SOUTHERN INDIANA GAS AND ELECTRIC COMPANY
d/b/a VECTREN ENERGY DELIVERY OF INDIANA, INC.
(VECTREN SOUTH)

IURC CAUSE NO. 44910

OFFICIAL
EXHIBITS

IURC
PETITIONER'S
EXHIBIT NO. 3
6-29-17
DATE
REPORTER

DIRECT TESTIMONY
OF
WILLIAM D. WILLIAMS
ASSOCIATE VICE PRESIDENT, ASSET MANAGEMENT,
BLACK & VEATCH MANAGEMENT CONSULTING LLC

ON

RISK ANALYSIS

SPONSORING PETITIONER'S EXHIBIT NO. 3,
ATTACHMENT WDW-1

DIRECT TESTIMONY OF WILLIAM D. WILLIAMS

I. INTRODUCTION

Q. Please state your name and business address.

A. My name is William D. Williams. My business address is 1120 Sanctuary Parkway, Alpharetta, GA 30009.

Q. By whom are you employed and in what capacity?

A. I am an Associate Vice President in the Asset Management Practice of Black & Veatch Management Consulting LLC.

Q. Please describe your educational background.

A. I obtained my Bachelor of Arts degree in Geography from Royal Holloway and Bedford New College, University of London, United Kingdom in 1989.

Q. Please describe your professional experience.

A. I have extensive experience in asset management planning, including capital prioritization, asset failure analysis, risk assessment, performance benchmarking, maintenance optimization, business planning, serviceability assessment, whole life costing, operational efficiency, ISO55001 asset management maturity assessments, business change management, and infrastructure rehabilitation. Prior to joining Black & Veatch, I served as the Vice President and Global Director of Asset Management of water and power for Halcrow, a multinational engineering and consultancy company. Prior to that, I was Director of Asset Management and Planning and an Executive Director at the United Kingdom Water Research Centre. I have more than 26 years of asset management experience.

Q. What are your present duties?

A. My primary responsibilities are business development and project delivery within the Asset Management Practice. This typically entails managing multi-disciplinary teams to deliver programs of work for utility clients.

Q. Have you previously testified before the Indiana Utility Regulatory Commission?

A. Yes, I testified on behalf of Duke Energy Indiana, Inc. ("Duke") in IURC Cause No. 44526. In those proceedings, I summarized the development and results of Black & Veatch's Risk Model for Duke. The Risk Model utilized a risk-based approach to prioritize TDSIC-eligible projects to assist Duke in developing projects for its Transmission, Distribution, and Storage System Improvement Charge ("TDSIC") 7-year plan. I explained the approach and results from both Black & Veatch's independent validation of Duke's project cost estimates. Additionally, I summarized the approach and results of Black & Veatch's economic impact assessment study based on Duke's proposed TDSIC plan.

Q. What is the purpose of your testimony in this proceeding?

A. In this proceeding, I am summarizing the methodology used by Black & Veatch to develop a risk-based model of Southern Indiana Gas and Electric Company d/b/a Vectren Energy Delivery of Indiana, Inc.'s ("Vectren South") transmission and distribution assets. This risk-based model is referred to as the "Risk Model" in my testimony. As part of this testimony, I discuss the analysis that Black & Veatch conducted for Vectren South, I describe the Risk Model and how it is used to identify TDSIC projects, I describe how risk is defined, with emphasis on consequence of failure ("CoF") and likelihood of failure ("LoF"), I explain how the calculations in the Risk Model are performed, and I describe the results and conclusions of the Risk Model. Additionally, I am sponsoring exhibits that support the aforementioned components of my testimony.

Q. Are you sponsoring any exhibits in this proceeding?

A. Yes. I am sponsoring the following exhibit:

- Petitioner's Exhibit No. 3, **Attachment WDW-1**: Executive Summary Report for the risk-based long term Transmission and Distribution ("T&D") capital plan ("TDSIC Plan") business case

II. VECTREN SOUTH'S TDSIC PLAN WILL REDUCE SYSTEM RISK

Q. Describe the analysis Black & Veatch conducted for Vectren South.

A. Black & Veatch conducted a risk based assessment of the T&D system to help Vectren South identify projects to be included in its TDSIC Plan. This approach has been utilized in TDSIC proceedings for Northern Indiana Public Service Company ("NIPSCO") and Duke. The approach is based on the ISO 31000 framework for risk management and the ISO55001 standard for asset management practices. As part of the approach, Black & Veatch collected asset data from Vectren South for its critical substation and circuit assets. The project team, under my direction, developed an asset-level Risk Model that prioritizes assets based on the amount of risk they pose to the Vectren South system through a series of workshops and close collaboration with Vectren South subject matter experts over several months. The Risk Model results combined with other key criteria were then used to identify projects that should be considered in Vectren South's TDSIC Plan.

