ACCOUNTS PRESCRIBED FOR PUBLIC UTILITIES AND LICENSEES SUBJECT TO THE PROVISIONS OF THE FEDERAL POWER ACT*. 2026.

follows a geometric depreciation in productivity because each address has the same chance of becoming unusable in any given period. The list will depreciate in productivity as people change jobs, abandon accounts, or unsubscribe. Like hyperbolic depreciation, geometric depreciation does not use retirements data and instead retires capital using the geometric depreciation profile.

Figure 11. Capital asset (with useful service life of 35 years) depreciation profiles



LEI ultimately determined OHS to be the most appropriate physical depreciation method for this industry study, based on two main factors. Firstly, the expected productivity profile of capital EDC assets matches OHS the closest out of the three, with full efficiency until the end of life. The OHS profile also allows us to consider retirements of capital reported by the utilities and therefore take into account explicitly when certain equipment is retired because it can no longer provide services. A hyperbolic decay profile may be considered a close second although it requires certain assumptions for which data is not readily available.[48] These assumptions are discussed in detail

[48] The hyperbolics sensitivity uses an estimated hyperbolic depreciation curve to depreciate assets over the course of the assumed economic life of electric distribution capital (35 years). However, we do not know how old the initial capital asset base is for each EDC. LEI assumes that the initial capital asset base is halfway through its useful life.

in Appendix C (Section 9.1). Therefore, LEI performed a sensitivity analysis using a hyperbolic decay profile, which is documented in Appendix C (see Section 9).

A geometric decay profile is unrealistic for representing physical depreciation of capital used by EDCs. A geometric decay profile is less appropriate for modelling the physical depreciation of EDC capital because it assumes that an asset loses a constant proportion of its productive capacity in every period, including relatively large losses early in its service life. This does not align well with the observed performance of many long-lived distribution assets, such as poles, overhead conductors, underground cable, transformers, and related line equipment. In practice, these assets generally remain in place and continue to provide the service for which they were installed until they are replaced, retired, or failed. While maintenance needs and failure risk may increase with age, the asset's productive capability typically does not decline smoothly at a constant geometric rate each year. For this reason, geometric depreciation can overstate the loss of service potential in the earlier years of an EDC asset's life and understate the "in-service until replacement" nature of much distribution plant.

3.3.3 Service life of capital under the monetary approach

A 35-year average service life ("ASL") for electric distribution assets was estimated through an empirical asset turnover analysis drawing on FERC Form 1 data for a broad sample of U.S. electric utilities. The cumulative sum of annual distribution plant retirements across the sample from 1989 through 2024 totaled approximately $88.6 billion, a figure that closely approximates the gross book value of distribution plant in service recorded at the end of 1988, which stood at approximately $88.7 billion. The convergence of these two figures implies that the industry required roughly 36 years to retire an asset base equivalent to its starting value, yielding an empirical estimate of the average service life in that range. Rounding to the nearest standard interval, a 35-year ASL was determined to represent a reasonable and appropriate estimate for use in the TFP analysis.

3.3.4 Deriving the capital input quantity

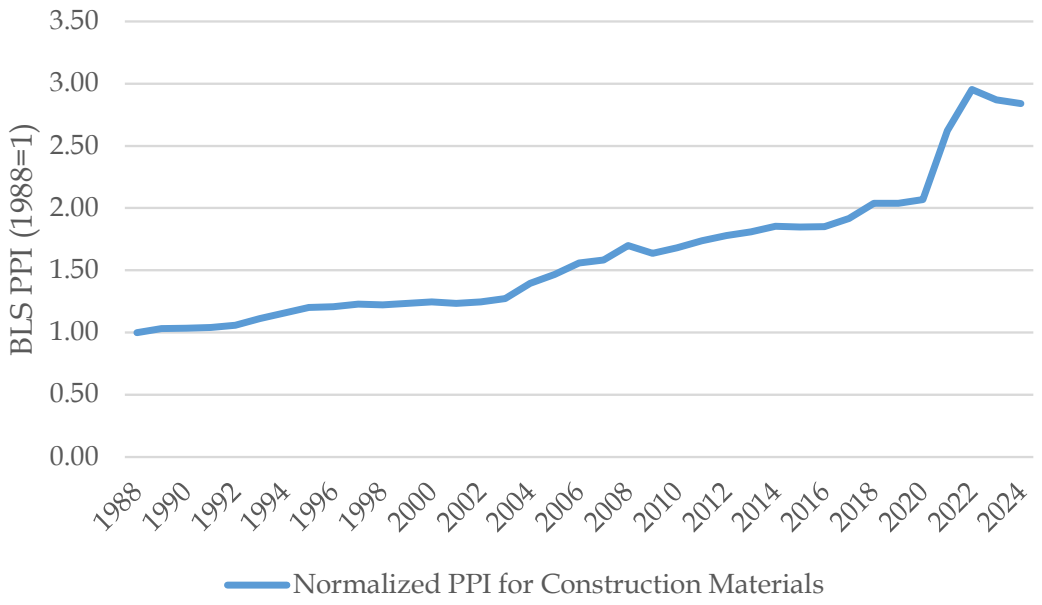
LEI obtained the quantity of capital stock using the perpetual inventory equation, which has been adopted in numerous TFP studies used in ratemaking globally.[49] To calculate the capital stock in the current year (K_t), the perpetual inventory equation takes the end of year capital stock (gross book value) from the previous year (K_{t-1}) and adds in the gross book value of new additions (I) and deducts the gross book value of retirements (R) in year t. The new additions and retirement data were collected from FERC Form 1.[50] However, because the equation is incorporating the monetary value of assets of different vintages (and therefore in nominal dollars from different

[49] This approach has been used in TFP studies that were ultimately accepted in Alberta, Australia, the UK, Massachusetts, New Hampshire, and Ontario.

[50] FERC Form 1. Line No. 16. Title of Schedule Electric Plant in Service. Reference Page No. 204.

years), the capital additions and retirements must be deflated. LEI used the BLS Producer Price Index for Construction Materials[51] to deflate the assets into real (1988) dollars; the trend in the BLS PPI since 1988 is shown in the figure below.[52]

Figure 12. Normalized BLS PPI trend 1988-2024 (1988=1)



Source: Bureau of Labor Statistics. *PPI Commodity data for Special indexes-Construction materials, not seasonally adjusted*. 2026

Because new additions are added in nominal dollars at time *t*, annual capital additions values are divided by the BLS PPI index also at time *t*. However, under the OHS approach, retirements need to be re-based to reflect their full real monetary value when they occur at the end of their service

[51] Bureau of Labor Statistics. *PPI Commodity data for Special indexes-Construction materials, not seasonally adjusted*. 2026.

[52] LEI also evaluated the Handy-Whitman Index ("HWI") of public utility construction costs as a potential capital price deflator. LEI ultimately selected the BLS Producer Price Index for two primary reasons. First, unlike the PPI, the HWI is proprietary, and its underlying methodology and data sources are not publicly disclosed, making it difficult to independently evaluate or replicate the resulting estimates. Second, sensitivity testing demonstrated that use of the HWI generated implausibly large real retirement values for certain utilities, resulting in negative estimates of real capital stock under the perpetual inventory method. These outcomes are not economically plausible and would have necessitated the exclusion of affected utilities from the sample. The issue became more pronounced under assumptions of longer asset service lives (i.e., 40, 45, and 50 years).

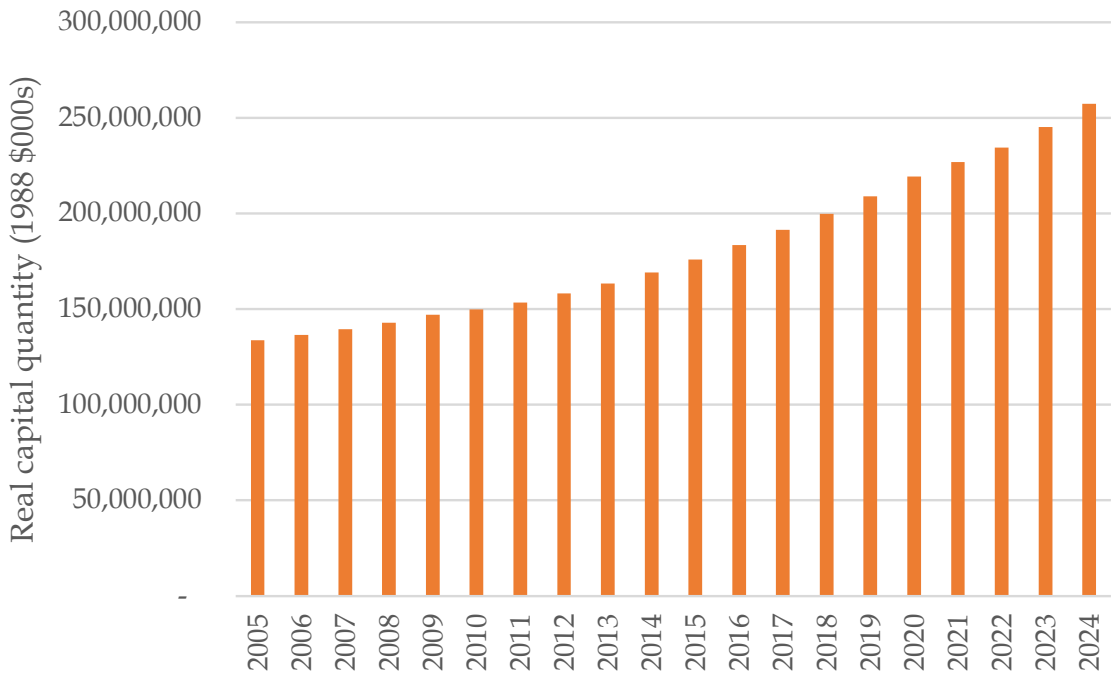
life (i.e., t minus the average service life s). As noted above, LEI assumed an average service life of 35 years (therefore t is equal to 1989 for a retirement that is taking place in 2024).

The equation for estimating the real capital quantity in any given year t under the perpetual inventory formula is shown below:

$$K_t = K_{t-1} + \frac{I_t}{BLS_PPI_t} - \frac{R_t}{BLS_PPI_{t-s}}$$

The first year for which one estimates the capital input quantity is called the "Benchmark Year". The best available information to construct a benchmark value is the gross book value of all capital assets and equipment, which is made up of assets of different vintages. The capital stock measure is sensitive to the age of the various capital components in the gross book value. To improve the precision of the capital stock estimates for the years in the TFP study, it is useful to select a benchmark year that is well before the beginning of the TFP study period (in the case of LEI's TFP Study, the first year of the study period is 2005). The results of the perpetual inventory equation in terms of real capital quantity are shown below in Figure 13.

Figure 13. Real capital quantity from 2005 to 2024 for the U.S. EDC industry, 1988 $000s



3.3.5 Capital input price

The capital input price measures the trend in the implicit rental price corresponding to a unit of capital quantity. Unlike the OM&A input price index, the capital input price is not used to deflate the capital input quantity. Instead, the capital input price is used to weight the capital input quantity in the total input quantities over time (mechanically, this is achieved by multiplying the capital input quantity by the capital input price, which results in the total capital quantity that is then represented in the calculation of the composite input index and the resulting TFP index).[53]

LEI used the implicit rental price formula developed in a seminal paper by Christensen and Jorgenson (1969) to estimate the capital input price, which has also been used in numerous TFP studies.[54] The price of capital under this approach is based on an equilibrium relationship between the price an investor is willing to pay for an asset and the after-tax expected value of services that the asset will provide over the asset's lifetime. This relationship is called the implicit rental price formula and has the following mathematical representation:

$$PK_t = \frac{1-uz}{1-u}(r-i)\left[1-\left(\frac{1+i}{1+r}\right)^{35}\right]^{-1} BLS_PPI_{t-1}$$

The variable u represents the corporate income tax rate, the variable z represents the present value of tax depreciation charges on one dollar of investment in distribution assets, the variable r represents the forward-looking cost of capital, and the variable i represents the forward-looking inflation rate. The service life (35 years) is also used in the implicit rental price formula.

Corporate income tax rate (u): LEI used the applicable corporate tax rate in each state for u for the 2005-2024 period. A 35% federal tax rate from 2005 to 2017 and 21% from 2018 to 2024 were used for states with no state tax (e.g., Nevada, Ohio, Texas, Washington, and Wyoming).
Present value of tax depreciation charges (z): This represents the present value of future depreciation on new investment. This component is used because depreciation for tax purposes typically takes place over a much shorter period than is allowed for ratemaking purposes. z is a function of the tax depreciation method used, the service life, and the weighted average cost of capital ("WACC"). LEI applied the sum of years' digits method, and the resulting value for this study was 0.68. z is summarized as follows:

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[53] The exogenous approach to weighting the capital input quantity is sometimes referred to as the "direct" approach as the annual cost of using capital inputs can be measured directly by applying the sum of an estimated depreciation rate and a rate reflecting the opportunity cost of capital to the value of the assets. This is different from an endogenous approach, which assumes that the capital cost weighting is the residual of the utility's total revenue minus OM&A.

[54] Originally derived from L.R. Christensen and D.W. Jorgenson. *The Measurement of Real Capital Input, 1929 – 1967.* Review of Income and Wealth, Series 15, No. 4, (December 1969). Pages 293-320.

$$z = \frac{2}{RT}\left[1 - \left[\frac{(1+R)}{R(T+1)}\right]\left[1 - \left(\frac{1}{(1+R)}\right)^{T+1}\right]\right]$$

Forward-looking cost of capital (WACC) and inflation rate (r): A common method is to assume that investor's forward-looking real rate of return (cost of capital less the inflation rate) is constant through time. This method produces a relatively stable input price series (in contrast to using just the current year WACC and inflation rates). The resulting average WACC[55] of 6.05% and expected long-term inflation rate[56] of 1.53% (over the study timeframe, 2005-2024) was then used in the implicit rental price formula for all U.S. EDCs.

3.4 Selecting an output metric

In U.S. EDC TFP studies, output is often measured using customer counts and/or kWh sales/deliveries. Customers proxy the scale of distribution service because utilities must connect and maintain service to customers regardless of usage, while sales capture the volume of electricity delivered. Studies often test both because sales can be affected by efficiency and DERs, while customer counts may not capture usage intensity. Customer data are based on EIA 861,[57] while sales data are compiled at the operating subsidiary level from FERC Form 1.[58]

LEI used the number of customers served by the distribution network(s) as the output measure. A key advantage of using this dataset is that it is a numerical data point which is both available and consistently measured across EDCs. Electricity sales, which LEI also considered as an output, are affected by weather patterns, which can vary considerably across geographies and years and therefore could cause some distortion to the resulting TFP trends. Figure 14 below presents trends in the number of customers and electricity sales, as well as their corresponding growth rates in Figure 15. This distinction shows that customer counts increased steadily over the study period,

[55] In calculating the WACC, the average cost of debt is based on the average Moody's seasoned AAA bond yield, published by the Federal Reserve Bank of St. Louis (Source: Federal Reserve Bank of St. Louis. *Moody's Seasoned Aaa Corporate Bond Yield*. 2026.) The cost of equity is based on the average approved return on equity ("ROE") of U.S. electric utilities in the sample over time (Source: S&P Global. *Regulatory Research (RRA), ROE rate case history dataset, 1977–2024, downloaded from S&P Capital IQ Pro*. 2026.). The debt/equity ratio was assumed to be 50%, based on an average of reported debt/equity ratios for U.S. electricity utilities. (Source: S&P Global. *Regulatory Research (RRA), ROE rate case history dataset, 1977–2024, downloaded from S&P Capital IQ Pro*. 2026.).

[56] The long-term expected inflation rate is calculated using the Fisher Ideal equation based on rates of the 10-Year U.S. Treasury bonds (Source: U.S. Department of the Treasury. *Daily Treasury Rates*. 2026.) and the 10-Year U.S. Treasury Inflation-Protected Securities ("TIPS") (Source: Board of Governors of the Federal Reserve System. *Selected Interest Rates (Daily) - H.15*. 2026.) from 2005-2024.

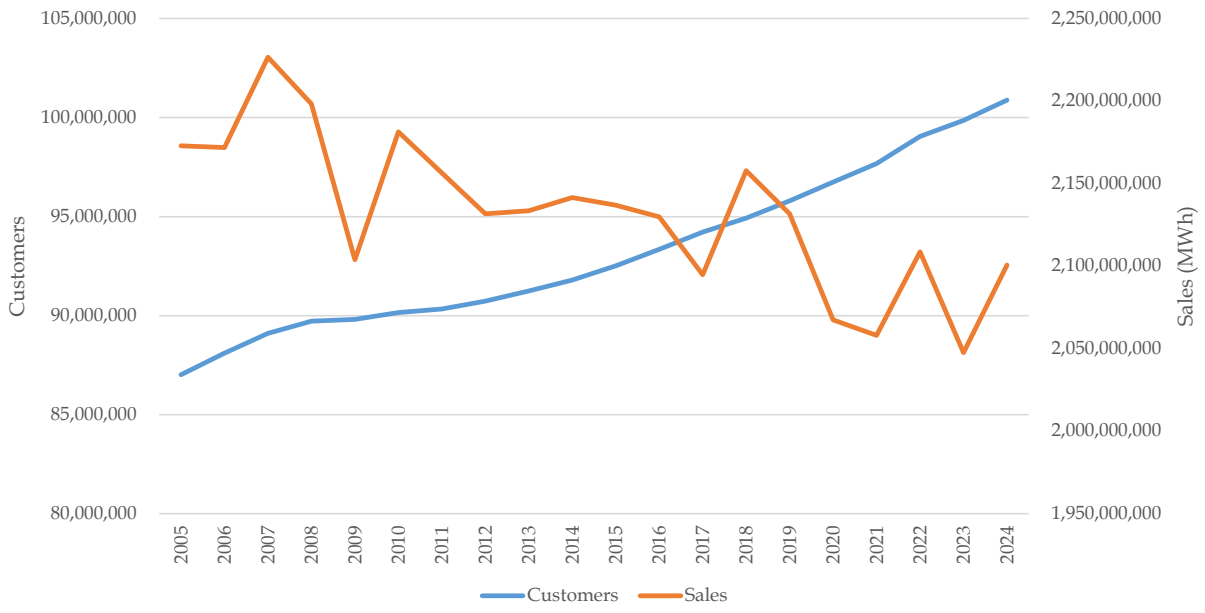
[57] EIA. *Annual Electric Power Industry Report.* Form EIA-861, detailed data files. Released October 7, 2025.

[58] FERC Form 1. Line No. 44. Title of Schedule Sales of Electricity by Rate Schedules. Reference Page No. 304.

while electricity sales were materially more volatile year-to-year, with periods of sharp decline and recovery.

Additionally, utilities build systems to serve customers and not necessarily the specific amount of electricity consumed per customer as that is likely to change with time. Notably, the use of total customers served has become a common practice among TFP studies for the EDC industry.[59] Regardless, LEI perform sensitivity analysis using sales (see Appendix B in Section 8).

Figure 14. Total number of customers served vs. electricity sales (reflecting all 88 EDCs studied)



Source: EIA 861 and FERC Form 1. Line No. 44. Title of Schedule Sales of Electricity by Rate Schedules. Reference Page No. 304.

[59] Customers are commonly used as the output variable in TFP studies. For example, National Grid (MA Electric Co.) (Docket No. 23-150), Public Service Company of New Hampshire (d/b/a Eversource Energy) (Docket No. DE 24-070), FortisBC Energy Inc. and Fortis BC Inc., together Fortis BC (Order Number G-69-25), and NSTAR Electric and Western MA Electric Co. (Docket No. DPU 22-22).

Figure 15. Total number of customers served vs. electricity sales growth rates (reflecting all 88 EDCs studied)

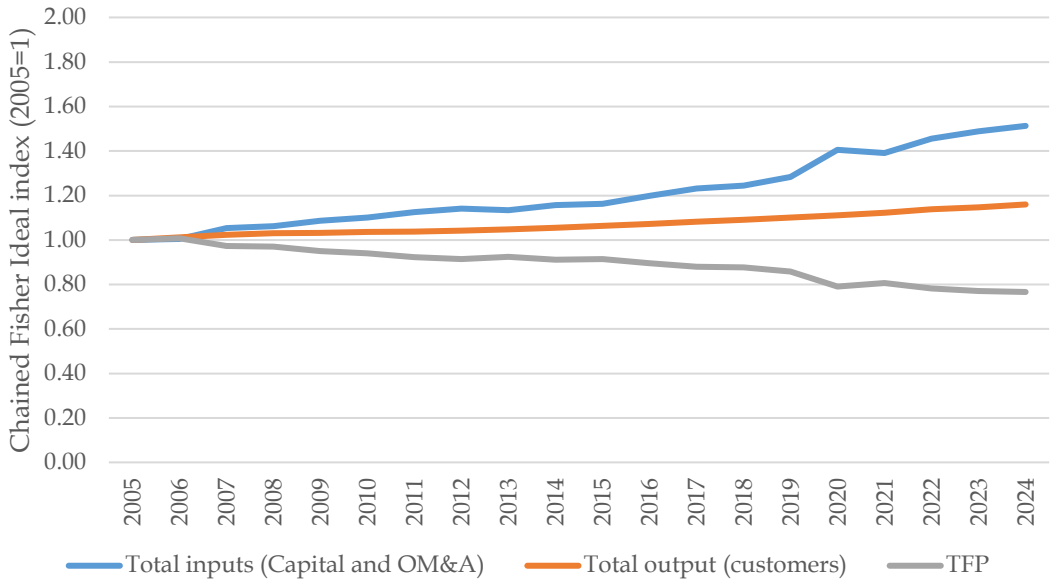


Source: EIA 861 and FERC Form 1. Line No. 44. Title of Schedule Sales of Electricity by Rate Schedules. Reference Page No. 304.

4 Industry TFP and PFP results

The TFP results indicate that productivity declined over the study period (2005-2024). While the number of customers increased gradually, total inputs (capital and OM&A) rose much more rapidly, particularly after the mid-2010s and again around 2020. This suggests that the sector required increasingly more resources to serve each customer over time. As a result, the chained Fisher TFP index fell from 1.00 in 2005 to 0.77 by 2024 (see grey line in Figure 16), indicating a deterioration in measured productivity by -1.40% annually between 2005 and 2024 (the tabular results are presented in Figure 22). In a PBR context, this pattern suggests limited or negative historical productivity growth, which would place downward pressure on the productivity factor used in the rate-setting formula.

Figure 16. Chained Fisher Ideal indices for industry TFP, inputs, and output

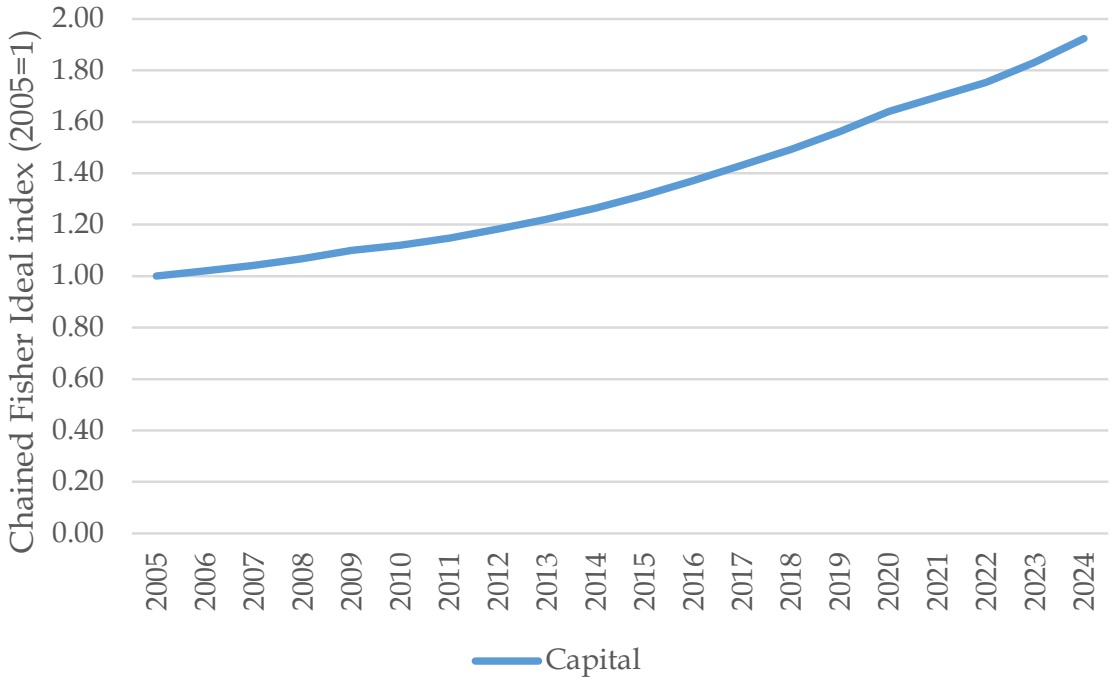


4.1 Industry input index

The chained Fisher Ideal index for capital inputs over the 2005 to 2024 period increased steadily, rising from 1.00 in 2005 to 1.92 by 2024 (see Figure 17). This indicates that the quantity of capital inputs used by the sector nearly doubled over the period. Growth was relatively gradual in the

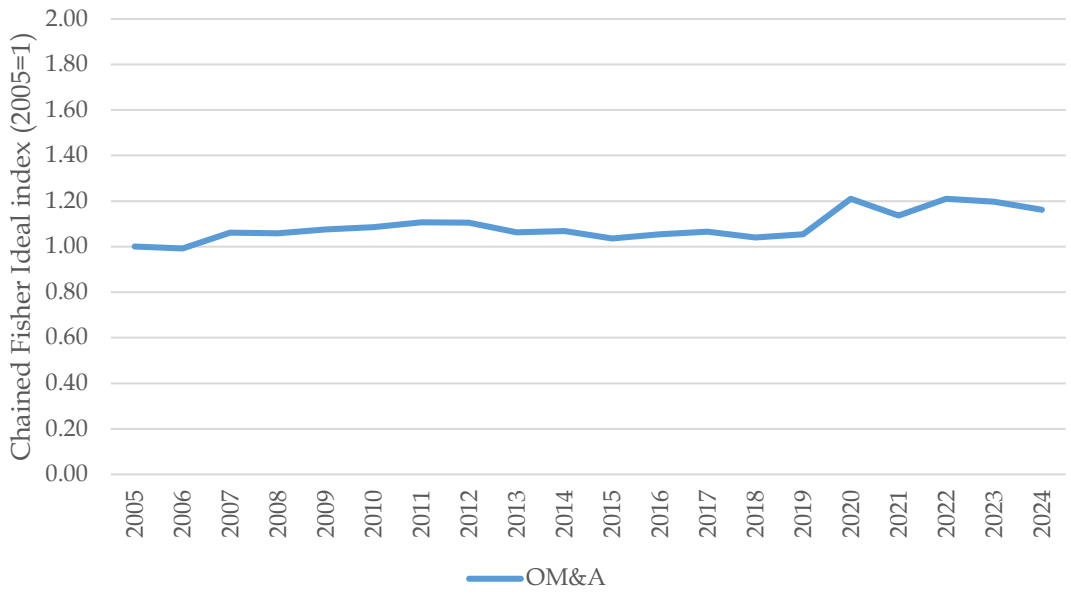
early years, but accelerated in later years, with a more pronounced increase through the late 2010s and early 2020s. Capital inputs grew at an average annual rate of 3.44% over the full period (see Figure 22). This suggests that capital investment was a major driver of overall input growth.

Figure 17. Chained Fisher Ideal index for industry capital



The chained Fisher Ideal index for OM&A inputs increased from 1.00 in 2005 to 1.16 by 2024, indicating more modest growth relative to capital inputs (see Figure 18). OM&A inputs rose during the early part of the period, reaching roughly 1.11 by 2011, then falling until 2020. The series shows some volatility around 2020, followed by a modest increase and then slight decline toward the end of the period. OM&A inputs have grown at an average annual rate of 0.79% over the full period (see Figure 22). Overall, OM&A input growth was positive but materially slower than capital input growth.

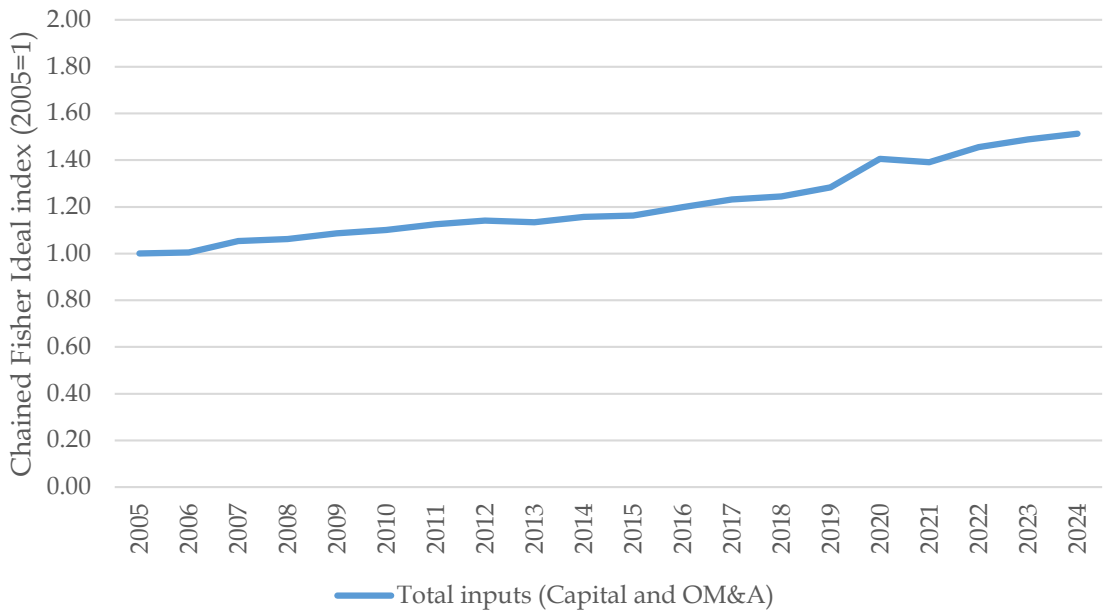
Figure 18. Chained Fisher Ideal index for industry OM&A



The chained Fisher Ideal index for total inputs, where total inputs equal the composite of capital inputs and OM&A inputs, increased from 1.00 in 2005 to around 1.51 by 2024 (see Figure 19). To develop the total composite input index, LEI used the capital-to-OM&A split between the implicit capital price in 1988 dollars and the implicit OM&A price in 1988 dollars as the relative input price weights.[60] This reflects sustained growth in the overall quantity of inputs used by the sector, with the increase driven primarily by the strong growth in capital inputs, partially offset by the more moderate growth in OM&A inputs. The total input index shows a steady upward trend throughout most of the period, with a noticeable increase around 2020 and continued growth thereafter. Total inputs have grown at an average annual rate of 2.18% over the full period (see Figure 22). This composite trend suggests that the sector became increasingly input-intensive over time, particularly due to rising capital inputs.

[60] The average capital-to-OM&A split between implicit capital price in 1988 dollars and the implicit OM&A price in 1988 dollars between 2005-2024 is 46%/54%.

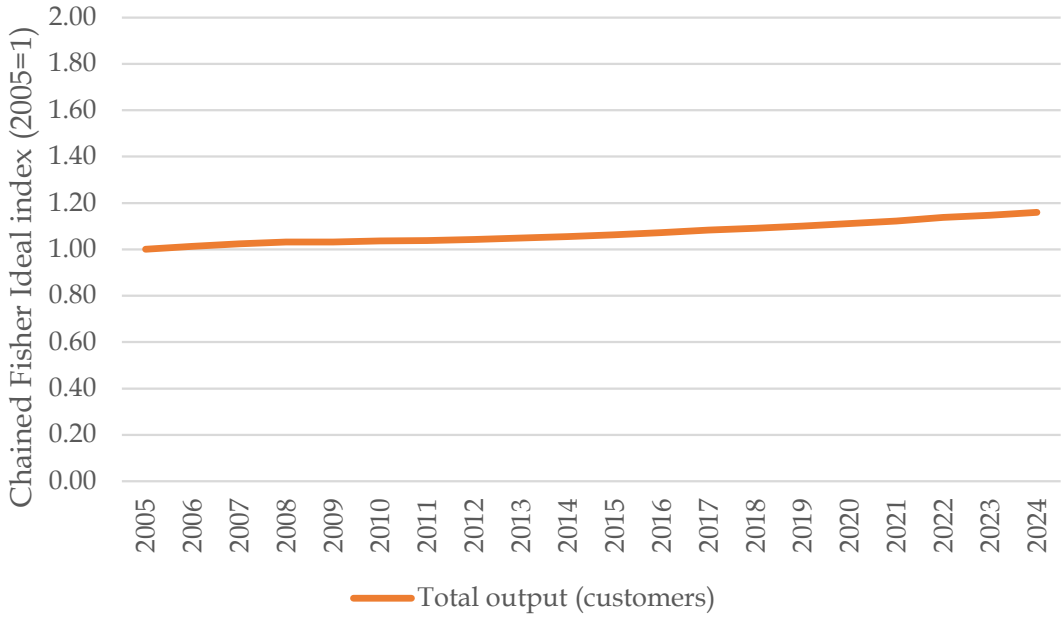
Figure 19. Chained Fisher Ideal index for total industry inputs (capital and OM&A)



4.2 Industry output index

The chained Fisher Ideal index for total output, measured using the number of customers, increased from 1.00 in 2005 to approximately 1.16 by 2024 (see Figure 20), indicating that the customer base grew by roughly 16% over the study period. Growth was relatively steady but modest through the mid-2010s, followed by a somewhat stronger increase beginning around 2018 and continuing through 2020. Total output has grown at an average annual rate of 0.78% over the full period (as summarized in Figure 22). Compared with the total input index, which reflects the composite of capital and OM&A inputs, output growth was considerably slower, contributing to the observed decline in measured TFP over the period.

Figure 20. Chained Fisher Ideal index for total industry output (customers)

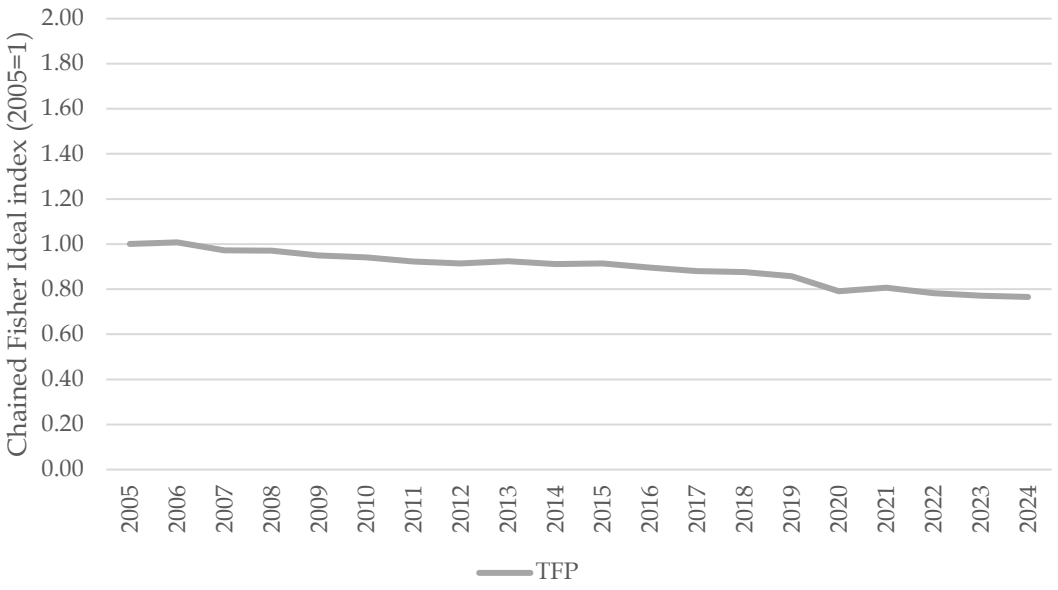


4.3 Detailed results for industry TFP and PFP growth

4.3.1 Industry total factor productivity

The chained Fisher Ideal index for TFP over the 2005 to 2024 period is calculated as the ratio of the total output index to the total input index, where output is measured using customers and inputs reflect the composite of capital and OM&A inputs. The TFP index declined from 1.00 in 2005 to 0.77 by 2024, indicating a material deterioration in measured productivity over the study period (see Figure 21).

Figure 21. Chained Fisher Ideal index for industry TFP



TFP **declined** at an average annual rate of approximately -1.40% over the full study period (*see* right hand column in Figure 22). This decline reflects the fact that total inputs grew substantially faster than total output, indicating that the industry required increasingly more capital and OM&A resources to serve each customer over time. Notably, the decline in TFP became more pronounced in recent years, averaging -1.47% per year over the past 15 years and -1.97% per year for the past 10 years. Figure 22 shows the Industry TFP results.

A negative TFP rate does not signal poor performance or inefficiency. Rather, it often results from cyclical investments, evolving compliance requirements, pressures from rising costs, economies of scale, capacity utilization, and patterns in customer growth over time.[61] In capital-intensive sectors, measured productivity can decline during periods of elevated investment because inputs increase before the associated benefits are fully reflected in measured outputs. This is particularly relevant for electricity distribution utilities, where investments may be driven by asset renewal, reliability improvements, grid modernization, resiliency, connecting customers to the grid, and evolving compliance requirements rather than immediate increases in customer numbers or delivered volumes.

[61] Organisation for Economic Co-operation and Development. *OECD Compendium of Productivity Indicators 2025*. 2025. P. 22.

Figure 22. Annual growth rates for industry output, input, PFP, and TFP

	Output	Input			Productivity		
Year	Customers	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	1.25%	2.01%	-0.77%	0.48%	-0.76%	2.02%	0.77%
2006-2007	1.12%	2.11%	6.78%	4.68%	-0.99%	-5.66%	-3.56%
2007-2008	0.68%	2.40%	-0.37%	0.89%	-1.72%	1.06%	-0.21%
2008-2009	0.10%	2.99%	1.62%	2.25%	-2.88%	-1.51%	-2.15%
2009-2010	0.39%	1.86%	0.97%	1.38%	-1.47%	-0.58%	-0.99%
2010-2011	0.19%	2.34%	1.87%	2.09%	-2.15%	-1.68%	-1.90%
2011-2012	0.45%	3.09%	-0.05%	1.41%	-2.64%	0.50%	-0.96%
2012-2013	0.56%	3.18%	-4.01%	-0.56%	-2.62%	4.56%	1.12%
2013-2014	0.61%	3.53%	0.58%	2.03%	-2.92%	0.03%	-1.42%
2014-2015	0.78%	3.87%	-3.10%	0.41%	-3.10%	3.87%	0.36%
2015-2016	0.90%	4.23%	1.72%	3.00%	-3.33%	-0.82%	-2.11%
2016-2017	0.92%	4.27%	1.07%	2.73%	-3.35%	-0.15%	-1.81%
2017-2018	0.75%	4.23%	-2.40%	1.09%	-3.48%	3.15%	-0.34%
2018-2019	0.92%	4.49%	1.41%	3.04%	-3.57%	-0.49%	-2.12%
2019-2020	0.98%	4.89%	13.70%	9.12%	-3.91%	-12.72%	-8.14%
2020-2021	0.97%	3.39%	-6.24%	-0.97%	-2.42%	7.21%	1.94%
2021-2022	1.40%	3.27%	6.23%	4.49%	-1.88%	-4.83%	-3.09%
2022-2023	0.80%	4.42%	-1.03%	2.20%	-3.62%	1.84%	-1.39%
2023-2024	1.02%	4.90%	-3.02%	1.69%	-3.88%	4.04%	-0.67%
Annual average 2005-2024	**0.78%**	**3.44%**	**0.79%**	**2.18%**	**-2.67%**	**-0.01%**	**-1.40%**
Annual average 2010-2024	**0.80%**	**3.86%**	**0.48%**	**2.27%**	**-3.06%**	**0.32%**	**-1.47%**
Annual average 2015-2024	**0.96%**	**4.23%**	**1.27%**	**2.93%**	**-3.27%**	**-0.31%**	**-1.97%**

4.3.2 Industry partial factor productivity

As previously explained, a PFP index evaluates the trend of a single input. The PFP for capital showed an average annual growth rate of -2.67% from 2005-2024, indicating that capital inputs grew faster than the number of customers (*see* Figure 22). This decline is consistent with the earlier observation that capital input growth was a major driver of total input growth, while output, measured by number of customers served, increased only modestly. Similarly, the PFP for OM&A had an average annual growth rate of -0.01%, suggesting that OM&A inputs increased at a slightly higher rate than customer growth (see Figure 22). Compared with capital PFP, the decline in OM&A PFP was more moderate, indicating that the deterioration in overall productivity was driven more heavily by capital input growth than by OM&A input growth.

The capital PFP results tell us that capital productivity has continued to decline over the study period. Capital inputs have grown much faster than the customer base, meaning the sector has become increasingly capital-intensive on a per-customer basis, requiring more capital investment to serve each customer over time. This does not necessarily indicate poor performance; it may reflect asset renewal, system modernization, reliability and resilience investments, and other long-lived infrastructure needs that increase capital inputs before producing measurable output growth. Indeed, according to a recent study by Lawrence Berkeley National Laboratory

("LBNL").[62] electric utility distribution costs have increased substantially over the past decade, driven primarily by rising capital investment. LBNL attributes this trend to utilities replacing aging infrastructure, modernizing the distribution grid, improving system resilience and reliability, integrating distributed energy resources, supporting transportation and building electrification, enhancing cybersecurity, and accommodating increasing electricity demand. Overall, the capital PFP trend suggests that capital input growth is the main driver of the broader decline in measured productivity.

Figure 23. Chained Fisher Ideal index for industry capital PFP

[62] Ryan H. Wiser et al., *Electric Utility Distribution Costs: Scoping Study on Trends, Drivers, and Possible Response Strategies* (Berkeley, CA: Lawrence Berkeley National Laboratory, May 2026), 10, 24, 31–33, https://eta-publications.lbl.gov/sites/default/files/2026-04/utility_distribution_costs_final.pdf

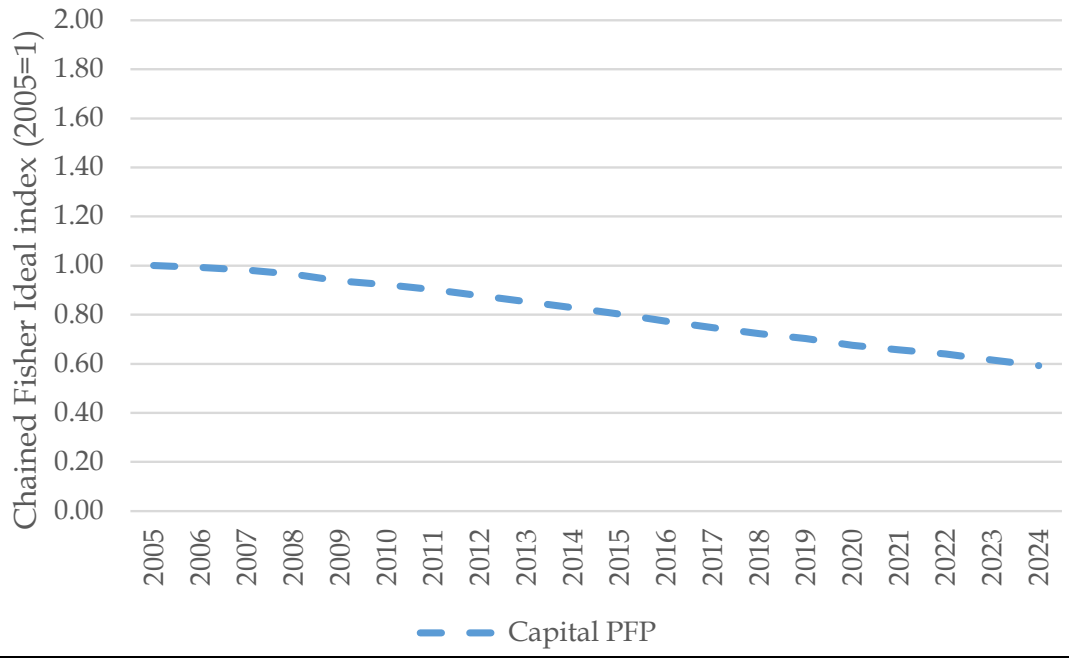
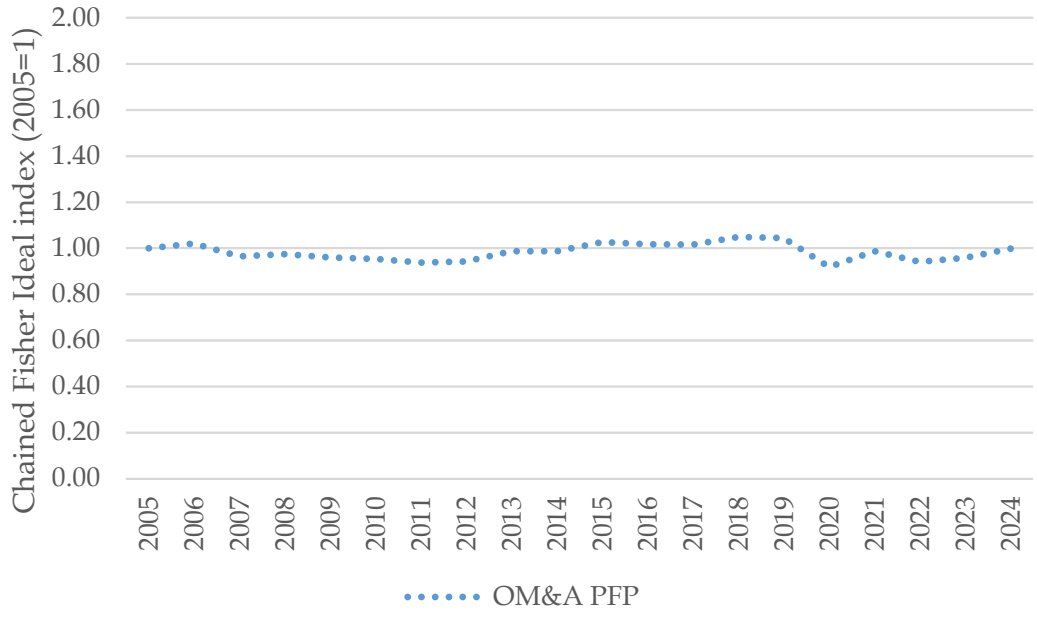