Q. Please describe the Risk Model Black & Veatch used to conduct its analysis.

A. The Risk Model consists of asset data, such as serial numbers, model numbers, voltage class, manufacturing and/or installation year, location, condition data and other information that allows the Black & Veatch and Vectren South team to individually assess each asset and determine its CoF and LoF. An asset's CoF is derived by developing several criticality criteria that consider the impact to Vectren South's customers or its system should the asset fail, such as the amount of system load lost, any environmental impacts, or the number of customers that would experience an outage. The criteria are assigned a weighting factor and each asset in the Risk Model is given a score for each of these criteria. This process produces a weighted score for CoF for each asset. Additionally, assets are given a LoF based on their age and Asset Health Index ("AHI"), which is derived from available asset condition information, inspection information, service history or test data.

The Risk Model uses this information to calculate risk for each of the assets that have been included in the model. Based on the risk score, replacement cost, and other resource constraints, the Risk Model provides a prioritized list of all these assets, highlights the highest risk assets, and identifies them for inclusion in the TDSIC Plan. The output of the Risk Model was reviewed and then used by Vectren South to develop both the projects included in the seven year program and the list of substitution projects.

Q. How does the risk model identify projects to be included in the TDSIC Plan?

A. The Risk Model was used to identify and develop projects in the TDSIC Plan. The Risk Model generated a prioritized list, based on the risk score, replacement cost, and other resource constraints, of all the assets evaluated by the model. The model was then used to assess the risk reduction achieved by replacing both these high priority assets and other assets Vectren South will repair or install to promote system modernization or enhanced functionality. Black & Veatch and Vectren South worked together to identify those programs which result in a risk reduction on the T&D system and included those in the risk model analysis.

By highlighting the highest risk assets on Vectren South's system with the Risk Model, the Vectren South team was able to develop asset specific TDSIC Plan projects, which consist of all types of assets, and utilize the results of the Risk Model to optimize project selection to ensure that assets representing the highest risk to the system are included in the TDSIC Plan. Utilizing the Risk Model in this manner allows Vectren South to develop a plan based on the selection of projects over the plan period that prudently and efficiently reduce its overall system risk.

Q. How is asset risk defined?

A. In the Risk Model, asset risk is defined as:

Asset Risk = Consequence of Failure x Likelihood of Failure

The total represented system asset risk is the summation of asset risks for individual groups of assets identified for investment, which collectively form the entire portfolio of the T&D system assets included in the Risk Model. It should be noted that certain investments, such as those related to system modernization or economic development were not included in the Risk Model.

Q. How was CoF estimated?

A. CoF is the first component of asset risk. Vectren South's assets were scored on a scale of 1 (low) to 5 (high). Scores were developed using several consequence criteria factors. Each of these factors was given a weighting and the sum of these weighted scores was used to determine the CoF score for the asset. The CoF for a specific asset represents the total impact to Vectren South's system if the asset fails. That impact is estimated using qualitative and quantitative arguments and analysis. Black & Veatch led and participated in risk workshops where Vectren South subject matter experts and staff provided input on the CoF criteria, associated definitions for the ordinal scale values (1-5), scoring of each asset, and determination of the CoF criteria weighting factors.