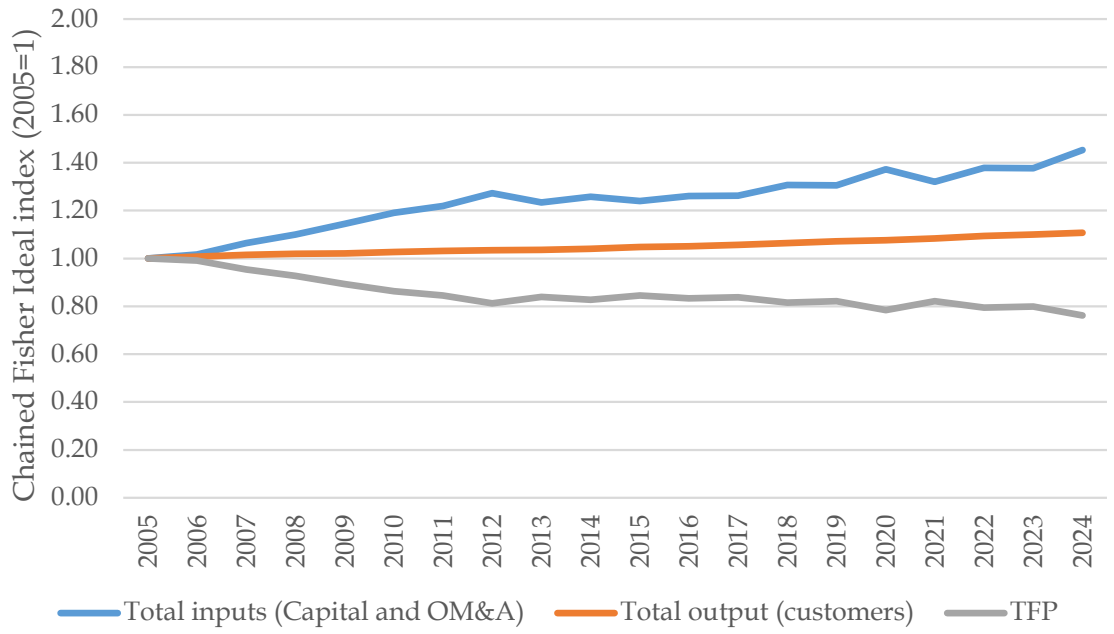
Figure 24. Chained Fisher Ideal index for industry OM&A PFP



5 Northeast Region TFP and PFP results

For the Northeast Region, the overall pattern is similar to what is observed across the U.S.: input growth outpacing output growth, therefore resulting in negative TFP and PFP trends. Total inputs, which combine capital and OM&A, increased substantially over the period, moving from 1.00 in 2005 to roughly 1.45 by 2024 (see Figure 25). By contrast, total output, measured by number of customers served, rose only modestly, ending at 1.11. The gap between these two series widened steadily over time, especially from the late 2000s onward, indicating that the Northeast Region EDCs required a growing amount of input to serve a relatively slow-growing customer base.

Figure 25. Chained Fisher Ideal indices for Northeast Region TFP, inputs, and output

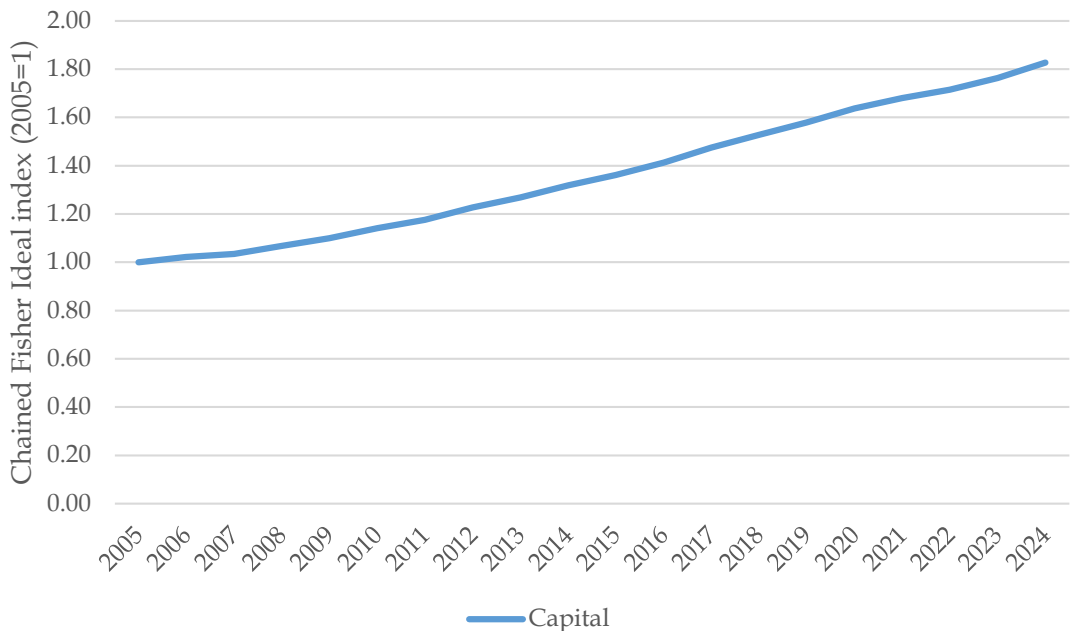


As a result, the TFP index fell from 1.00 to 0.76 by 2024 for the Northeast Region (see grey line in Figure 25). Total inputs grew by 1.97% per year, while customer output increased by only around 0.53% per year (see blue and orange lines, respectively, in Figure 25 and the tabular data in Figure 31). This implies an average annual TFP **decline** of approximately 1.43% over the full period. In the PBR context, this suggests that the Northeast Region's measured productivity trend is slightly more negative than the broader U.S. industry results reviewed in Section 4, largely because input growth materially outpaced customer growth.

5.1 Northeast Region input index

For the Northeast utilities, capital input shows a clear and persistent upward trajectory across the full 2005–2024 period. The index begins at 1.00 in 2005 and rises to 1.83 by 2024, indicating that capital inputs increased by over 80% over the study period (see Figure 26). The Northeast Region capital inputs grew at an average annual rate of 3.17% (see Figure 31). This is important for the productivity analysis because capital is a major component of total inputs; when capital grows this quickly while customer output grows only modestly, it places downward pressure on measured TFP. In a PBR setting, this trend helps explain why the Northeast Region TFP results are negative: the region appears to have become increasingly capital-intensive over time, likely reflecting ongoing infrastructure renewal, modernization, and reliability-related investment needs.

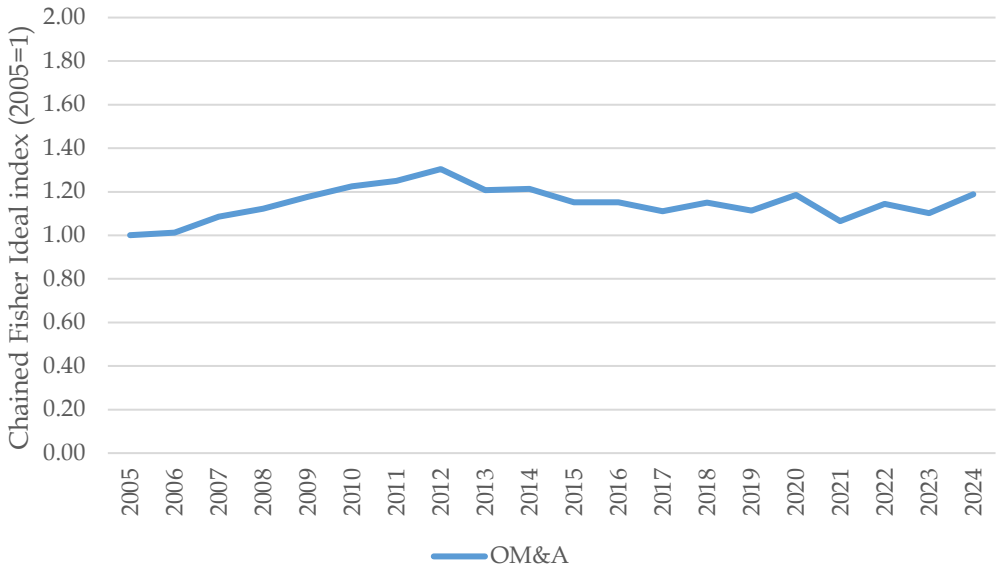
Figure 26. Chained Fisher Ideal index for Northeast Region capital



For Northeast Region OM&A, the series shows a moderate increase over the full period, but with more year-to-year movement than the capital index. OM&A inputs rise from 1.00 in 2005 to 1.19 by 2024 (see Figure 27). The Northeast Region OM&A inputs have increased at an average annual rate of 0.91% (see Figure 31) during the 20-year period. Compared with the Northeast Region capital index, OM&A growth is less pronounced and less consistently upward, but it still contributes meaningfully to the rise in total inputs. From a productivity and PBR perspective, this suggests that the decline in Northeast Region TFP is not solely capital-driven; OM&A

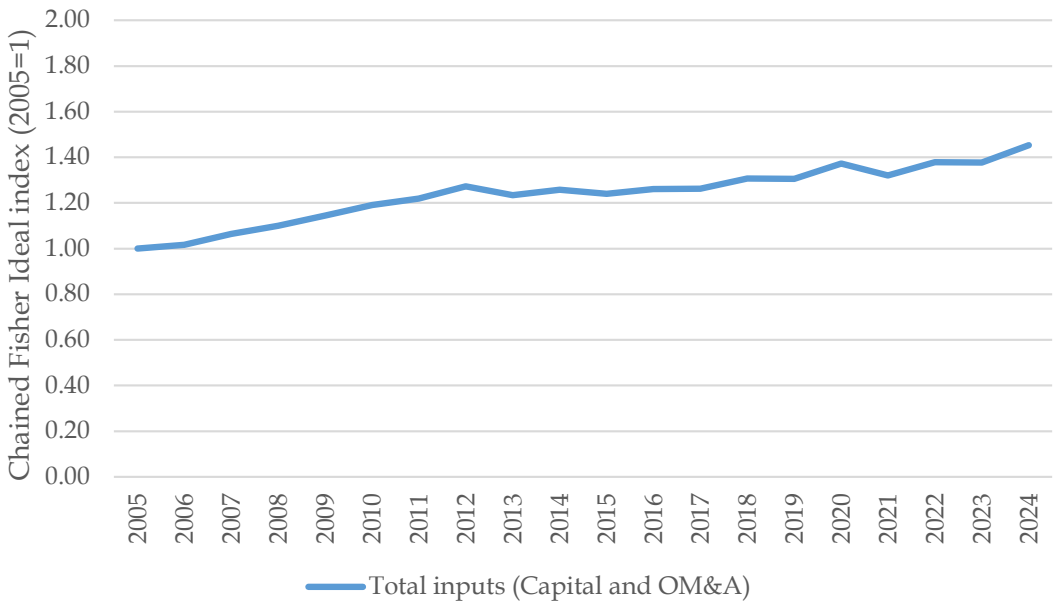
requirements also increased faster than customer output, although capital growth remains the more significant driver of rising input intensity.

Figure 27. Chained Fisher Ideal index for Northeast Region OM&A



The Northeast Region total input index combines capital and OM&A inputs into a single composite measure. Over the 2005–2024 period, the index rises from 1.00 to 1.45 (see Figure 28). The series climbs fairly consistently through 2014 and levels off somewhat between 2014 and 2017. Total inputs grew at an average annual rate of approximately 1.97% (see Figure 31). This confirms that the Northeast Region sample became increasingly input-intensive over time. In the PBR and productivity context, this matters because total input growth substantially exceeded customer output growth, which helps explain the negative TFP trend observed for the Northeast Region.

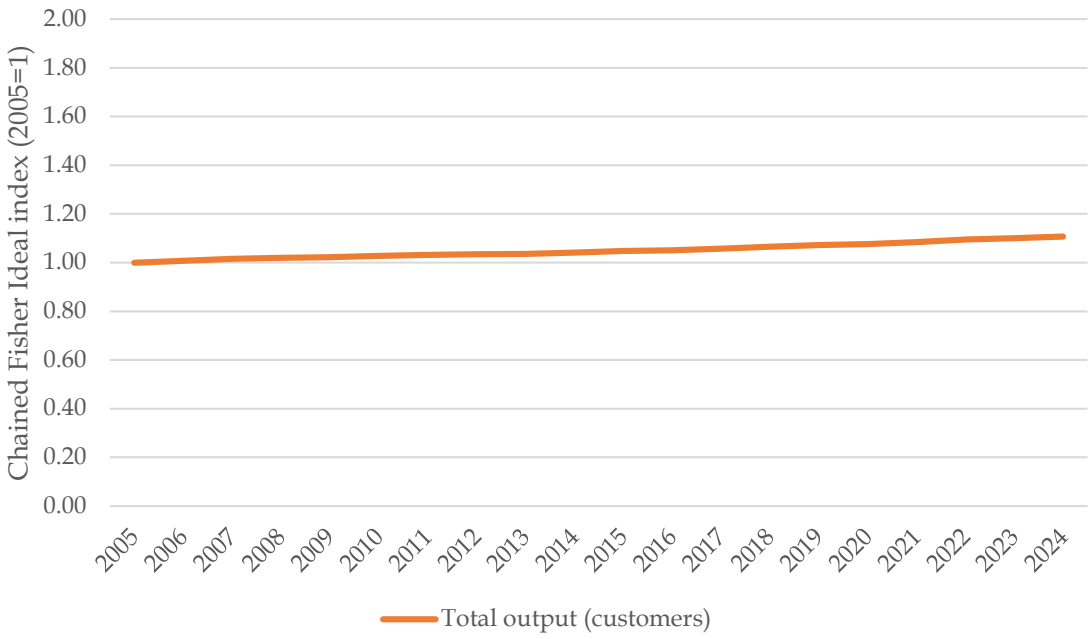
Figure 28. Chained Fisher Ideal index for total Northeast Region inputs (capital and OM&A)



5.2 Northeast Region output index

The Northeast Region customer output index is comparatively flat, with only modest growth over the 2005–2024 period. The index starts at 1.00 in 2005 and ends at 1.11 in 2024, indicating that the customer base increased by roughly 11% over the full study period (see Figure 29). Most of the series remains close to 1.0 through the mid-2010s, followed by a small step-up around 2018–2020 and a slight increase again toward the end of the period. Customer output grew at an average annual rate of 0.53% (see Figure 31). For the Northeast Region productivity analysis, this slow output growth is central to the TFP result: because total inputs increased much more rapidly than customers, the region's measured productivity declined even though customer counts continued to rise modestly.

Figure 29. Chained Fisher Ideal index for total Northeast Region output (customers)

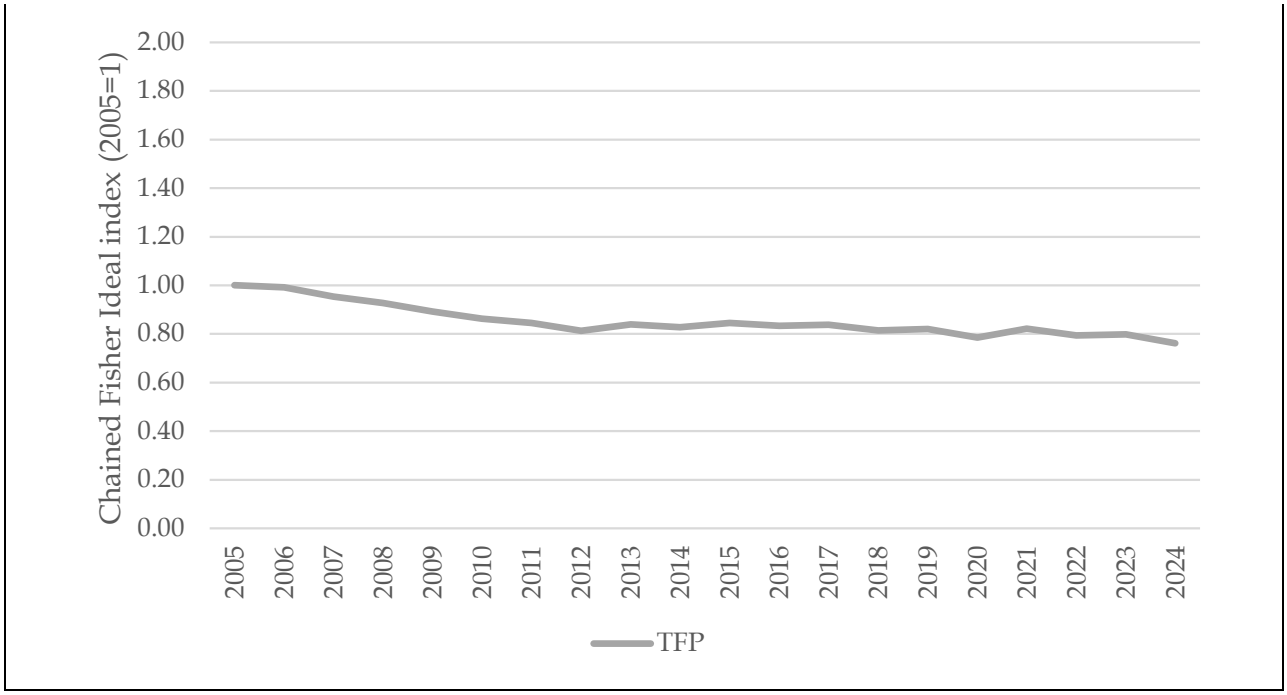


5.3 Detailed results for Northeast Region TFP and PFP growth

5.3.1 Northeast Region TFP

The Northeast Region TFP results show a sustained decline in measured productivity over the 2005–2024 period. As shown in Figure 30, the TFP index falls from 1.00 in 2005 to around 0.76 in 2024. The decline is most pronounced between 2006 and 2012, after which the index moves within a narrower range but remains well below its starting value.

Figure 30. Chained Fisher Ideal index for Northeast Region TFP



The Northeast Region TFP declined by an average of 1.43% per year over the full 2005–2024 study period (see Figure 31). The decline was less severe over the 2010–2024 period, at -0.89% per year, and the 2015–2024 period, at approximately -1.16% per year. This suggests that while productivity remained negative, the rate of decline was less pronounced in the more recent period.

The annual growth rates provide additional context for the TFP trend. Customer output grew slowly, averaging only 0.53% per year from 2005 to 2024, while total inputs increased by 1.97% per year over the same period. This gap explains the negative TFP result: the Northeast Region utilities expanded their use of capital and OM&A inputs much faster than the customer base grew. Capital was the larger contributor to input growth, increasing by 3.17% per year on average, while OM&A grew by 0.91% per year (see Figure 31). In productivity terms, capital PFP declined by -2.64% per year, OM&A PFP declined by -0.37% per year, and overall TFP declined by 1.43% per year (see Figure 31). For the PBR analysis, these results indicate that the Northeast Region sample experienced rising input intensity over the study period, with productivity pressure driven primarily by capital growth and only partially offset by the more moderate OM&A trend in recent years.

Figure 31. Annual growth rates for Northeast Region output, input, PFP, and TFP

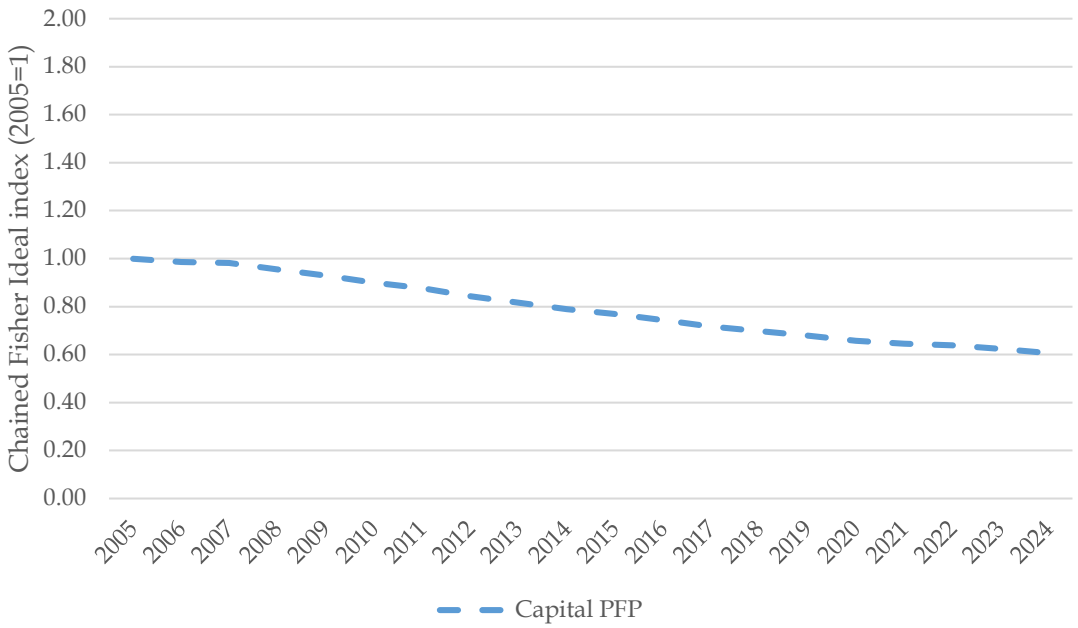
	Output	Input			Productivity		
Year	Customers	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	0.80%	2.22%	1.23%	1.64%	-1.43%	-0.43%	-0.84%
2006-2007	0.76%	1.22%	6.95%	4.61%	-0.46%	-6.18%	-3.85%
2007-2008	0.38%	3.05%	3.43%	3.27%	-2.67%	-3.05%	-2.90%
2008-2009	0.21%	3.01%	4.62%	3.96%	-2.80%	-4.41%	-3.75%
2009-2010	0.56%	3.74%	4.12%	3.97%	-3.18%	-3.56%	-3.41%
2010-2011	0.36%	2.94%	1.98%	2.37%	-2.58%	-1.62%	-2.00%
2011-2012	0.25%	4.25%	4.28%	4.26%	-4.00%	-4.03%	-4.02%
2012-2013	0.19%	3.31%	-7.71%	-3.11%	-3.12%	7.90%	3.31%
2013-2014	0.48%	3.92%	0.40%	1.93%	-3.44%	0.08%	-1.45%
2014-2015	0.70%	3.19%	-5.15%	-1.42%	-2.50%	5.85%	2.11%
2015-2016	0.29%	3.70%	-0.01%	1.69%	-3.41%	0.30%	-1.40%
2016-2017	0.58%	4.29%	-3.70%	0.07%	-3.71%	4.28%	0.51%
2017-2018	0.73%	3.51%	3.55%	3.53%	-2.78%	-2.82%	-2.80%
2018-2019	0.63%	3.30%	-3.19%	-0.11%	-2.67%	3.82%	0.75%
2019-2020	0.47%	3.60%	6.18%	4.95%	-3.13%	-5.71%	-4.48%
2020-2021	0.68%	2.61%	-10.69%	-3.85%	-1.93%	11.37%	4.53%
2021-2022	0.94%	2.02%	7.25%	4.33%	-1.09%	-6.31%	-3.39%
2022-2023	0.53%	2.85%	-3.85%	-0.10%	-2.32%	4.38%	0.63%
2023-2024	0.60%	3.54%	7.54%	5.34%	-2.94%	-6.94%	-4.74%
Annual average 2005-2024	**0.53%**	**3.17%**	**0.91%**	**1.97%**	**-2.64%**	**-0.37%**	**-1.43%**
Annual average 2010-2024	**0.53%**	**3.36%**	**-0.22%**	**1.42%**	**-2.83%**	**0.75%**	**-0.89%**
Annual average 2015-2024	**0.61%**	**3.27%**	**0.34%**	**1.76%**	**-2.66%**	**0.26%**	**-1.16%**

5.3.2 Northeast Region partial factor productivity

As previously explained, a PFP index evaluates the trend of a single input. The PFP for capital showed an average annual growth rate of -2.64% from 2005-2024, indicating that capital inputs grew faster than the number of customers (see Figure 31). Similarly, the PFP for OM&A had an average annual growth rate of -0.37% from 2005 to 2024, suggesting that OM&A inputs increased at a higher rate than customer growth (see Figure 31). Notably, this is more negative than the average PFP for OM&A for the industry. PFP results approximate the efficiency with which inputs are used to produce outputs.

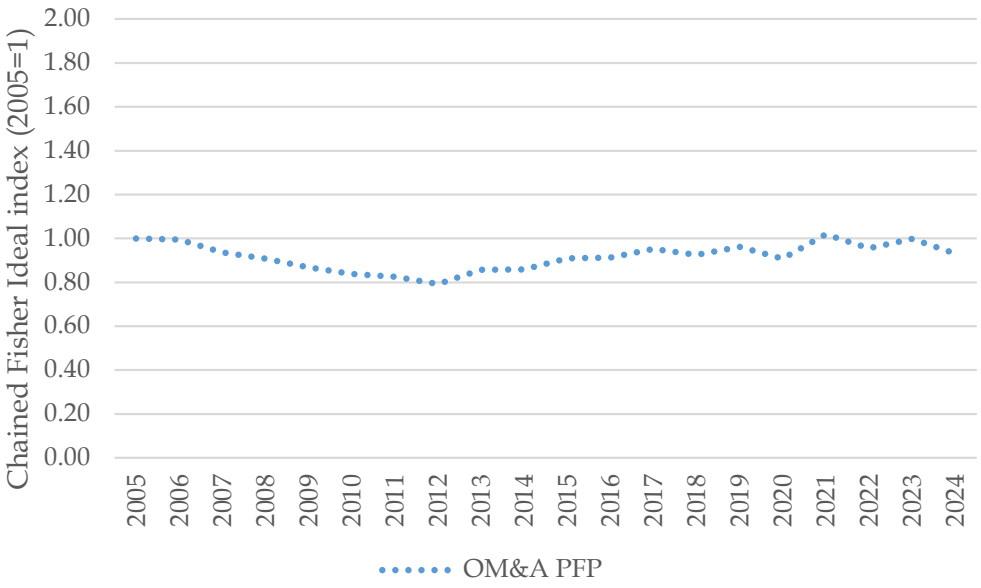
From a productivity and PBR perspective, this reinforces that capital growth is the primary source of the Northeast Region's negative TFP trend. The result should not be read automatically as inefficiency; rather, it likely reflects the increasingly capital-intensive nature of electricity distribution, including asset replacement, grid modernization, reliability investments, and resilience-related spending that increase the capital stock without producing a proportional increase in customer counts.

Figure 32. Chained Fisher Ideal index for Northeast Region capital PFP



The Northeast Region OM&A PFP index points to a decline in OM&A productivity early in the period, followed by a relatively stable pattern in later years. The downward movement indicates that OM&A inputs increased faster than the Northeast Region customer base. The index falls from 1.00 in 2005 to 0.79 by 2012, before stabilizing mostly between 0.91 and 1.02 through 2015-2024 (see Figure 33). OM&A PFP has declined at an average annual rate of approximately 0.37% per year over the full 2005–2024 period, although the OM&A PFP actually becomes positive in the more recent 2010-2024 period and 2015–2024 period (see Figure 31). In the context of the Northeast Region productivity results, this suggests that OM&A productivity weakened materially in the first half of the study period, but has comparatively improved since then. This more positive recent OM&A PFP trend partly moderates the overall TFP decline, though it is not enough to offset the stronger and more persistent decline in capital PFP.

Figure 33. Chained Fisher Ideal index for Northeast Region OM&A PFP



6 Converting the estimated U.S. and Northeast Region TFP annual average growth rates into an X Factor

If CL&P were to use the GDP-FSDP as the inflation factor in the I-X formula, the inflation factor would incorporate the effects of economy-wide productivity because GDP-FSDP is an output price index rather than an input price index. Accordingly, the X Factor must be adjusted to account for differences in both productivity growth and input price inflation between the electric distribution industry and the economy as a whole. These adjustments are commonly referred to as the TFP differential and the input price differential.

LEI estimated the TFP differential as the difference between calculated industry TFP growth and economy-wide TFP growth, using the BLS private business sector total factor productivity index as a proxy for economy-wide TFP growth, as shown in columns A, B, and C in Figure 34. LEI also estimated the input price differential, which reflects the difference between input price growth in the broader economy and input price growth for the electric distribution industry. For this purpose, economy-wide input price growth is calculated as the sum of GDP-FSDP growth and economy-wide TFP growth, while industry input price growth is based on a weighted average of OM&A and capital input prices, as determined in LEI's TFP study. These values are summarized in Figure 34 below.

Including these differentials ensures that the I-X framework is consistent with the theoretical foundation of an index-based approach. Specifically, it adjusts the inflation factor so that the resulting price-cap formula more accurately reflects the expected cost trends of the electric distribution industry relative to the broader economy. As shown in Figure 34, over the 2005–2024 period, the industry TFP differential is -2.09%, while the industry input price differential is 0.14%. Together, these components produce an average industry X Factor of -1.95% over the period. Notably, the X Factor becomes more negative in more recent years. The X Factor became increasingly negative in more recent years, averaging -1.99% per year over the most recent 15-year period and -2.6% per year over the most recent 10-year period.

Figure 34. Industry X Factor results 2005-2024

Year	TFP differential			Input price differential			X-factor
	Industry TFP	National TFP	Difference	National input price	Industry input price	Difference	
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	0.77%	0.32%	0.45%	3.55%	6.08%	-2.53%	-2.08%
2006-2007	-3.56%	0.27%	-3.82%	2.99%	0.38%	2.61%	-1.22%
2007-2008	-0.21%	-0.97%	0.76%	1.88%	4.99%	-3.11%	-2.35%
2008-2009	-2.15%	0.41%	-2.55%	-0.05%	-1.41%	1.36%	-1.19%
2009-2010	-0.99%	2.51%	-3.50%	4.01%	2.87%	1.14%	-2.36%
2010-2011	-1.90%	-0.40%	-1.49%	2.02%	2.98%	-0.96%	-2.45%
2011-2012	-0.96%	0.68%	-1.64%	2.44%	2.09%	0.36%	-1.29%
2012-2013	1.12%	0.58%	0.53%	2.03%	1.81%	0.22%	0.75%
2013-2014	-1.42%	0.60%	-2.03%	2.18%	1.99%	0.19%	-1.84%
2014-2015	0.36%	0.91%	-0.54%	1.14%	0.55%	0.59%	0.05%
2015-2016	-2.11%	0.01%	-2.11%	0.70%	0.68%	0.02%	-2.09%
2016-2017	-1.81%	0.64%	-2.45%	2.43%	2.70%	-0.27%	-2.72%
2017-2018	-0.34%	0.71%	-1.05%	2.94%	-0.29%	3.22%	2.18%
2018-2019	-2.12%	1.21%	-3.33%	2.64%	1.00%	1.64%	-1.68%
2019-2020	-8.14%	-0.56%	-7.58%	0.75%	0.63%	0.12%	-7.46%
2020-2021	1.94%	3.94%	-2.00%	8.18%	15.64%	-7.46%	-9.46%
2021-2022	-3.09%	-1.04%	-2.06%	5.86%	8.79%	-2.93%	-4.99%
2022-2023	-1.39%	1.66%	-3.05%	5.15%	-0.02%	5.17%	2.12%
2023-2024	-0.67%	1.58%	-2.25%	4.01%	0.74%	3.27%	1.02%
Annual average 2005-2024	**-1.40%**	**0.69%**	**-2.09%**	**2.89%**	**2.75%**	**0.14%**	**-1.95%**
Annual average 2010-2024	**-1.47%**	**0.75%**	**-2.22%**	**3.03%**	**2.81%**	**0.23%**	**-1.99%**
Annual average 2015-2024	**-1.97%**	**0.91%**	**-2.87%**	**3.63%**	**3.32%**	**0.31%**	**-2.56%**

LEI also estimated the X Factor using the Northeast Region utility sample, with customers used as the output metric, to test whether regional productivity and input price trends differ from the broader industry results. Over the 2005–2024 period, the Northeast Region TFP differential is –2.12%, compared with -2.09% for the broader industry (see Figure 35). The Northeast Region input price differential is 0.16%, slightly higher than the industry input price differential of 0.14%. Together, these components produce an average Northeast Region X Factor of -1.96% over the full 20-year period. Unlike the broader industry, where the X Factor became increasingly negative in more recent years, the Northeast Region exhibited a less negative X Factor over the most recent 15- and 10-year periods, averaging -1.49% and -1.85% per year, respectively.

Figure 35. Northeast Region X Factor results 2005-2024

Year	TFP differential			Input price differential			
	Industry TFP	National TFP	Difference	National input price	Industry input price	Difference	X-factor
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	-0.84%	0.32%	-1.16%	3.55%	5.77%	-2.22%	-3.38%
2006-2007	-3.85%	0.27%	-4.12%	2.99%	0.16%	2.83%	-1.29%
2007-2008	-2.90%	-0.97%	-1.93%	1.88%	4.33%	-2.46%	-4.38%
2008-2009	-3.75%	0.41%	-4.16%	-0.05%	-1.48%	1.43%	-2.73%
2009-2010	-3.41%	2.51%	-5.92%	4.01%	2.73%	1.28%	-4.64%
2010-2011	-2.00%	-0.40%	-1.60%	2.02%	2.92%	-0.89%	-2.50%
2011-2012	-4.02%	0.68%	-4.69%	2.44%	1.82%	0.62%	-4.07%
2012-2013	3.31%	0.58%	2.72%	2.03%	2.24%	-0.21%	2.51%
2013-2014	-1.45%	0.60%	-2.05%	2.18%	1.98%	0.21%	-1.85%
2014-2015	2.11%	0.91%	1.21%	1.14%	0.62%	0.52%	1.73%
2015-2016	-1.40%	0.01%	-1.40%	0.70%	0.83%	-0.14%	-1.54%
2016-2017	0.51%	0.64%	-0.13%	2.43%	3.14%	-0.71%	-0.84%
2017-2018	-2.80%	0.71%	-3.51%	2.94%	-0.13%	3.07%	-0.44%
2018-2019	0.75%	1.21%	-0.46%	2.64%	1.21%	1.43%	0.96%
2019-2020	-4.48%	-0.56%	-3.92%	0.75%	1.28%	-0.53%	-4.45%
2020-2021	4.53%	3.94%	0.59%	8.18%	15.25%	-7.07%	-6.48%
2021-2022	-3.39%	-1.04%	-2.36%	5.86%	8.43%	-2.57%	-4.93%
2022-2023	0.63%	1.66%	-1.03%	5.15%	0.30%	4.86%	3.82%
2023-2024	-4.74%	1.58%	-6.32%	4.01%	0.49%	3.52%	-2.80%
Annual average 2005-2024	**-1.43%**	**0.69%**	**-2.12%**	**2.89%**	**2.73%**	**0.16%**	**-1.96%**
Annual average 2010-2024	**-0.89%**	**0.75%**	**-1.64%**	**3.03%**	**2.88%**	**0.15%**	**-1.49%**
Annual average 2015-2024	**-1.16%**	**0.91%**	**-2.06%**	**3.63%**	**3.42%**	**0.21%**	**-1.85%**

7 Appendix A: List of EDCs included in the industry TFP study by BLS region

7.1 Midwest

1. AES Indiana
2. Ameren Illinois Company
3. Commonwealth Edison Company
4. Consumers Energy Company
5. DTE Electric Company
6. Duke Energy Indiana, LLC
7. Duke Energy Ohio, Inc.
8. Evergy Kansas South, Inc.
9. Evergy Metro, Inc.
10. Indiana Michigan Power Company
11. MDU Resources Group, Inc.
12. Minnesota Power Enterprises, Inc.
13. Northern Indiana Public Service Company, LLC
14. Northern States Power Company - MN
15. Northern States Power Company - WI
16. Ohio Edison Company

17. Southern Indiana Gas and Electric Company
18. The Cleveland Electric Illuminating Company
19. The Dayton Power and Light Company
20. The Empire District Electric Company
21. Union Electric Company
22. Wisconsin Electric Power Company
23. Wisconsin Public Service Corporation

7.2 Northeast

24. Atlantic City Electric Company
25. Central Hudson Gas & Electric Corporation
26. Central Maine Power Company
27. Consolidated Edison Company of New York, Inc.
28. Duquesne Light Company
29. FirstEnergy Pennsylvania Electric Company
30. Green Mountain Power Corporation
31. Jersey Central Power & Light Company
32. Massachusetts Electric Company
33. New York State Electric & Gas Corporation
34. Niagara Mohawk Power Corporation
35. NSTAR Electric Company
36. Orange and Rockland Utilities, Inc.
37. PECO Energy Company
38. PPL Electric Utilities Corporation
39. Public Service Company of New Hampshire
40. Public Service Electric and Gas Company
41. Rochester Gas and Electric Corporation
42. The Connecticut Light and Power Company
43. The Narragansett Electric Company
44. The United Illuminating Company
45. Versant Power

7.3 South

46. Alabama Power Company
47. Appalachian Power Company
48. Baltimore Gas and Electric Company
49. Cleco Power LLC
50. Delmarva Power & Light Company
51. Dominion Energy South Carolina, Inc.
52. Duke Energy Carolinas, LLC

53. Duke Energy Florida, LLC
54. Duke Energy Kentucky, Inc.
55. Duke Energy Progress, LLC
56. Entergy Arkansas, LLC
57. Entergy Mississippi, LLC
58. Entergy New Orleans, LLC
59. Florida Power & Light Company
60. Georgia Power Company
61. Kentucky Utilities Company
62. Louisville Gas and Electric Company
63. Mississippi Power Company
64. Monongahela Power Company
65. Oklahoma Gas and Electric Company
66. Potomac Electric Power Company
67. Public Service Company of Oklahoma
68. Southwestern Electric Power Company
69. Southwestern Public Service Company
70. Tampa Electric Company
71. The Potomac Edison Company
72. Virginia Electric and Power Company

7.4 West

73. Arizona Public Service Company
74. Avista Corporation
75. Black Hills Power, Inc.
76. El Paso Electric Company
77. Idaho Power Company
78. Nevada Power Company
79. Pacific Gas and Electric Company
80. PacifiCorp
81. Portland General Electric Company
82. Public Service Company of Colorado
83. Public Service Company of New Mexico
84. Puget Sound Energy, Inc.
85. San Diego Gas & Electric Company
86. Sierra Pacific Power Company
87. Southern California Edison Company
88. Tucson Electric Power Company

8 Appendix B: Sensitivity analysis - Industry and Northeast TFP and PFP results using sales as the output metric

For the full industry sample, the sales-based TFP results show a clear widening gap between total inputs and output over the 2005–2024 period. Total inputs, which reflect the composite of capital and OM&A, rise from 1.00 in 2005 to 1.51 by 2024, indicating input growth of about 51% over the study period (see Figure 36). By contrast, total output measured using sales remains broadly flat, ending at 0.97 in 2024 after some year-to-year variation. Because input growth substantially exceeds sales growth, the TFP index declines from 1.00 to 0.64 by the end of the period (see Figure 36). Total inputs increased at an average annual rate of approximately 2.18%, while sales output was roughly flat, actually declining slightly by -0.18% per year (see Figure 40). This implies an estimated average TFP decline of approximately 2.36% (see Figure 40). In the PBR context, the sales-based results suggest a more pronounced productivity decline than a customer-based output measure, because sales did not grow materially over the period while the sector continued to add capital and OM&A inputs.

For the Northeast sample, the sales-based productivity picture is similar, but somewhat more pronounced. Total inputs increase from 1.0 in 2005 to 1.45 by 2024, reflecting an increase in the combined use of capital and OM&A inputs (see Figure 37). Sales output declined modestly over the same period, falling from 1.00 to 0.88 by 2024. As a result, Northeast TFP drops from 1.0 to 0.61, indicating that measured productivity declined materially when sales are used as the output metric (see Figure 37). The Northeast total inputs have grown at an average annual rate of 1.97% while sales declined by 0.66% per year (see Figure 41). This implies an estimated average annual TFP decline of 2.63%. Relative to the industry-wide sales-based results, the Northeast appears to show a weaker productivity trend, driven by the combination of strong input growth and declining sales output.

Figure 36. Chained Fisher Ideal indices for industry TFP, inputs, and output using sales as the output metric

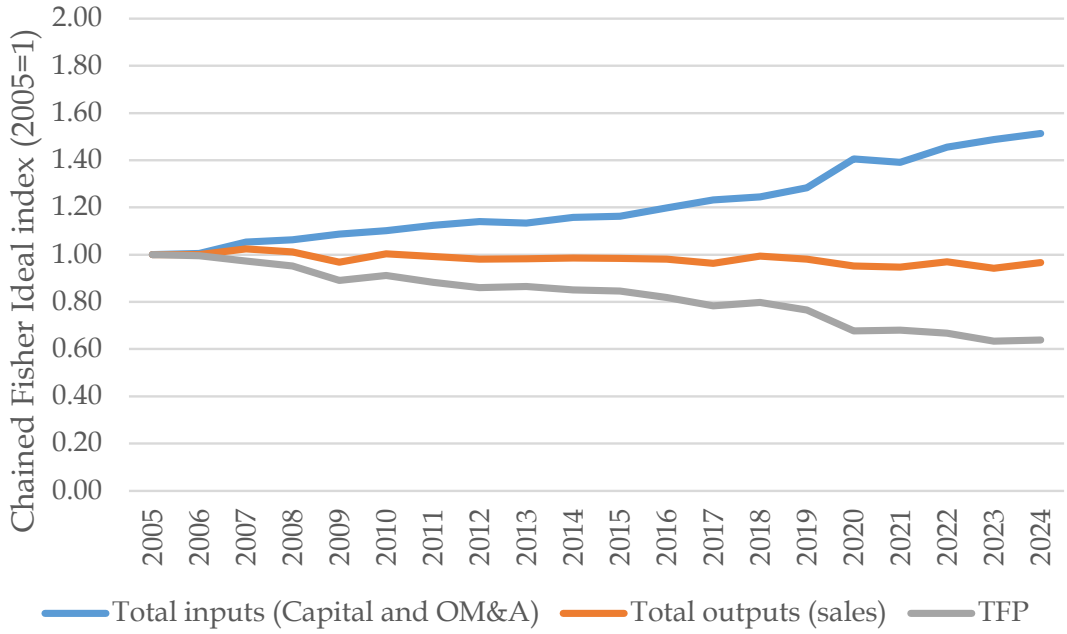
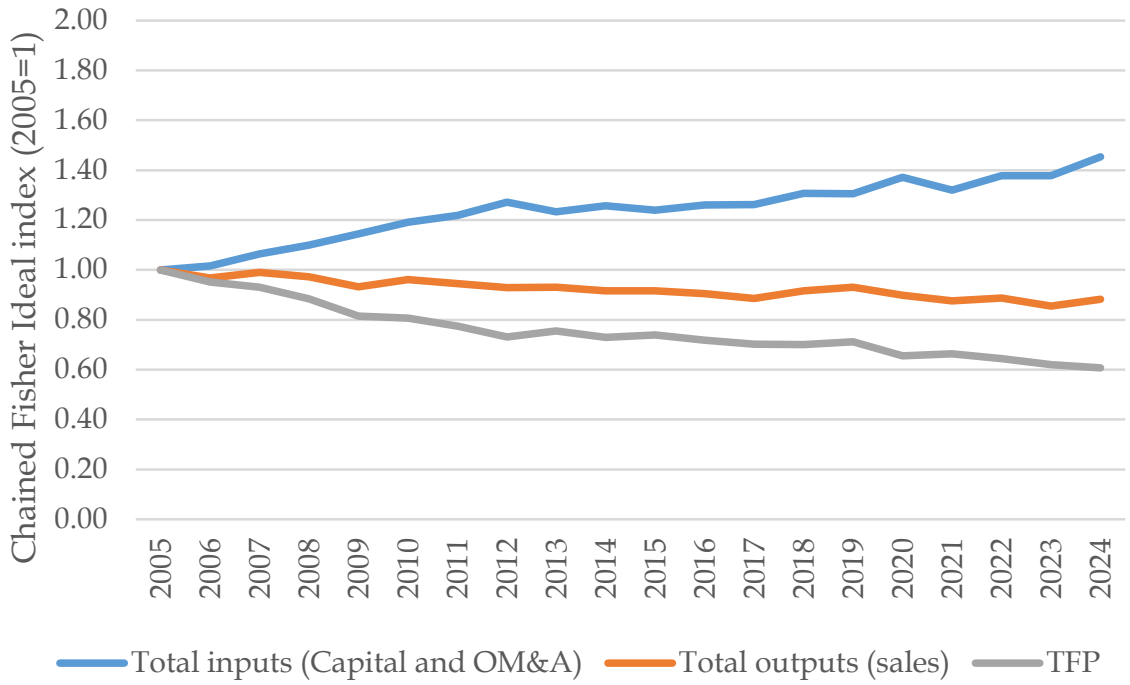


Figure 37. Chained Fisher Ideal indices for Northeast TFP, inputs, and output using sales as the output metric



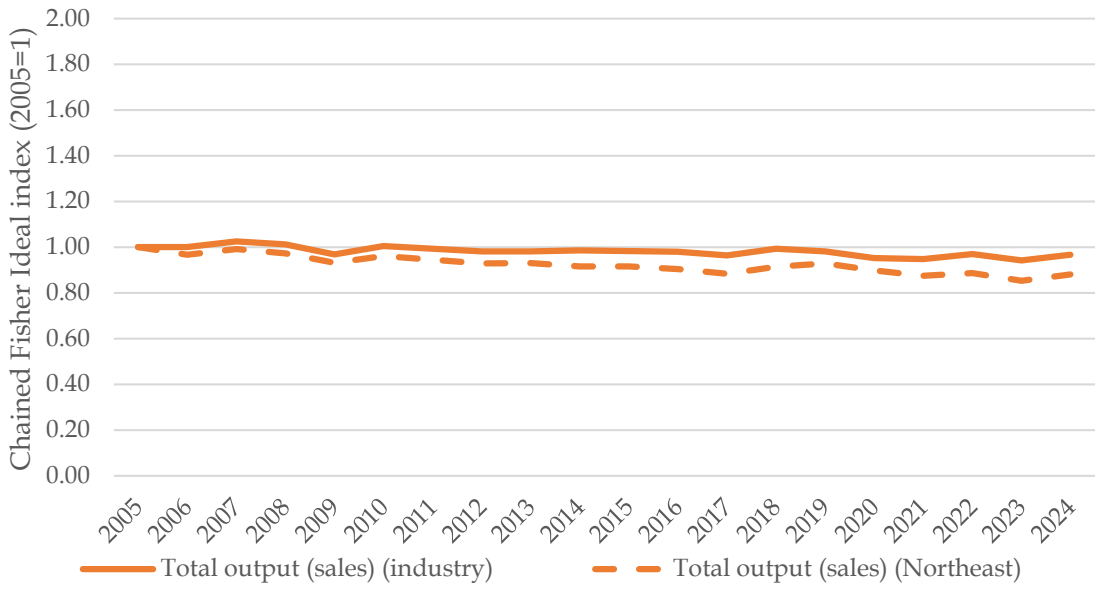
8.1 Industry and Northeast Region input index

Using sales as the output metric will not alter the industry or Northeast input index. These industry and Northeast input indices under the baseline model can be found in Sections 4.1 and 5.1 respectively.