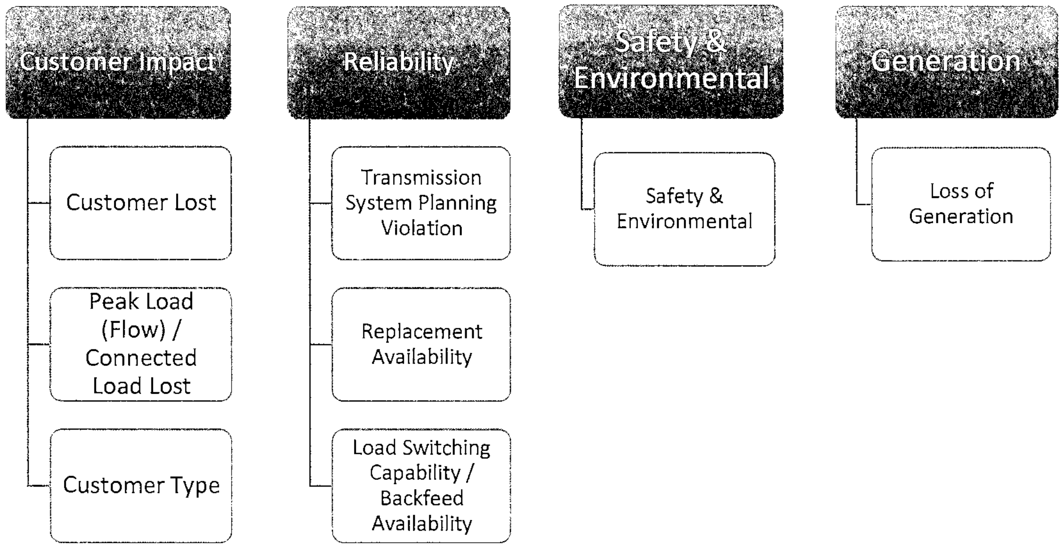
Through these workshops, consequence criteria were developed for each asset and voltage class (transmission and distribution). The criteria consider a number of factors related to an asset failure on the system and are categorized as follows:

- Customer type and impact
- Loss of load or generation
- Reliability impact
- Safety and environmental
- Operational impact

Each asset is rated using these criteria on a 1 (low) to 5 (high) scale and the ratings are used to calculate a cumulative CoF score for each asset. The detailed definitions for each system asset in the Risk Model are included in Petitioner's Exhibit No. 3, Attachment WDW-1.

Q. Please provide an example of a CoF analysis for an asset?

A. A specific example of the CoF analysis we undertook was for the transmission circuit breaker assets. In determining the CoF for each transmission circuit breaker we applied four categories of criteria: customer impact, reliability, safety & environmental, and generation. These categories represent a classification of the type of impacts that are caused by the failure of an asset. The chart below shows both the four categories and their subcategories that have been scored for each of the transmission circuit breaker assets evaluated. Each of these scoring criteria was rated by Vectren South staff on a 1 to 5 scale (very low to very high) based on expert experience, system knowledge and quantifiable data where applicable. Once tabulated, the ratings were used to calculate a consequence score using a weighted average of the criteria.



The Boonville Pioneer 199 circuit breaker results are shown below as an example of this methodology. The table below shows the individual scoring and weighted CoF score.

Sub Category	Safety and Environmental	Customer Lost	Peak Load Lost	Customer Type	Transmission System Planning Violation	Replacement Availability	Load Switching Capability	Loss of Generation	Weighted Consequence of Failure Score
Weighting	**25%**	**10%**	**15%**	**10%**	**10%**	**10%**	**15%**	**5%**	**100%**
Scoring	3	5	5	5	1	4	5	1	3.9

The weighted scoring process demonstrates this circuit breaker has a high consequence of failure.

Q. How was likelihood of failure estimated?

A. LoF is the second component of asset risk. For this assessment, the defined and modeled risk event was based on a deterioration-related asset failure that results in an outage where the asset is not repairable, and must be replaced. This is commonly referred to as an "end-of-life" failure event. To help determine reasonable estimates of end-of-life timeframes and likelihood, survivor curves are used widely in the utility industry to forecast end of life and the deterioration of assets for likelihood of failure asset management analyses. Survivor curves create a continuous function relating to the likelihood of an asset failure event (a value from 0 to 1) to the time period in years of this likelihood. Survivor curves were developed for each Vectren South T&D asset class included in the model that represented end of live probabilities for these assets to be used in the LoF analysis. Each survivor curve used in the analysis combines the Iowa survivor curve type, by asset class, from Vectren South's latest depreciation study with the average service life of that asset class from a Black & Veatch industry survey of 15 U.S. electric utilities. The likelihood of failure scores were then calculated for each asset based on its actual or effective age and asset class survivor curve.