8.2 Industry and Northeast Region output index using sales as the output metric

The sales output comparison shows that both the full industry and Northeast series are relatively flat over the 2005–2024 period, with neither showing meaningful long-term growth. The industry sales index remains close to 1.0 throughout the period and ends at 0.97 in 2024 (see Figure 38), with average annual growth of -0.18% (see Figure 40). The Northeast sales index follows a broadly similar pattern but sits slightly below the industry measure for much of the period, ending at 0.88 by 2024 (see Figure 38). Northeast sales output declined at an average annual rate of roughly 0.66% (see Figure 41). In the productivity analysis, this is important because sales-based output provides much less offset to input growth than the customer-based output measure. For the Northeast in particular, the combination of rising capital and OM&A inputs with flat or declining sales output places stronger downward pressure on measured TFP.

Figure 38. Chained Fisher Ideal index for total industry and Northeast output (sales)



8.3 Detailed results for industry and Northeast Region TFP and PFP growth using sales as the output metric

8.3.1 Industry and Northeast Region total factor productivity using sales as the output metric

The sales-based TFP comparison shows a sustained decline in measured productivity for both the full industry and the Northeast, with the Northeast generally tracking below the industry after the early years of the study period. The industry TFP index falls from 1.0 in 2005 to 0.64 by 2024, while the Northeast TFP index declines somewhat further, ending at 0.61 (see Figure 39). The accompanying growth-rate tables show that, using sales as the output metric, industry TFP declined by approximately 2.36% per year from 2005 to 2024 (see Figure 40), while Northeast TFP declined by approximately 2.63% per year over the same period (see Figure 41). The more negative Northeast result reflects the fact that Northeast sales output declined on average, while total inputs continued to rise. This is especially important in a PBR context because a sales-based output measure produces a weaker productivity result than a customer-based measure when electricity sales are flat or declining despite continued network investment.

The annual growth results help explain the difference between the industry and Northeast trends. For the industry, sales output growth was low over the full period, declining by 0.18% per year, while total inputs increased by approximately 2.18% per year (see Figure 40). For the Northeast, sales output declined by about 0.66% per year, while total inputs increased by approximately 1.97% per year (see Figure 41). Capital productivity was negative in both samples, with capital PFP declining by roughly 3.62% per year for the industry and 3.83% per year for the Northeast. OM&A PFP also declined, but the Northeast shows a more pronounced decline over the full period, at approximately 1.57% per year, compared with 0.97% per year for the industry. Overall, the sales-based results indicate that productivity pressures are present across the broader industry but are somewhat stronger in the Northeast because input growth occurred alongside declining sales output.

Figure 39. Chained Fisher Ideal index for industry and Northeast Region TFP using sales as the output metric

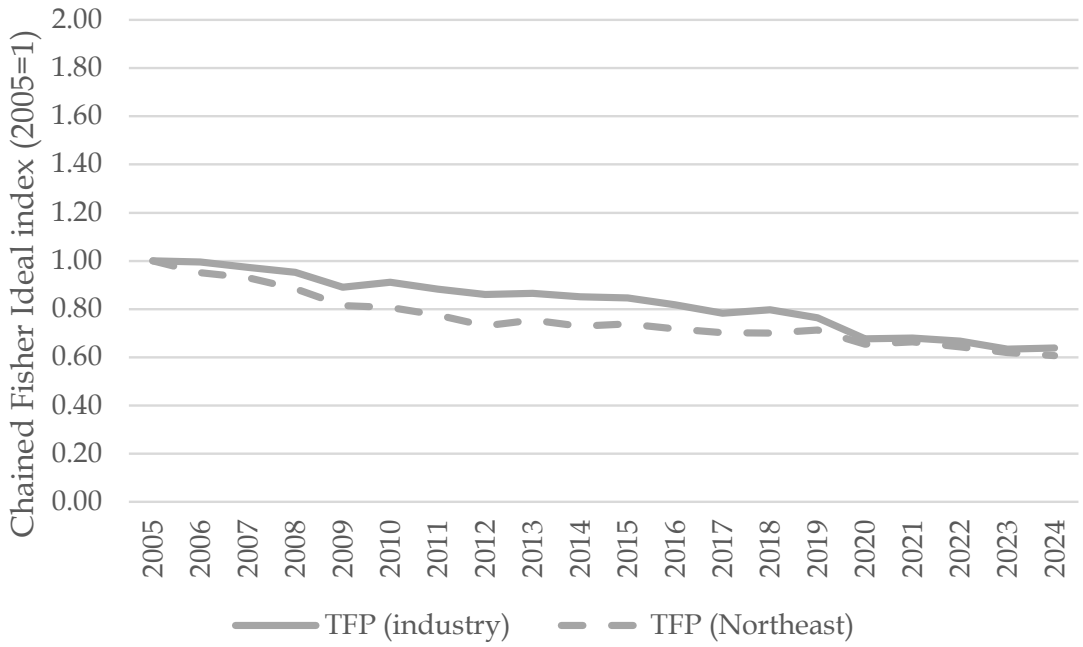


Figure 40. Annual growth rates for industry output, input, PFP, and TFP using sales as the output metric

	Output	Input			Productivity		
Year	Sales	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	-0.05%	2.01%	-0.77%	0.48%	-2.06%	0.73%	-0.53%
2006-2007	2.49%	2.11%	6.78%	4.68%	0.38%	-4.30%	-2.19%
2007-2008	-1.28%	2.40%	-0.37%	0.89%	-3.68%	-0.91%	-2.17%
2008-2009	-4.39%	2.99%	1.62%	2.25%	-7.38%	-6.01%	-6.64%
2009-2010	3.62%	1.86%	0.97%	1.38%	1.76%	2.65%	2.24%
2010-2011	-1.15%	2.34%	1.87%	2.09%	-3.49%	-3.02%	-3.23%
2011-2012	-1.16%	3.09%	-0.05%	1.41%	-4.24%	-1.11%	-2.57%
2012-2013	0.08%	3.18%	-4.01%	-0.56%	-3.09%	4.09%	0.65%
2013-2014	0.38%	3.53%	0.58%	2.03%	-3.15%	-0.21%	-1.66%
2014-2015	-0.21%	3.87%	-3.10%	0.41%	-4.08%	2.88%	-0.62%
2015-2016	-0.33%	4.23%	1.72%	3.00%	-4.56%	-2.05%	-3.33%
2016-2017	-1.66%	4.27%	1.07%	2.73%	-5.94%	-2.73%	-4.39%
2017-2018	2.97%	4.23%	-2.40%	1.09%	-1.26%	5.37%	1.88%
2018-2019	-1.22%	4.49%	1.41%	3.04%	-5.71%	-2.64%	-4.26%
2019-2020	-3.06%	4.89%	13.70%	9.12%	-7.95%	-16.76%	-12.18%
2020-2021	-0.46%	3.39%	-6.24%	-0.97%	-3.84%	5.78%	0.52%
2021-2022	2.43%	3.27%	6.23%	4.49%	-0.84%	-3.80%	-2.06%
2022-2023	-2.94%	4.42%	-1.03%	2.20%	-7.36%	-1.91%	-5.14%
2023-2024	2.55%	4.90%	-3.02%	1.69%	-2.34%	5.57%	0.87%
Annual average 2005-2024	**-0.18%**	**3.44%**	**0.79%**	**2.18%**	**-3.62%**	**-0.97%**	**-2.36%**
Annual average 2010-2024	**-0.27%**	**3.86%**	**0.48%**	**2.27%**	**-4.13%**	**-0.75%**	**-2.54%**
Annual average 2015-2024	**-0.19%**	**4.23%**	**1.27%**	**2.93%**	**-4.42%**	**-1.46%**	**-3.12%**

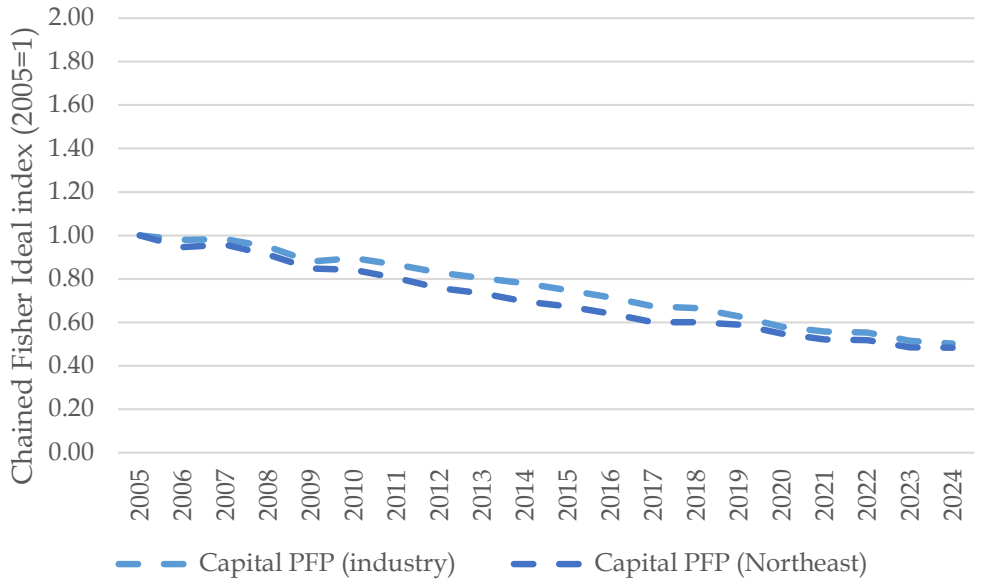
Figure 41. Annual growth rates for Northeast output, input, PFP, and TFP using sales as the output metric

	Output	Input			Productivity		
Year	Sales	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	-3.37%	2.22%	1.23%	1.64%	-5.59%	-4.60%	-5.01%
2006-2007	2.41%	1.22%	6.95%	4.61%	1.19%	-4.54%	-2.20%
2007-2008	-1.83%	3.05%	3.43%	3.27%	-4.88%	-5.26%	-5.11%
2008-2009	-4.24%	3.01%	4.62%	3.96%	-7.25%	-8.86%	-8.21%
2009-2010	3.02%	3.74%	4.12%	3.97%	-0.73%	-1.10%	-0.95%
2010-2011	-1.62%	2.94%	1.98%	2.37%	-4.56%	-3.60%	-3.99%
2011-2012	-1.66%	4.25%	4.28%	4.26%	-5.91%	-5.94%	-5.93%
2012-2013	0.14%	3.31%	-7.71%	-3.11%	-3.18%	7.84%	3.25%
2013-2014	-1.52%	3.92%	0.40%	1.93%	-5.43%	-1.91%	-3.44%
2014-2015	-0.05%	3.19%	-5.15%	-1.42%	-3.24%	5.11%	1.37%
2015-2016	-1.25%	3.70%	-0.01%	1.69%	-4.94%	-1.24%	-2.94%
2016-2017	-2.22%	4.29%	-3.70%	0.07%	-6.51%	1.48%	-2.29%
2017-2018	3.48%	3.51%	3.55%	3.53%	-0.03%	-0.06%	-0.04%
2018-2019	1.47%	3.30%	-3.19%	-0.11%	-1.83%	4.66%	1.59%
2019-2020	-3.45%	3.60%	6.18%	4.95%	-7.05%	-9.63%	-8.40%
2020-2021	-2.53%	2.61%	-10.69%	-3.85%	-5.14%	8.16%	1.32%
2021-2022	1.34%	2.02%	7.25%	4.33%	-0.69%	-5.91%	-3.00%
2022-2023	-3.87%	2.85%	-3.85%	-0.10%	-6.72%	-0.02%	-3.77%
2023-2024	3.21%	3.54%	7.54%	5.34%	-0.33%	-4.33%	-2.13%
Annual average 2005-2024	**-0.66%**	**3.17%**	**0.91%**	**1.97%**	**-3.83%**	**-1.57%**	**-2.63%**
Annual average 2010-2024	**-0.61%**	**3.36%**	**-0.22%**	**1.42%**	**-3.97%**	**-0.39%**	**-2.03%**
Annual average 2015-2024	**-0.42%**	**3.27%**	**0.34%**	**1.76%**	**-3.69%**	**-0.77%**	**-2.19%**

8.3.2 Industry and Northeast Region partial factor productivity

The sales-based capital PFP results show a sustained decline for both the full industry and the Northeast, indicating that capital inputs increased much faster than sales output over the study period. Both series begin at 1.00 in 2005 and fall to roughly 0.50 by 2024, meaning capital productivity, measured as sales output per unit of capital input, declined by about half over the period (see Figure 42). The industry and Northeast trends move closely together, although the Northeast generally sits slightly below the industry from around 2009 onward, suggesting somewhat weaker capital productivity performance in the region. Capital PFP for the industry and the Northeast has declined at an average annual rate of approximately 3.62% to 3.83% respectively (see Figure 40 and Figure 41). In the PBR context, this reinforces the main finding from the sales-based TFP analysis: continued capital growth, combined with flat or declining sales output, places significant downward pressure on measured productivity, especially in the Northeast.

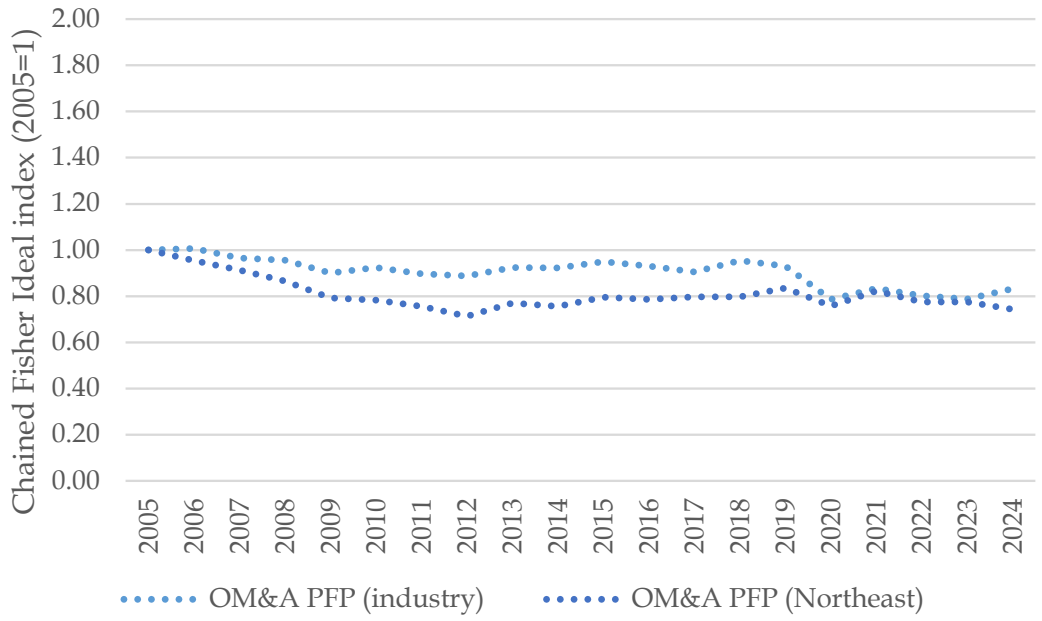
Figure 42. Chained Fisher Ideal index for industry and Northeast capital PFP using sales as the output metric



The sales-based OM&A PFP comparison shows that both the industry and Northeast experienced a decline in OM&A productivity, although the Northeast generally performs below the industry for most of the period. Both series start near 1.00 in 2005, decline through the late 2000s and early 2010s, and then stabilize at a lower level. By 2024, the industry OM&A PFP index is approximately 0.83, while the Northeast index is closer to 0.74, indicating a larger decline in OM&A productivity

for the Northeast (see Figure 43). Industry OM&A PFP has declined at an average annual rate of 0.97%, while Northeast OM&A PFP declined by 1.57% per year (see Figure 40 and Figure 41). In the sales-based productivity framework, this suggests that OM&A inputs grew faster than sales output in both samples, but the effect was more pronounced in the Northeast. Combined with the capital PFP results, this helps explain why Northeast sales-based TFP falls below the broader industry trend.

Figure 43. Chained Fisher Ideal index for industry and Northeast OM&A PFP using sales as the output metric



8.4 Converting the estimated U.S. industry and Northeast Region TFP annual average growth rate into an X factor using sales as the output metric

The sales-based X Factor results are negative for both the full industry and the Northeast over the 2005–2024 period, reflecting the combination of negative TFP differentials and only modestly positive input price differentials. For the full industry sample, calculated industry TFP declined by 2.36% per year on average, compared with national TFP growth of 0.69%, producing a TFP differential of -3.05% (see Figure 44). The input price differential was slightly positive at 0.14%, as the economy-wide input price proxy, measured as GDP-FSDP plus national TFP, grew slightly faster than the weighted average of OM&A and capital prices. Combining these components results in an average industry X Factor of approximately -2.91% over 2005–2024 (see Figure 44).

The results get more negative across the alternative averaging periods, with X Factors of -3.06% for 2010–2024 and -3.72% for 2015–2024 (see Figure 44).

In the PBR context, this indicates that when sales are used as the output metric, the industry's measured productivity performance is materially weaker than the national economy benchmark, and the positive input price differential is not large enough to offset the negative productivity differential.

The Northeast sales-based X Factor results are also negative, and slightly more negative than the U.S. industry results over the full period. From 2005 to 2024, Northeast Region calculated TFP declined by 2.63% per year, while national TFP increased by 0.69%, producing a TFP differential of -3.31% (see Figure 45). The input price differential was positive at 0.16%, resulting in an average X Factor of approximately -3.16% (see Figure 45). Over the 2010–2024 period, the Northeast X Factor was -2.63%, while the 2015–2024 period shows a more negative X Factor of -2.88% (see Figure 45).

This more recent moderation reflects a smaller negative TFP differential, although the overall result remains below zero. Relative to the full industry, the Northeast Region results suggest somewhat greater productivity pressure under the sales-based specification, largely because sales output declined while capital and OM&A inputs continued to increase.

Figure 44. U.S. Industry X Factor results 2005-2024 using sales as the output metric

Year	TFP differential			Input price differential			X-factor
	Industry TFP	National TFP	Difference	National input price	Industry input price	Difference	
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	-0.53%	0.32%	-0.85%	3.55%	6.08%	-2.53%	-3.37%
2006-2007	-2.19%	0.27%	-2.46%	2.99%	0.38%	2.61%	0.15%
2007-2008	-2.17%	-0.97%	-1.20%	1.88%	4.99%	-3.11%	-4.31%
2008-2009	-6.64%	0.41%	-7.05%	-0.05%	-1.41%	1.36%	-5.68%
2009-2010	2.24%	2.51%	-0.27%	4.01%	2.87%	1.14%	0.87%
2010-2011	-3.23%	-0.40%	-2.83%	2.02%	2.98%	-0.96%	-3.79%
2011-2012	-2.57%	0.68%	-3.25%	2.44%	2.09%	0.36%	-2.89%
2012-2013	0.65%	0.58%	0.06%	2.03%	1.81%	0.22%	0.28%
2013-2014	-1.66%	0.60%	-2.26%	2.18%	1.99%	0.19%	-2.07%
2014-2015	-0.62%	0.91%	-1.53%	1.14%	0.55%	0.59%	-0.94%
2015-2016	-3.33%	0.01%	-3.34%	0.70%	0.68%	0.02%	-3.32%
2016-2017	-4.39%	0.64%	-5.03%	2.43%	2.70%	-0.27%	-5.31%
2017-2018	1.88%	0.71%	1.17%	2.94%	-0.29%	3.22%	4.40%
2018-2019	-4.26%	1.21%	-5.47%	2.64%	1.00%	1.64%	-3.83%
2019-2020	-12.18%	-0.56%	-11.61%	0.75%	0.63%	0.12%	-11.49%
2020-2021	0.52%	3.94%	-3.43%	8.18%	15.64%	-7.46%	-10.88%
2021-2022	-2.06%	-1.04%	-1.02%	5.86%	8.79%	-2.93%	-3.95%
2022-2023	-5.14%	1.66%	-6.80%	5.15%	-0.02%	5.17%	-1.62%
2023-2024	0.87%	1.58%	-0.71%	4.01%	0.74%	3.27%	2.56%
Annual average 2005-2024	**-2.36%**	**0.69%**	**-3.05%**	**2.89%**	**2.75%**	**0.14%**	**-2.91%**
Annual average 2010-2024	**-2.54%**	**0.75%**	**-3.29%**	**3.03%**	**2.81%**	**0.23%**	**-3.06%**
Annual average 2015-2024	**-3.12%**	**0.91%**	**-4.03%**	**3.63%**	**3.32%**	**0.31%**	**-3.72%**

Figure 45. Northeast Region X Factor results 2005-2024 using sales as the output metric

Year	TFP differential			Input price differential			X-factor
	Industry TFP	National TFP	Difference	National input price	Industry input price	Difference	
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	-5.01%	0.32%	-5.33%	3.55%	5.77%	-2.22%	-7.55%
2006-2007	-2.20%	0.27%	-2.47%	2.99%	0.16%	2.83%	0.36%
2007-2008	-5.11%	-0.97%	-4.14%	1.88%	4.33%	-2.46%	-6.59%
2008-2009	-8.21%	0.41%	-8.61%	-0.05%	-1.48%	1.43%	-7.18%
2009-2010	-0.95%	2.51%	-3.46%	4.01%	2.73%	1.28%	-2.18%
2010-2011	-3.99%	-0.40%	-3.59%	2.02%	2.92%	-0.89%	-4.48%
2011-2012	-5.93%	0.68%	-6.61%	2.44%	1.82%	0.62%	-5.98%
2012-2013	3.25%	0.58%	2.66%	2.03%	2.24%	-0.21%	2.45%
2013-2014	-3.44%	0.60%	-4.04%	2.18%	1.98%	0.21%	-3.84%
2014-2015	1.37%	0.91%	0.46%	1.14%	0.62%	0.52%	0.99%
2015-2016	-2.94%	0.01%	-2.94%	0.70%	0.83%	-0.14%	-3.08%
2016-2017	-2.29%	0.64%	-2.93%	2.43%	3.14%	-0.71%	-3.64%
2017-2018	-0.04%	0.71%	-0.75%	2.94%	-0.13%	3.07%	2.32%
2018-2019	1.59%	1.21%	0.38%	2.64%	1.21%	1.43%	1.80%
2019-2020	-8.40%	-0.56%	-7.84%	0.75%	1.28%	-0.53%	-8.36%
2020-2021	1.32%	3.94%	-2.62%	8.18%	15.25%	-7.07%	-9.70%
2021-2022	-3.00%	-1.04%	-1.96%	5.86%	8.43%	-2.57%	-4.53%
2022-2023	-3.77%	1.66%	-5.43%	5.15%	0.30%	4.86%	-0.58%
2023-2024	-2.13%	1.58%	-3.71%	4.01%	0.49%	3.52%	-0.19%
Annual average 2005-2024	**-2.63%**	**0.69%**	**-3.31%**	**2.89%**	**2.73%**	**0.16%**	**-3.16%**
Annual average 2010-2024	**-2.03%**	**0.75%**	**-2.78%**	**3.03%**	**2.88%**	**0.15%**	**-2.63%**
Annual average 2015-2024	**-2.19%**	**0.91%**	**-3.09%**	**3.63%**	**3.42%**	**0.21%**	**-2.88%**

9 Appendix C: Sensitivity analysis - Industry and Northeast Region TFP and PFP results using hyperbolic depreciation of capital

9.1 Assumptions required under hyperbolic depreciation

Average age of the 1988 opening capital asset base

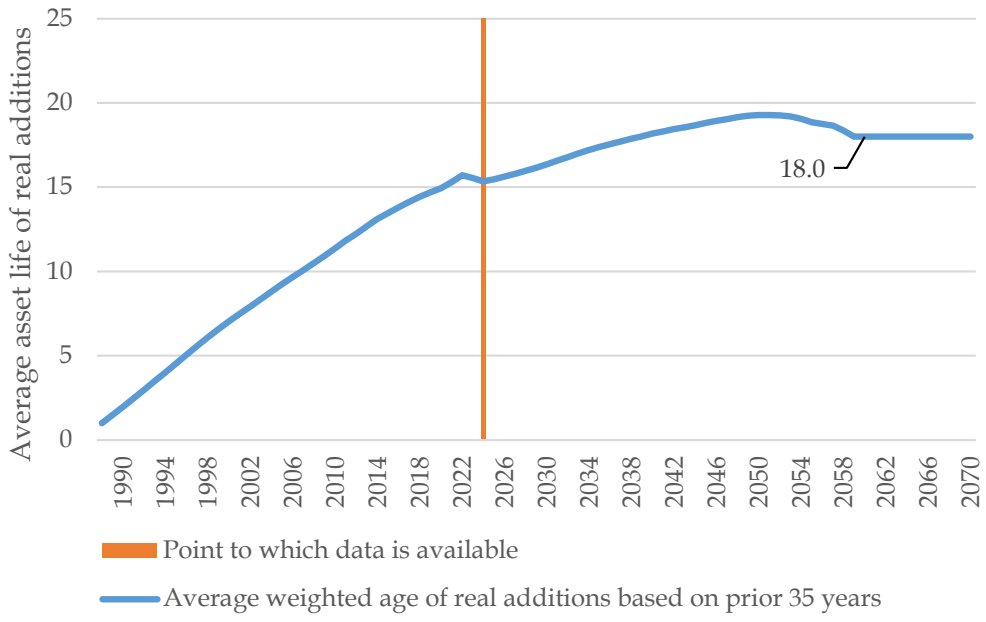
A key assumption in LEI's hyperbolic capital model relates to the age profile of the capital asset base in the first year of the analysis. The capital asset base observed in 1988 is not a single vintage of assets; rather, it reflects distribution assets that were placed in service over a number of prior years. In the absence of detailed vintage-level data showing the original installation year for each asset included in the 1988 asset base, LEI must assign an assumed average age to this opening stock of capital.

LEI assumes that the 1988 opening capital asset base is, on average, halfway through its assumed useful life. Given an assumed useful life of 35 years, this implies an average age of approximately 18 years, with the midpoint rounded up. This assumption is reasonable where EDCs have historically invested relatively consistent amounts of capital each year. Under a stable long-run investment profile, the weighted average age of the stock of assets still in service, when looking back over the prior 35 years of real capital additions, will tend toward the midpoint of the asset service life. The assumption therefore provides a practical way to initialize the hyperbolic model where detailed asset-vintage information is unavailable.

This assumption is distinct from a standard perpetual inventory equation applied from a complete historical investment series. With a complete history, the model could directly track each year's real additions and apply the relevant age-efficiency weight to each vintage. In this case, however, the opening capital base already exists in 1988, and the vintages embedded in that base are not separately observed. The assumed average age is therefore necessary to translate the observed opening asset base into an estimated productive capital stock for use in the hyperbolic model.

In order to establish a realistic growth rate, we require additions data for 35 years (average useful asset life) to establish a base of capital and then need an additional 20 years for our TFP Study, for a total of 55 years of data. However, data is only available for 36 years total meaning the majority of the time series is spent building up the capital profile resulting in stronger growth, and a more negative TFP. If allowed to play out over a longer period of time then is currently possible, hyperbolic depreciated capital would begin to plateau once a consistent base of additions and decay had been established.

Figure 46. Average age of prior 35 years of real capital additions



Note: After 2024, the last year for which data is available, we assume real additions continue each year and are equal to the average of all preceding years.

Hyperbolic efficiency parameter

A second key assumption is the selection of the beta parameter in the hyperbolic age-efficiency function. This parameter determines the shape of the age-efficiency curve and, therefore, the rate at which an asset is assumed to lose productive efficiency as it ages. In practical terms, the beta value affects how much productive capital service is attributed to older assets relative to newer assets. A higher or lower beta assumption can change the estimated productive capital stock, particularly where a utility has a relatively old or relatively young asset base.

LEI assumes an efficiency parameter of 0.75. This is the same parameter used by the BLS for structures in its capital input methodology. The BLS approach uses a hyperbolic age-efficiency function to estimate the relative efficiency of assets at different ages and assumes an efficiency-decline parameter of 0.75 for structures. [63] This parameter produces an age-efficiency profile in which assets lose efficiency relatively slowly early in their service lives and more rapidly later in their service lives.

[63] Bureau of Labor Statistics. *Productivity Measures: Business Sector and Major Subsectors: Calculation*. 2020.

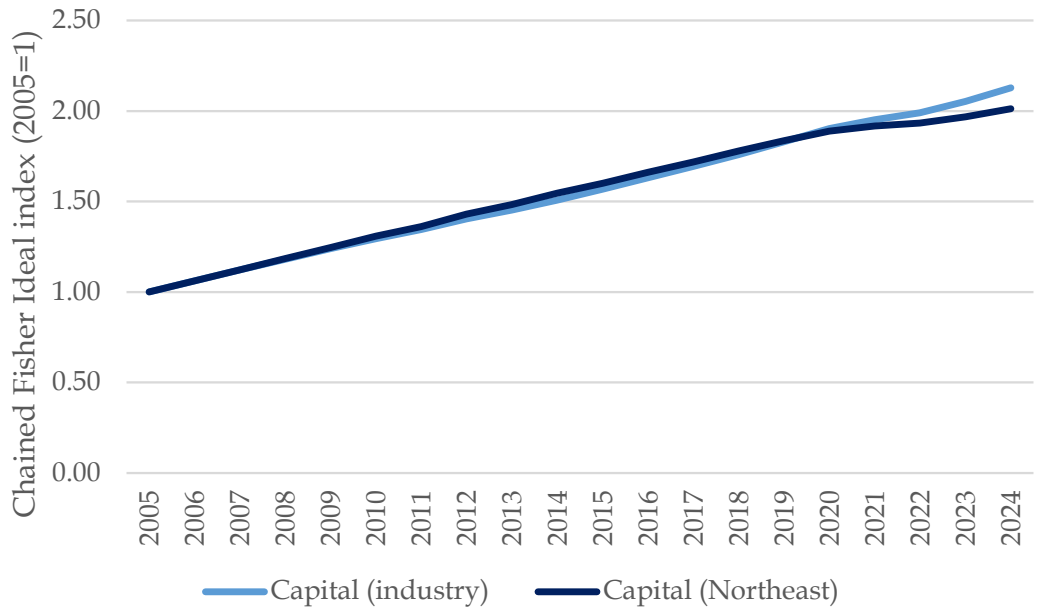
The use of the BLS structures parameter is a reasonable proxy for electric distribution assets. The NIPA definition of structures includes assets such as commercial buildings, highways, dams, and single-family houses, which are generally constructed in place and have long economic lives.[64] Electric distribution networks share several of these characteristics: they are location-specific, long-lived, and constructed using many of the same broad types of construction inputs, skills, and materials as other infrastructure assets. While electric distribution assets are not identical to the full NIPA structures category, the BLS structures parameter provides a defensible external benchmark in the absence of asset-specific observed depreciation or age-efficiency data for the EDC capital stock.

9.2 U.S. Industry and Northeast Region input index

Under the hyperbolic depreciation specification, the capital input indices for both the full industry and the Northeast follow a very similar upward path. Both series start at 1.00 in 2005 and rise to above 2.00 by 2024, indicating that capital inputs roughly doubled over the study period (see Figure 47). The industry index ends slightly above the Northeast index, at 2.13 compared with 2.01, suggesting somewhat stronger capital growth for the broader industry in the most recent years. Capital inputs have grown at an average annual rate of 3.97% for the industry (see Figure 52) and 3.68% for the Northeast (see Figure 53). In the productivity analysis, this confirms that the hyperbolic depreciation model still produces substantial capital input growth, which is a key driver of negative TFP when measured output grows more slowly. Relative to the OHS model, the hyperbolic approach produces a somewhat higher capital input index by the end of the period, but the overall conclusion is unchanged: capital accumulation is a major source of rising total inputs and downward pressure on measured productivity.

[64] Bureau of Economic Analysis. *Concepts and Methods of the U.S. National Income and Product Accounts*. 2024.

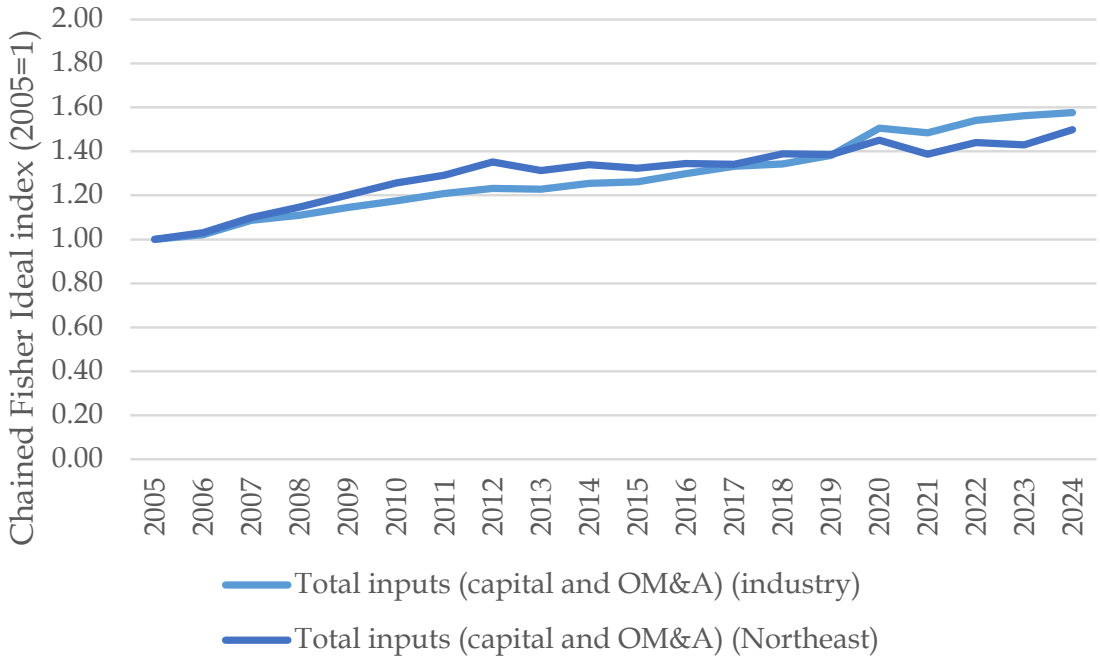
Figure 47. Chained Fisher Ideal index for U.S. industry and Northeast Region capital using hyperbolic depreciation of capital



Using hyperbolic depreciation of capital will have no impact on the industry or Northeast Region chained Fisher Ideal index for OM&A, but will ultimately impact the total input index (capital and OM&A). For a discussion on OM&A, see Sections 4.1 and 5.1.

The total input indices for the industry and Northeast Region move closely together over the 2005–2024 period, with both showing substantial growth in the composite of capital and OM&A inputs. The industry total input index rises from 1.00 in 2005 to 1.58 by 2024, while the Northeast index ends at a slightly lower level of 1.50 (see Figure 48). The Northeast Region series is somewhat higher than the industry for much of the mid-period, particularly from around 2009 through 2019, but the two series converge by the end of the period with the industry index slightly higher. Total inputs have grown at an average annual rate of approximately 2.39% for the industry and 2.13% for the Northeast Region (see Figure 52 and Figure 53). In the productivity analysis, this indicates that slower total input growth in the Northeast Region largely offsets its slower customer output growth, resulting in a TFP decline that is slightly less negative than the broader industry.

Figure 48. Chained Fisher Ideal index for total industry and Northeast Region inputs (capital and OM&A)



9.3 Industry and Northeast Region output index

Using hyperbolic depreciation of capital will not alter the industry or Northeast Region output index. These industry and Northeast Region input indices under the baseline model can be found in Sections 4.2 and 5.2 respectively.

9.4 Detailed results for U.S. industry and Northeast TFP and PFP growth using hyperbolic depreciation of capital

Under the hyperbolic depreciation model, the industry results show the same broad productivity pattern as the baseline model specification: **total inputs increase materially while customer output grows only gradually, resulting in a declining TFP index**.

Total inputs, measured as the composite of capital and OM&A, rise from 1.00 in 2005 to 1.58 by 2024 (see Figure 49), an average annual input growth of 2.39% for the U.S. industry (see Figure 52). Customer output increases more slowly, moving from 1.0 to 1.16 over the same period, or 0.78% per year. Because input growth outpaces output growth, TFP declines from 1.00 to about 0.74 by 2024, an average annual decline of 1.62%. In the PBR context, the hyperbolic depreciation specification still points to negative measured productivity, although the decline appears somewhat less severe than in some of the sales-based results because customer output grows

modestly over the period. However, the hyperbolic depreciation results appear to show a slightly more negative productivity trend than the OHS results. The capital depreciation methodology affects the magnitude of the productivity estimate, but it does not change the overall finding that input growth has outpaced customer growth.

For the Northeast Region sample, the hyperbolic depreciation results also show rising input intensity and declining productivity. Total inputs increase from 1.00 in 2005 to approximately 1.50 by 2024, with average annual growth of 2.13% (see Figure 53). Customer output rises only slightly, ending near 1.11 by 2024, or roughly 0.53% per year on average. As a result, the Northeast TFP falls from 1.0 to approximately 0.74 by the end of the period, corresponding to an estimated average annual decline of 1.59%. Compared with the industry, the Northeast shows a slightly better productivity trend under the hyperbolic depreciation model, as slower total input growth (2.13% versus 2.39% for the industry) more than offsets slower customer growth (0.53% versus 0.78% for the industry).

Figure 49. Chained Fisher Ideal indices for U.S. industry TFP, inputs, and output using hyperbolic depreciation of capital

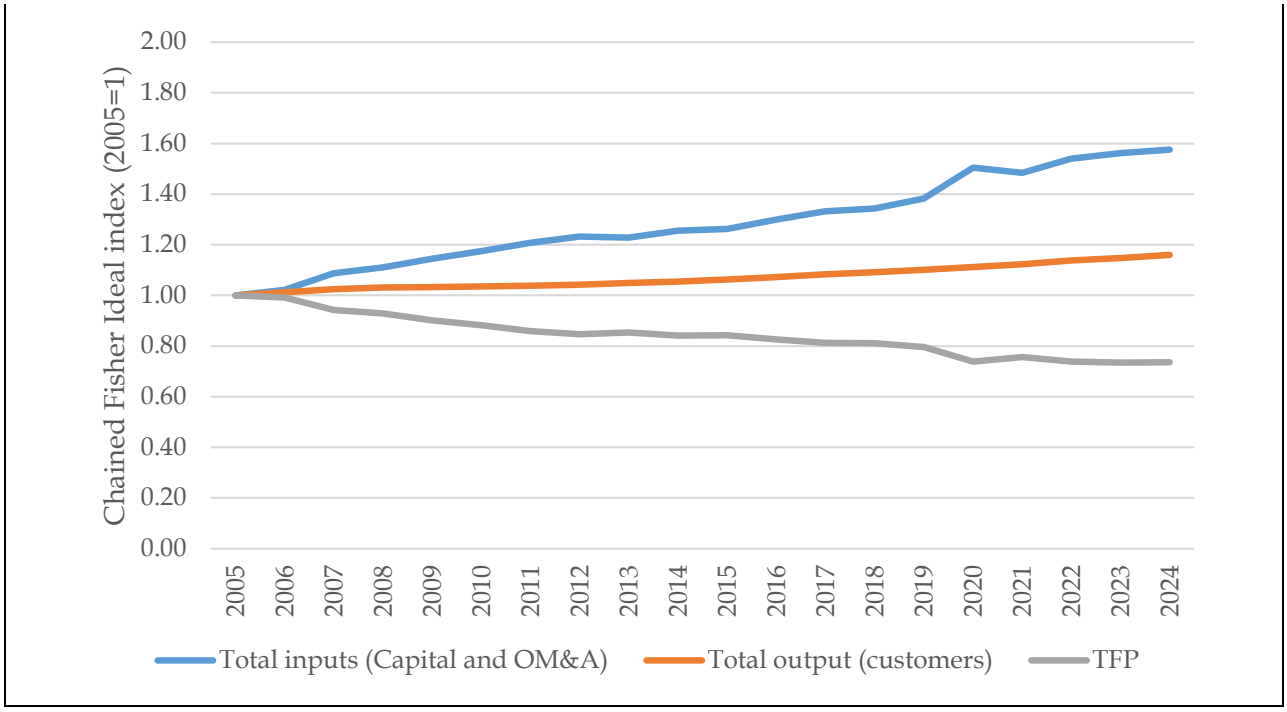
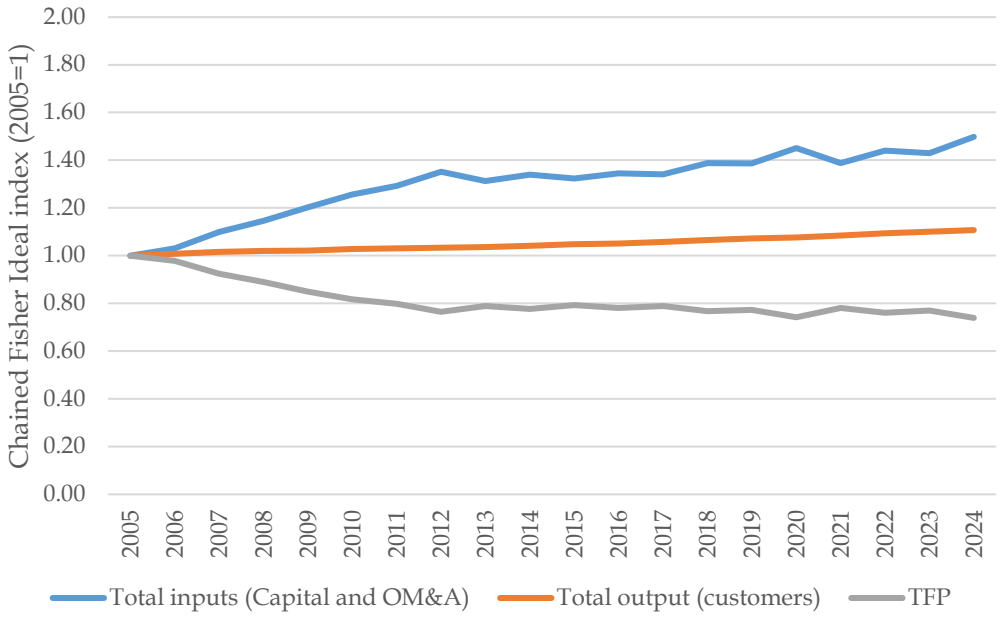

Chained Fisher Ideal index (2005=1)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Total inputs (Capital and OM&A)
Total output (customers)
TFP

Figure 50. Chained Fisher Ideal indices for Northeast Region TFP, inputs, and output using hyperbolic depreciation of capital



9.4.1 Industry and Northeast Region total factor productivity using hyperbolic depreciation of capital

Under the hyperbolic depreciation specification, both the U.S. industry and Northeast Region TFP indices decline over the 2005–2024 period, but the Northeast Region generally remains slightly below the industry for most of the period. The U.S. industry TFP index falls from 1.00 in 2005 to 0.74 by 2024, while the Northeast Region index ends at the same level (see Figure 51). The annual growth tables show that industry TFP declined by 1.62% per year on average from 2005 to 2024 (see Figure 52), compared with a smaller Northeast decline of 1.59% (see Figure 53). The similarity in productivity trends reflects the fact that slower customer growth in the Northeast (0.53% versus 0.78% industry) was largely offset by slower total input growth (2.13% versus 2.39% industry). U.S. industry customer output grew by 0.78% per year on average (see Figure 52), compared with 0.53% for the Northeast Region (see Figure 53), while total inputs grew by 2.39% in the industry and 2.13% the Northeast Region. In a PBR context, this indicates that the hyperbolic depreciation model produces negative measured productivity for both samples, with somewhat greater productivity pressure observed for the Industry.

The shorter-period averages show that the negative TFP trend moderates over time, especially for the Northeast. For the industry, TFP declined by 1.30% per year over 2010–2024 and 1.51% over 2015–2024 (see Figure 52). For the Northeast, TFP declined by 0.72% over 2010–2024 and

only 0.78% over 2015–2024 (see Figure 53). This suggests that although measured productivity remains negative, the rate of decline is less severe in the more recent period. The productivity detail also shows that capital PFP remains the main source of pressure, with average capital productivity declining by 3.19% for the industry (see Figure 52) and 3.15% for the Northeast over 2005–2024 (see Figure 53). OM&A productivity is weaker over the full period but improves in the later window, particularly in the Northeast Region, where OM&A PFP is positive at 0.75% over 2010–2024 and 0.26% over 2015-2024. Relative to the OHS model, the hyperbolic depreciation model produces a broadly similar conclusion: input growth continues to exceed measured output growth, but the depreciation methodology affects the magnitude and timing of the estimated TFP decline.

Figure 51. Chained Fisher Ideal index for U.S. industry and Northeast Region TFP using hyperbolic depreciation of capital

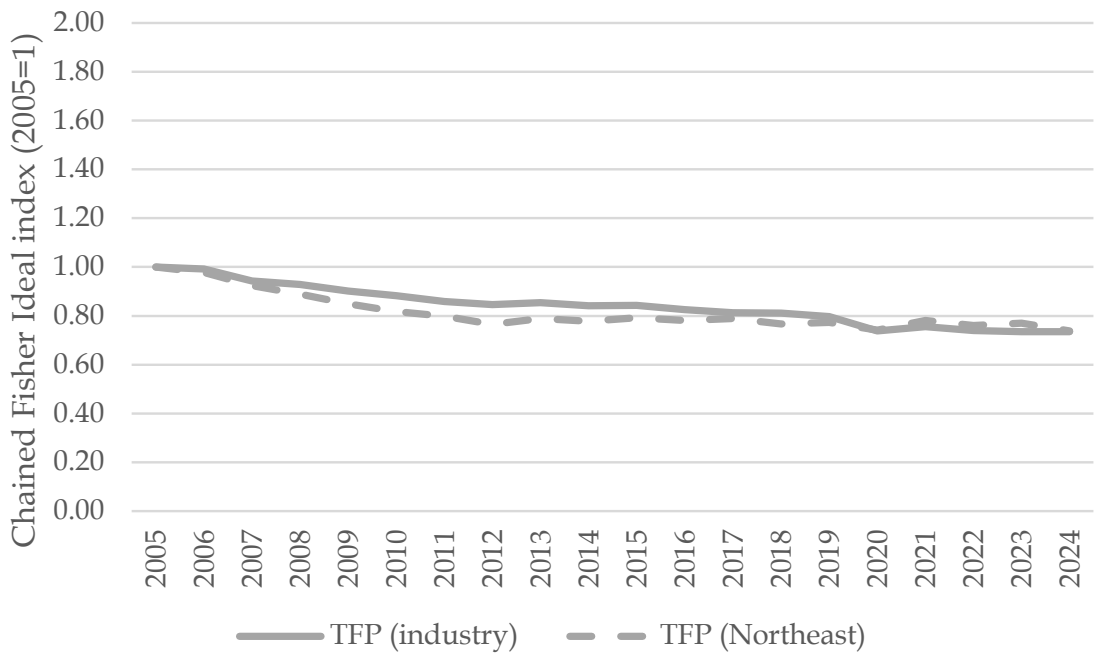


Figure 52. Annual growth rates for U.S. industry output, input, PFP, and TFP using hyperbolic depreciation of capital

	Output	Input			Productivity		
Year	Customers	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	1.25%	6.05%	-0.77%	2.14%	-4.80%	2.02%	-0.89%
2006-2007	1.12%	5.45%	6.78%	6.20%	-4.33%	-5.66%	-5.08%
2007-2008	0.68%	5.18%	-0.37%	2.12%	-4.50%	1.06%	-1.44%
2008-2009	0.10%	4.84%	1.62%	3.10%	-4.73%	-1.51%	-2.99%
2009-2010	0.39%	4.32%	0.97%	2.52%	-3.93%	-0.58%	-2.13%
2010-2011	0.19%	3.89%	1.87%	2.82%	-3.70%	-1.68%	-2.63%
2011-2012	0.45%	4.19%	-0.05%	1.98%	-3.74%	0.50%	-1.53%
2012-2013	0.56%	3.49%	-4.01%	-0.31%	-2.93%	4.56%	0.86%
2013-2014	0.61%	3.66%	0.58%	2.15%	-3.05%	0.03%	-1.54%
2014-2015	0.78%	3.93%	-3.10%	0.55%	-3.15%	3.87%	0.23%
2015-2016	0.90%	3.94%	1.72%	2.89%	-3.04%	-0.82%	-1.99%
2016-2017	0.92%	3.77%	1.07%	2.51%	-2.85%	-0.15%	-1.59%
2017-2018	0.75%	3.72%	-2.40%	0.89%	-2.97%	3.15%	-0.15%
2018-2019	0.92%	4.02%	1.41%	2.82%	-3.10%	-0.49%	-1.90%
2019-2020	0.98%	3.90%	13.70%	8.51%	-2.92%	-12.72%	-7.54%
2020-2021	0.97%	2.49%	-6.24%	-1.40%	-1.52%	7.21%	2.37%
2021-2022	1.40%	2.00%	6.23%	3.72%	-0.60%	-4.83%	-2.32%
2022-2023	0.80%	3.11%	-1.03%	1.43%	-2.31%	1.84%	-0.62%
2023-2024	1.02%	3.51%	-3.02%	0.85%	-2.49%	4.04%	0.17%
Annual average 2005-2024	**0.78%**	**3.97%**	**0.79%**	**2.39%**	**-3.19%**	**-0.01%**	**-1.62%**
Annual average 2010-2024	**0.80%**	**3.54%**	**0.48%**	**2.10%**	**-2.74%**	**0.32%**	**-1.30%**
Annual average 2015-2024	**0.96%**	**3.38%**	**1.27%**	**2.47%**	**-2.42%**	**-0.31%**	**-1.51%**

Figure 53. Annual growth rates for Northeast Region output, input, PFP, and TFP using hyperbolic depreciation of capital

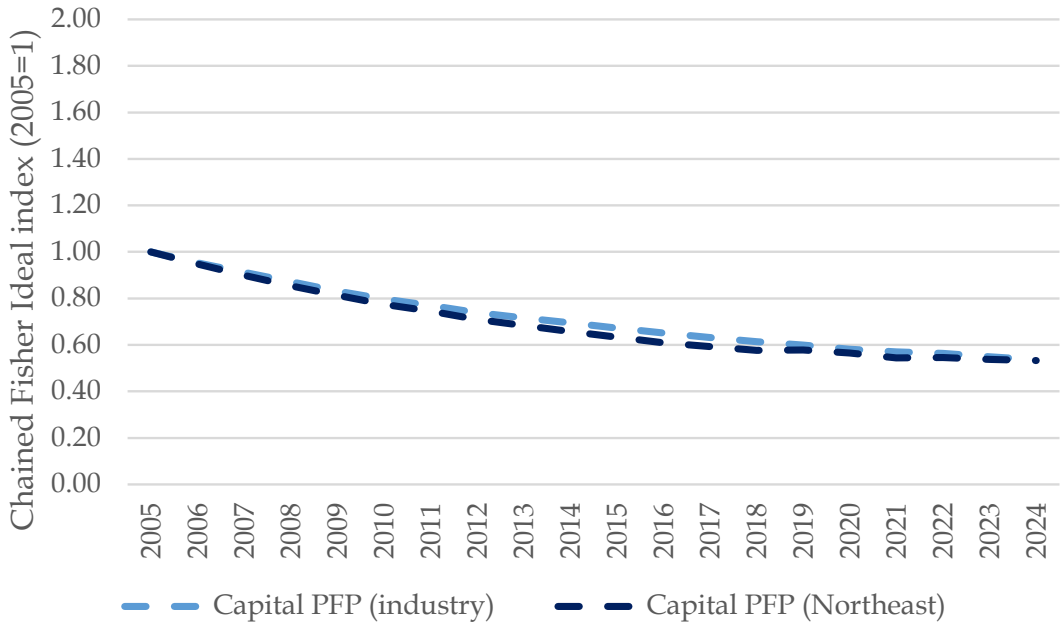
	Output	Input			Productivity		
Year	Customers	Capital	OM&A	Total	Capital	OM&A	TFP
	[A]	[B]	[C]	[D]	[A-B]	[A-C]	[A-D]
2005-2006	0.80%	5.91%	1.23%	3.00%	-5.11%	-0.43%	-2.20%
2006-2007	0.76%	5.56%	6.95%	6.41%	-4.80%	-6.18%	-5.65%
2007-2008	0.38%	5.49%	3.43%	4.24%	-5.11%	-3.05%	-3.86%
2008-2009	0.21%	4.99%	4.62%	4.77%	-4.78%	-4.41%	-4.56%
2009-2010	0.56%	4.90%	4.12%	4.43%	-4.34%	-3.56%	-3.87%
2010-2011	0.36%	4.00%	1.98%	2.79%	-3.64%	-1.62%	-2.42%
2011-2012	0.25%	4.92%	4.28%	4.53%	-4.67%	-4.03%	-4.29%
2012-2013	0.19%	3.59%	-7.71%	-2.99%	-3.40%	7.90%	3.19%
2013-2014	0.48%	4.14%	0.40%	2.03%	-3.66%	0.08%	-1.55%
2014-2015	0.70%	3.58%	-5.15%	-1.23%	-2.88%	5.85%	1.93%
2015-2016	0.29%	3.69%	-0.01%	1.70%	-3.40%	0.30%	-1.40%
2016-2017	0.58%	3.35%	-3.70%	-0.36%	-2.77%	4.28%	0.95%
2017-2018	0.73%	3.47%	3.55%	3.51%	-2.74%	-2.82%	-2.78%
2018-2019	0.63%	3.17%	-3.19%	-0.18%	-2.53%	3.82%	0.81%
2019-2020	0.47%	2.82%	6.18%	4.58%	-2.34%	-5.71%	-4.11%
2020-2021	0.68%	1.55%	-10.69%	-4.44%	-0.86%	11.37%	5.13%
2021-2022	0.94%	0.79%	7.25%	3.68%	0.15%	-6.31%	-2.75%
2022-2023	0.53%	1.78%	-3.85%	-0.75%	-1.25%	4.38%	1.28%
2023-2024	0.60%	2.25%	7.54%	4.70%	-1.65%	-6.94%	-4.10%
Annual average 2005-2024	**0.53%**	**3.68%**	**0.91%**	**2.13%**	**-3.15%**	**-0.37%**	**-1.59%**
Annual average 2010-2024	**0.53%**	**3.08%**	**-0.22%**	**1.25%**	**-2.55%**	**0.75%**	**-0.72%**
Annual average 2015-2024	**0.61%**	**2.54%**	**0.34%**	**1.38%**	**-1.93%**	**0.26%**	**-0.78%**

9.4.2 U.S. Industry and Northeast Region partial factor productivity using hyperbolic depreciation of capital

Under the hyperbolic depreciation specification, capital PFP declines steadily for both the U.S. industry and Northeast samples, indicating that customer output did not keep pace with the growth in capital inputs. Both series begin near 1.00 in 2005, and then trend downward for the period, ending at approximately 0.55 by 2024 (see Figure 54). The industry and Northeast lines are very close throughout, suggesting that capital productivity trends are broadly similar across the two samples under this depreciation method. Capital PFP declined at an average annual rate of 3.19% and 3.15% for both the industry (see Figure 52) and the Northeast (see Figure 53) respectively over the full 2005–2024 period. In the PBR context, this reinforces the conclusion that capital accumulation is a key driver of declining measured productivity: capital inputs increased substantially, while measured output grew much more slowly. Relative to the OHS model, the hyperbolic depreciation approach produces a similar directional result, but the precise level and timing of capital PFP differ because the depreciation method changes the measured profile of capital input growth.

The use of hyperbolic depreciation of capital will have no impact on the OM&A PFP. The OM&A PFP for the industry and Northeast under the baseline model can be found in Sections 4.3.2 and 5.3.2 respectively.

Figure 54. Chained Fisher Ideal index for the U.S. industry and Northeast Region capital PFP using hyperbolic depreciation of capital



9.5 Converting the estimated U.S. industry and Northeast Region TFP annual average growth rate into an X factor using hyperbolic depreciation of capital

Under the hyperbolic depreciation specification, the U.S. industry X Factor is negative across all three averaging periods, primarily because the industry TFP differential is negative. Over 2005–2024, calculated U.S. industry TFP declined by 1.62% per year, while national TFP increased by 0.69%, producing a TFP differential of -2.30% (see Figure 55). The input price differential is modestly positive at 0.16%, reflecting that the economy-wide input price proxy grew slightly faster than the weighted average of OM&A and capital prices. Combining these components results in an average industry X Factor of -2.14% over the full period (see Figure 55). The X Factor is somewhat less negative at -1.90% for 2010–2024 but more negative at -2.20% for 2015–2024, suggesting that the negative productivity trend increased somewhat in more recent years (see Figure 55).

Relative to the OHS model, the hyperbolic depreciation approach produces a broadly similar conclusion, but with a somewhat more negative X Factor because the measured TFP differential is more negative under this specification.

For the Northeast Region, the hyperbolic depreciation X Factor is also negative, though it improves materially in the most recent averaging period. Over 2005–2024, calculated Northeast Region TFP declined by 1.59% per year, compared with national TFP growth of 0.69%, resulting in a TFP differential of -2.28% (see Figure 56). The input price differential is positive at 0.16%, which only partially offsets the negative productivity differential, producing an average X Factor of -2.12% (see Figure 56). Over 2010–2024, for the hyperbolic depreciation, the Northeast Region X Factor is -1.32%, while over 2015–2024 it becomes more negative at -1.47% (see Figure 56).

This pattern indicates that the Northeast Region productivity gap narrows in the more recent period but remains negative overall. In a PBR context, the results indicate that even under the hyperbolic depreciation model, input growth continues to exceed measured customer output growth, leading to a negative X Factor for both the broader industry and the Northeast sample.

Figure 55. U.S. industry X Factor results 2005-2024 using hyperbolic depreciation of capital

Year	TFP differential			Input price differential			X-factor
	Industry TFP	National TFP	Difference	National input price	Industry input price	Difference	
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	-0.89%	0.32%	-1.21%	3.55%	5.76%	-2.21%	-3.42%
2006-2007	-5.08%	0.27%	-5.35%	2.99%	0.11%	2.88%	-2.47%
2007-2008	-1.44%	-0.97%	-0.47%	1.88%	4.28%	-2.40%	-2.86%
2008-2009	-2.99%	0.41%	-3.40%	-0.05%	-1.45%	1.40%	-2.00%
2009-2010	-2.13%	2.51%	-4.64%	4.01%	2.73%	1.28%	-3.36%
2010-2011	-2.63%	-0.40%	-2.23%	2.02%	2.91%	-0.89%	-3.12%
2011-2012	-1.53%	0.68%	-2.21%	2.44%	1.82%	0.62%	-1.59%
2012-2013	0.86%	0.58%	0.28%	2.03%	2.25%	-0.21%	0.06%
2013-2014	-1.54%	0.60%	-2.14%	2.18%	1.98%	0.20%	-1.94%
2014-2015	0.23%	0.91%	-0.68%	1.14%	0.61%	0.53%	-0.15%
2015-2016	-1.99%	0.01%	-1.99%	0.70%	0.83%	-0.13%	-2.13%
2016-2017	-1.59%	0.64%	-2.23%	2.43%	3.15%	-0.72%	-2.95%
2017-2018	-0.15%	0.71%	-0.85%	2.94%	-0.13%	3.07%	2.22%
2018-2019	-1.90%	1.21%	-3.11%	2.64%	1.21%	1.43%	-1.68%
2019-2020	-7.54%	-0.56%	-6.97%	0.75%	1.28%	-0.52%	-7.50%
2020-2021	2.37%	3.94%	-1.57%	8.18%	15.15%	-6.97%	-8.54%
2021-2022	-2.32%	-1.04%	-1.29%	5.86%	8.37%	-2.50%	-3.79%
2022-2023	-0.62%	1.66%	-2.28%	5.15%	0.39%	4.76%	2.48%
2023-2024	0.17%	1.58%	-1.41%	4.01%	0.54%	3.47%	2.05%
Annual average 2005-2024	**-1.62%**	**0.69%**	**-2.30%**	**2.89%**	**2.73%**	**0.16%**	**-2.14%**
Annual average 2010-2024	**-1.30%**	**0.75%**	**-2.05%**	**3.03%**	**2.88%**	**0.15%**	**-1.90%**
Annual average 2015-2024	**-1.51%**	**0.91%**	**-2.41%**	**3.63%**	**3.42%**	**0.21%**	**-2.20%**

Figure 56. Northeast Region X Factor results 2005-2024 using hyperbolic depreciation of capital

Year	TFP differential			Input price differential			X-factor
	Industry TFP	National TFP	Difference	National input price	Industry input price	Difference	
	(a)	(b)	(c) = (a) - (b)	(d)	(e)	(f) = (d) - (e)	(x) = (c) + (f)
2005-2006	-2.20%	0.32%	-2.52%	3.55%	5.77%	-2.22%	-4.74%
2006-2007	-5.65%	0.27%	-5.92%	2.99%	0.16%	2.83%	-3.09%
2007-2008	-3.86%	-0.97%	-2.89%	1.88%	4.33%	-2.46%	-5.34%
2008-2009	-4.56%	0.41%	-4.96%	-0.05%	-1.48%	1.43%	-3.53%
2009-2010	-3.87%	2.51%	-6.38%	4.01%	2.73%	1.28%	-5.10%
2010-2011	-2.42%	-0.40%	-2.02%	2.02%	2.92%	-0.89%	-2.92%
2011-2012	-4.29%	0.68%	-4.97%	2.44%	1.82%	0.62%	-4.34%
2012-2013	3.19%	0.58%	2.60%	2.03%	2.24%	-0.21%	2.39%
2013-2014	-1.55%	0.60%	-2.15%	2.18%	1.98%	0.21%	-1.95%
2014-2015	1.93%	0.91%	1.02%	1.14%	0.62%	0.52%	1.54%
2015-2016	-1.40%	0.01%	-1.41%	0.70%	0.83%	-0.14%	-1.55%
2016-2017	0.95%	0.64%	0.31%	2.43%	3.14%	-0.71%	-0.41%
2017-2018	-2.78%	0.71%	-3.49%	2.94%	-0.13%	3.07%	-0.42%
2018-2019	0.81%	1.21%	-0.40%	2.64%	1.21%	1.43%	1.03%
2019-2020	-4.11%	-0.56%	-3.55%	0.75%	1.28%	-0.53%	-4.08%
2020-2021	5.13%	3.94%	1.18%	8.18%	15.25%	-7.07%	-5.89%
2021-2022	-2.75%	-1.04%	-1.71%	5.86%	8.43%	-2.57%	-4.28%
2022-2023	1.28%	1.66%	-0.38%	5.15%	0.30%	4.86%	4.48%
2023-2024	-4.10%	1.58%	-5.68%	4.01%	0.49%	3.52%	-2.16%
Annual average 2005-2024	**-1.59%**	**0.69%**	**-2.28%**	**2.89%**	**2.73%**	**0.16%**	**-2.12%**
Annual average 2010-2024	**-0.72%**	**0.75%**	**-1.47%**	**3.03%**	**2.88%**	**0.15%**	**-1.32%**
Annual average 2015-2024	**-0.78%**	**0.91%**	**-1.68%**	**3.63%**	**3.42%**	**0.21%**	**-1.47%**

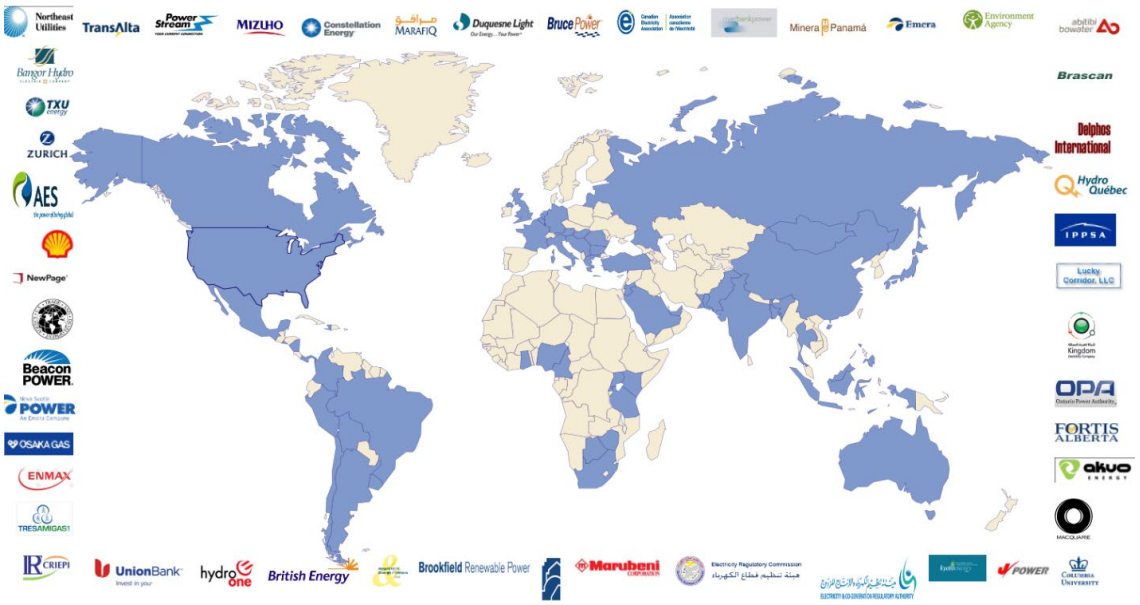
10 Appendix D: Introduction to London Economics International LLC

10.1 Background on the firm

LEI is a global economic, financial, and strategic advisory professional services firm specializing in energy, water, and infrastructure. The firm combines detailed understanding of specific network and commodity industries, such as electricity generation and distribution, with a suite of proprietary quantitative models to produce reliable and comprehensible results.

The firm has in-depth expertise in economic and financial issues related to the electricity, gas, and water sectors, such as asset valuation, procurement, regulatory economics, and market design, assessment, and analysis. The firm has its roots in advising on the initial round of privatization of electricity, gas, and water companies in the UK. Since then, LEI has advised private sector clients, market institutions, and governments on privatization, asset valuation, deregulation, tariff design, market power, strategy, and strategy development in virtually all deregulated markets worldwide. Figure 57 provides a summary of selected LEI clients throughout the world.

Figure 57. Selected LEI clients throughout the world



LEI has extensively studied regulatory regimes involving PBR and advised utilities, regulators, and investors on best practices with respect to the design of PBR formula and implementation. In some of LEI's work, we have advised on how PBR implementation may affect consumers, while in other engagements, we have focused on implications for regulated utilities and regulators. That work has exposed LEI to various forms of PBR and the technical studies that regulators and

utilities use to calibrate the trajectory of future rates, consider investment needs, and align the incentives of customers, the regulated utility, and the regulator.

10.2 Relevant experience

LEI is active across North America's electric distribution sector, specifically in Massachusetts and New England, and has a comprehensive understanding of issues faced by utilities and regulators alike. LEI's areas of expertise include regulatory economics, PBR, and market design; expert testimony and litigation consulting; electric and gas distribution advisory; and asset valuation and price forecasting.

LEI has solid experience with the evaluation of productivity trends and the development of TFP studies. LEI has examined and performed TFP trends in electric distribution, generation sectors, and gas distribution and has defended our work in front of regulators. Furthermore, LEI has U.S. and Northeast electric and gas distribution database for TFP and benchmarking analysis.

LEI also has advised utilities on the appropriate inflation factor and the reasonableness of stretch factors/consumer dividends as well as other features of PBR such as earnings sharing mechanisms, efficiency carryover schemes, and capital trackers. LEI has advised on the formulaic approach of an "I-X" application and has studied the building-blocks approach historically applied in the UK and Australia, as well as the "RIIO" model currently adopted in the UK.

LEI team members have also testified before several regulators in various aspects of rate design, and PBR specifically. Some of the LEI team members have served as an expert witness in MA and several Canadian jurisdictions that have applied PBR to regulated electric and gas utilities. These include the MA D.P.U. (on behalf of Eversource Energy), Ontario Energy Board (on behalf of the Coalition of Large Distributors, Ontario Power Generation, Enbridge Gas, and Union Gas), Alberta Utilities Commission (on behalf of FortisAlberta and ENMAX), Malaysian Energy Commission (on behalf of Tenaga Nasional Berhad), Nova Scotia Utility and Regulatory Board (on behalf of Nova Scotia Power), Manitoba Public Utilities Board (on behalf of Manitoba Hydro customer classes and Keystone Agricultural Producers), and New Hampshire Public Utilities Commission (on behalf of Northeast Utilities).Sample of relevant engagements

- ***Yankee Gas - Development and Support for Performance-Based Distribution Ratemaking Plan:*** LEI was retained to support Yankee Gas Services Company d/b/a Eversource Energy of Connecticut in developing a first-generation PBR plan for its gas distribution business. As part of its scope of work, LEI was tasked with conducting both TFP (peer groups consisting of national and Northeast states) and econometric benchmarking studies, filed as part of the utility's rate case application in Q4 2024. The results of the empirically-based TFP and benchmarking studies informed LEI's proposed design for the utility's PBR plan (i.e., components of the PBR design, including revenue adjustment mechanism and incremental capital funding mechanism). In addition to these quantitative workstreams, LEI also

methodically reviewed filings submitted as part of the ongoing electric distribution PBR reopener proceedings in the state of Connecticut, as well as the gas and electric distribution PBR frameworks as designed in New England states operating under PBR - both of which helped to inform PBR design recommendations (and justifications thereof) developed by LEI as part of this engagement. LEI will defend the methodology it used in its quantitative studies and in developing PBR design elements in testimony, hearings, briefs, and other regulatory technical sessions.

- ***Ontario Power Generation PBR - OPG TFP Study 2024:*** LEI was engaged to support Ontario Power Generation ("OPG") in connection with its application to the OEB for payment amounts in respect of its prescribed electricity generation facilities for a period starting in 2027. The project involved performing: (i) an assessment of the appropriateness of the inflation factor; (ii) an updated TFP study on trends in the North American hydroelectric generation industry; and (iii) an updated cost benchmarking analysis of the costs of hydroelectric generation companies in North America.

- ***Versant – multi-year rate plan:*** LEI was hired to provide technical assistance on the development of a utility's first multi-year rate plan. The purpose of the MRP was to address a series of issues highlighted by the regulatory commission and reduce regulatory lags. The scope of work included guidance on strategic planning and MRP design. This effort was supported by a combination of case studies and pre-planning work sessions with executive leadership and subject matter experts for alignment on multi-year strategy and conceptual approach. In addition, LEI provided pre-filing and litigation support to the utility from the inception of the design throughout the rate case proceeding

- ***Advisor on the first generation PBR development process in Connecticut:*** LEI was retained to support Eversource Energy d/b/a Connecticut Light & Power, an electric distribution company in New England, in navigating Connecticut's PBR proceeding. This specifically entails evaluating the PBR design components proposed by the regulator and public stakeholders engaged in the process, assessing gaps in proposed regulatory design, and determining what PBR elements are suitable (or unsuitable) in the context of the state's regulatory and market structures. As part of its scope of work, LEI will also support its client in choosing and/or designing performance incentive mechanisms ("PIMs") which will be included in the company's rate filing. As part of this engagement, LEI performs in-depth research of PBR/PIMs across select jurisdictions, provides advisory support in the PBR/PIMs development process, drafts various proposals or other reports for public filing, and defends its analysis in both written work and oral stakeholder meetings.

- ***Advised NSTAR Gas on its PBR filing:*** LEI supported NSTAR Gas, a gas distribution company in Massachusetts, in its PBR filing for the 2021-2025 regulatory term. More specifically, LEI performed a TFP study to determine the X Factor that will be used for the IBR plan. LEI also conducted a benchmarking study to assess the empirical basis for a

consumer dividend. In addition, LEI advised NSTAR Gas on the Gas Systems Enhancement Plan and capital arrangements and discussed the benefits of IBR for consumers. Finally, LEI served as an expert witness on the PBR piece.

- ***Enbridge Gas Distribution Inc:*** LEI performed a review and analysis of ratemaking approaches applied to the client's capital expenditure profile, including demonstrating the potential negative impact of "I-X" ratemaking approaches on a utility's ability to earn a fair return. The objective of this engagement will be to demonstrate to stakeholders and the Ontario Energy Board the reasonableness of the revenue cap per customer model that the client has previously relied upon and planned to propose in its next ratemaking review. Furthermore, the secondary objective was to conceptualize the insufficiency of the "I-X" regime, even with a revenue cap per customer model, in consideration of the fair return standard and given the client's business is operating in an environment where substantial capital expenditure needs are projected over the next Incentive Regulation Plan period. [Docket Number EB 2012-0459]
- ***Presentation on the use of TFP in North America:*** LEI presented on the experience with TFP methods in the regulation of North American electric utilities (California, Canada, New England). Key messages include: the use of TFP is the exception, rather than the norm, for North America; where TFP is used, no agreed model exists for either analysis or the regulatory framework; hybrid models incorporating ESMs often preferred; regulators struggle with choice of relevant geographical regions and historical time periods for comparative analysis; on the wires side of the business, North American regulators have tended to be followers rather than leaders, with limited awareness of trends overseas.

- ***TFP study:*** LEI was engaged to support Ontario Power Generation in relation to its second-generation hydroelectric payment amounts price-cap application before the OEB. The project involved performing an updated TFP study reflecting the OEB's 2017 Decision on the first-generation price-cap index. Other key tasks were the preparation of analysis and written evidence assessing whether the inflation factor and treatment of the Capacity Refurbishment Variance Account remain appropriate.

- ***OPG Total Factor Productivity Study 2013:*** LEI assisted the OPG in performing a productivity study on their hydroelectric assets to fulfill the mandate of the OEB. LEI proposed a structured approach to address how productivity should be measured, what methods are available, identify a peer relevant group, and ultimately provide the client with a productivity study for filing with the OEB.

- ***Testimony on PBR:*** LEI provided a supporting testimony for FortisAlberta Inc., a Canadian electricity utility, in its filing for a PBR plan. The testimony provides detailed data analysis (including inflation and TFP trends), underpinning PBR economic theory, and reviews of best practices in various North American and International jurisdictions. The testimony offers

backup elements for each of the multiple components of the PBR plan that is being proposed by FortisAlberta, Inc. [Alberta Utilities Commission, Proceeding: 566]

- ***Preparation of expert testimony related to PBR:*** LEI was engaged by ENMAX Power Corporation to provide expert evidence and assist in its participation in the Alberta Utilities Commission proceeding to establish parameters for the third PBR term in the province. LEI provided recommendations related to the timing of PBR rate adjustments, merits of the price cap versus revenue-per-customer cap approaches, I Factor, X Factor, capital funding provisions, earnings sharing mechanisms, and quantifying and tracking efficiencies. LEI based its recommendations on industry best practices and analysis of Alberta-specific data.

- ***Design of second-generation incentive regulation:*** LEI advised the OEB on the design of second-generation IR for electricity distribution companies. As part of the engagement, LEI examined methods of quantifying TFP, determined the appropriateness of yardstick competition models, identified service quality indicators, and explored the role of demand-side management. LEI also conducted extensive stakeholder interaction, built databases, advised on a final draft plan, and testified during associated regulatory proceedings.

- ***Advised on PBR filing and reviewing the Malaysian electricity regulatory framework:*** LEI was engaged by Tenaga Nasional Berhad ("TNB") in Malaysia to work as the project manager of its PBR submission for the 2nd regulatory term. LEI's role in this project includes two phases. In phase 1, LEI's role includes advising on the policy and governance framework for the implementation of IBR, providing strategic advice to IBR Council and TNB management regarding the IBR submission, managing and monitoring the submission process, coordinating with business entities, and attending IBR Council meetings, progress meetings, and challenge workshops. Furthermore, LEI reviewed the current Regulatory Implementation Guidelines ("RIGs") set by the Energy Commission and proposed enhancements to the RIGs. LEI was also in the process of negotiation with the Energy Commission regarding proposed changes to the RIGs. LEI was also responsible for reviewing and enhancing the revenue requirement model, which sets the PBR tariff for each business entity. In addition, LEI was also co-drafting the IBR submission report with TNB and will review the final IBR report before the submission.

- ***PBR review for Caribbean utility***: LEI was retained by a power utility in the Caribbean to perform an intensive study of the types of PBR employed by regulators worldwide and the implications for key stakeholders, culminating in workshops for the regulator, utility managers, and government representatives. Key issues covered in LEI's analysis included the tradeoffs between using RPI-X style formulations and revenue sharing techniques, accounting for the unique nature of island systems, impacts on employment, and calculation of an appropriate return on equity.

- ***Analysis of PBR components:*** LEI advised the Coalition of Large Distributors in Ontario on third-generation Incentive Regulation Mechanism proceedings of the Ontario Energy Board. The work involved expert testimony filed with the Board with detailed analysis of the theory behind the various components of the IBR system, including inflation and efficiency gains factors and treatment of capital expenditures, among others. The analysis was supplemented with a comparison of actual factors and indices and determined more robust and appropriate indices for Ontario's distribution industry, including total factor productivity analysis for the sector.

- ***Analysis of ownership and regulatory models in the electricity sector*:** The Hawaii Department of Business, Economic Development, and Tourism contracted LEI to evaluate the costs and benefits of various electric utility ownership and regulatory models, supporting the State's energy goals. In this project, LEI calculated each county's revenue requirements through 2045, assessed the feasibility and implementation steps for each regulatory model, and evaluated their impact on promoting DERs, among other objectives. The regulatory models considered include: (i) maintaining the status quo with enhanced oversight by a Hawaii Electricity Reliability Administrator ("HERA") entity; (ii) various PBR models; (iii) an Integrated Grid Operator; (iv) a Distributed System Platform Provider; and (v) lighter regulation for the Kauai Island Utility Cooperative.

- ***Reviewed ratemaking procedures in the electric, gas, and water sectors:*** LEI was retained by the Iowa Utilities Board ("IUB") to assess Iowa Code Provisions and ratemaking procedures. As part of this engagement, LEI evaluated the adequacy and efficiency of the state's ratemaking laws, procedures, and administrative rules, with a specific focus on advance ratemaking; evaluated the ratemaking laws and procedures of a sample case study of states that are comparable to the Iowa context; assessed the rates and trackers (riders) of the rate-regulated utilities; and identified potential changes to ratemaking procedures and rules given the research conducted, policy charrettes held with proceeding stakeholders, and anticipated future industry supply conditions. LEI recommended PBR as one of the options that the IUB should explore.

11 Appendix E: Overview of the EDC Industry in the U.S.

In the U.S., there is a total of 144 investor-owned electric distribution utilities and 88 of these are included in LEI's TFP Industry Study.[65] As of 2024, the total number of customers served by the EDCs in LEI's Industry Study was approximately 98.6 million, mostly residential customers.[66] The total electricity sales to customers across the U.S. in 2024 was approximately 2.1 billion MWh.[67] The growth rates for both the number of customers and sales in the U.S electric distribution industry for various periods of time can be seen in Figure 58 below. Over the past twenty years (2005-2024), the total number of customers and sales volume in the electricity sector grew at an average annual rate of 0.72% and -0.02%, respectively.[68] However, growth patterns have varied over shorter time frames: average customer growth has ranged between 0.66% and 0.84% annually,[69] while average sales volumes growth have been lower ranging between -0.29% and -0.01%.

Figure 58. Average customer growth and electricity sales growth in the U.S. EDC industry

Period	Customer CAGR	Sales CAGR
20-Year	0.72%	-0.02%
15-Year	0.66%	-0.01%
10-Year	0.84%	-0.19%
5-Year	0.75%	-0.29%

Source: U.S. Energy Information Administration. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files.* 2024.

11.1.1 Customer and sales growth in the U.S. electric distribution industry

Customer growth has remained relatively steady across all periods, ranging from 0.66% to 0.84% annually, indicating consistent expansion in the number of electricity customers over time. In contrast, electricity sales growth has been weaker and negative over the 10- and 15-year periods, suggesting that sales volumes have not kept pace with customer growth. This trend may reflect

[65] U.S. Energy Information Administration. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files. 2026.*

[66] U.S. Energy Information Administration. *Table 2.1. Number of Ultimate Customers Served by Sector, by Provider, 2014 through 2024.* 2025.

[67] U.S. Energy Information Administration. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files: Sales to Ultimate Customers 2024*. 2024.

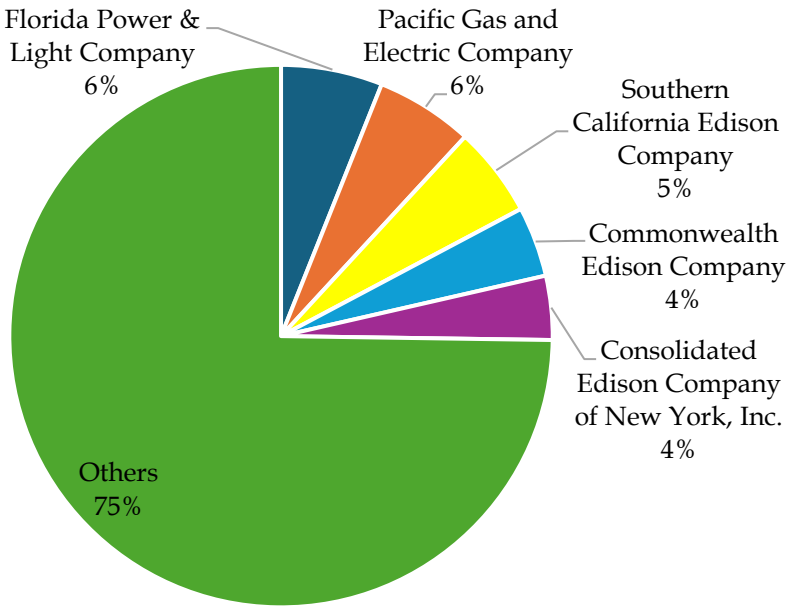
[68] Ibid.

[69] Ibid.

improvements in energy efficiency, changing consumption patterns, and increased adoption of distributed energy resources.

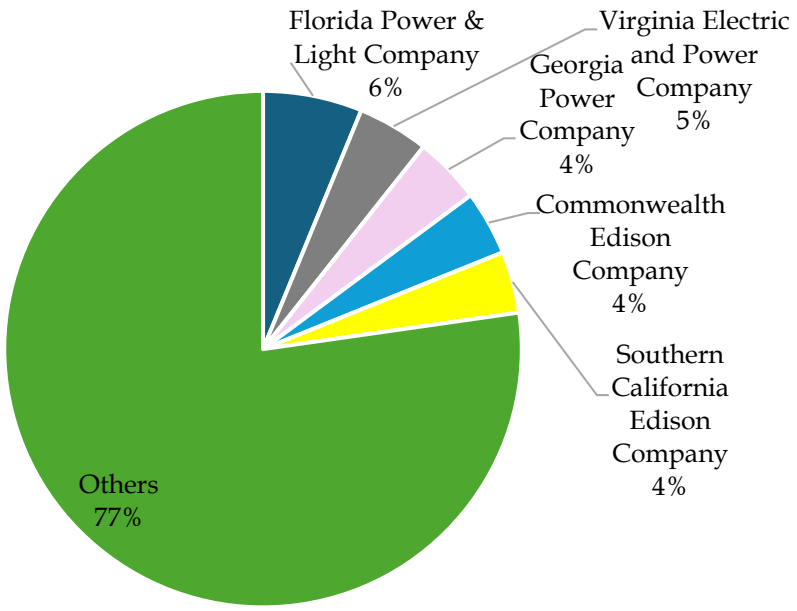
The largest EDCs in the U.S., in terms of number of customers, are Florida Power & Light Company ("FPL"), Pacific Gas and Electric Company, Southern California Edison Company, Commonwealth Edison Company, and Consolidated Edison Company of New York, Inc., as shown in Figure 59 below. All these EDCs are in LEI's Industry TFP Study. On the other hand, the largest EDCs in the U.S., in terms of total electric sales are FPL, Virginia Electric and Power Company, Georgia Power Company, Commonwealth Edison Company, and Southern California Edison Company, as shown in Figure 60 below. These five companies represent a quarter (or 25.3%) of the U.S. electricity distribution market, based on the total electricity sales sold and customers served as of 2024. All these EDCs are in LEI's Industry TFP Study. CL&P is significantly smaller than FPL, serving about one-fifth as many customers and delivering roughly one-sixth the electricity sales. Specifically, FPL serves approximately 4.6 times more customers and records about 6.4 times higher electricity sales than CL&P.

Figure 59. Top 5 electric distribution utilities in terms of 2024 total number of customers across the U.S. (88 EDCs)



Source: U.S. Energy Information Administration. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files.* 2024.

Figure 60. Top 5 EDCs in terms of 2024 total sales volume across the U.S. (88 EDCs)

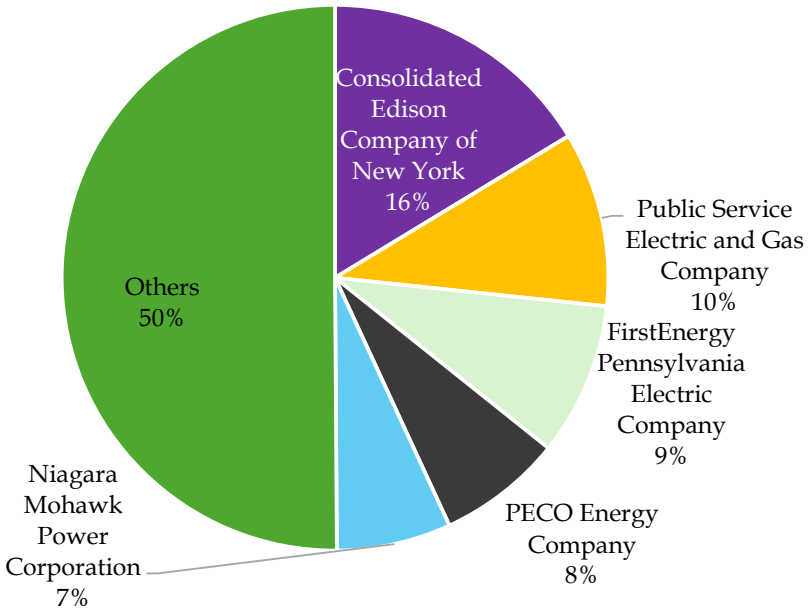


Source: U.S. Energy Information Administration. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files.* 2024.

11.1.2 Customer and sales growth among electric distribution companies in the Northeast Region

The largest EDCs in the Northeast Region in terms of number of customers, are Consolidated Edison Company of New York, Inc., Public Service Electric and Gas Company, FirstEnergy Pennsylvania Electric Company, PECO Energy Company, and Niagara Mohawk Power Corporation, as shown in Figure 61 below. All of these EDCs are in LEI's Industry TFP Study. Together, these companies account for approximately half of the customers served by the top electric distribution utilities in the Northeast Region, while all other electric distribution companies collectively account for the remaining half. CL&P is significantly smaller than the largest EDC in the region, Consolidated Edison, serving approximately one-third as many customers.

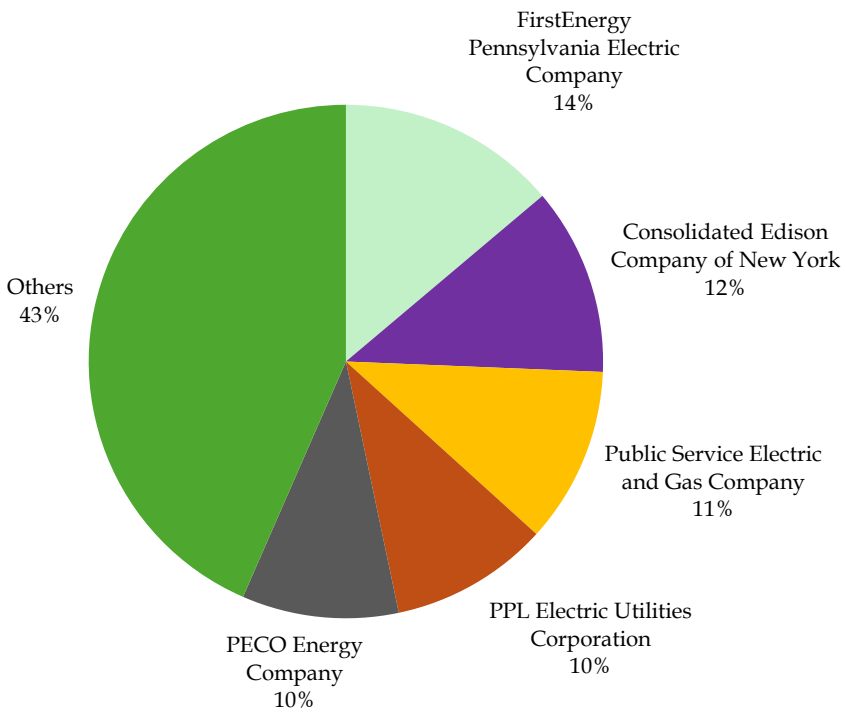
Figure 61. Top 5 electric distribution utilities in terms of 2024 total number of customers across the Northeast Region



Source: U.S. Energy Information Administration. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files.* 2024.

The largest EDCs in the Northeast Region, in terms of total electric sales volume in 2024, are FirstEnergy Pennsylvania Electric Company, Consolidated Edison Company of New York, Inc., Public Service Electric and Gas Company, PPL Electric Utilities Corporation, and PECO Energy Company, as shown in Figure 62below. Similarly, all these EDCs are in the LEI Industry TFP Study. Together, these EDCs account for approximately 56.6% of total electric sales volume among electric distribution utilities in the Northeast Region. CL&P is substantially smaller than Consolidated Edison's delivering less than half its electricity sales.

Figure 62. Top 5 EDCs in terms of 2024 total sales volume across the Northeast Region



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