Q. What is an Iowa survivor curve?

A. Survivor curves are widely used by utilities as part of depreciation studies to estimate the probable average service life of different assets and set depreciation rates in line with those lives. The continuing property records ("CPR") for a utility track the initial purchase date of equipment to its retirement from service. A plot of the retirement dispersions calculated from the CPR data for each FERC account is used to determine "best fit" Iowa survivor curves and probable life. Referred to as 'Iowa' curves, the Iowa Type Curves are a codified system commonly used in utility depreciation analysis. They were developed at the University of Iowa in the early 1900s, hence the name 'Iowa curve'. Iowa survivor curves were chosen for each asset class based on its FERC account. Each asset class has a survivor curve that is representative of its CPR retirement history.

Q. What is the difference between actual age and effective age?

A. As part of the analysis, Black & Veatch obtained manufacturing and/or install date information for each of the T&D assets included in the Risk Model to calculate its chronological or 'actual' age. While the use of actual age is appropriate in determining LoF, the estimation of LoF can be enhanced by incorporating available information on asset health or condition obtained from utility inspections, service history, test data, or other sources. In the case of transformers and circuit breakers with sufficient data, Black & Veatch developed an 'effective age' based on the asset's condition. Thus, if an asset's actual age exceeds the median useful life but Vectren South's data shows it to be in good condition based on maintenance and monitoring activities, its actual age is reduced to create an effective age that is more representative of its current health. More information on the development of effective age is provided in Petitioner's Exhibit No. 3, Attachment WDW-1. Therefore, for all assets where sufficient data were available, the effective age was calculated and used to assess LoF. Where these data were not available, then chronological age was used to assess LoF.

Q. Please provide an example of an assessment of an LoF analysis for an asset.

A. Sticking with the Boonville Pioneer 199 circuit breaker as a specific example of a LoF analysis, the table below shows the criteria used to evaluate the asset health of the breaker, the weightings applied to calculate the effective age of the asset and the subsequent LoF score.

Criteria	Contact Resistance	Condition of Main Contacts	Condition of Arcing Contacts	Operations Counter	SF6 Leakage	Bushing Megger	Weighted Asset Health Score	Current Age	Effective Age
Weighting	**15%**	**10%**	**10%**	**15%**	**25%**	**25%**	**100%**		
Scoring	4	4	4	2	1	1	2.2	36	36

In this specific example, the weighted asset health index demonstrates based on the asset's condition an average asset health score and therefore the current age of the asset and effective age are equal. This effective asset age is then applied to the specific survivor curve for transmission circuit breakers to develop the LoF score over the analysis period.

Q. Please explain how the asset risk calculations were used.

A. With the CoF and LoF of each asset assessed as described above, the asset risk scores and a total system asset risk score were then calculated. The list of assets was then prioritized based on risk score, thereby ensuring that the highest risk assets were considered first for capital investment.

Once the asset risks were calculated, Black & Veatch created four scenarios to enable comparisons with the optimized TDSIC Plan; the Run-To-Failure Scenario, LoF 4+ (medium to high likelihood of failure), LoF 5 (high likelihood of failure), and the TDSIC Plan Scenario (described below). The Run-to-Failure Scenario presents the temporal increase in total system asset risk over 7 years, by summing asset risk each year during the study period. The LoF 4+ (medium to high likelihood of failure) and LoF 5 (high likelihood of failure) scenarios represent age-based scenarios that only allow replacement of assets at LoF 4 or higher or LoF 5 score. These scenarios do not restrict selection of assets for replacement based on their consequence of failure. These scenarios provide a comparison to the Run-to-Failure Scenario and the TDSIC Plan Scenario that represents replacements based on age.

The creation of the TDSIC Plan Scenario was an iterative exercise. Vectren South utilized the initial Risk Model results and considered high risk assets as candidates for replacement while developing projects for inclusion in the TDSIC Plan Scenario. After the Vectren South team scoped projects and developed a schedule of implementation, Black & Veatch finalized the TDSIC Plan Scenario in the Risk Model by adjusting the year in which assets get replaced based on Vectren South's schedule. This produced a TDSIC Plan Scenario in the Risk Model that accurately reflects the total system asset risk score and risk reduction achieved by Vectren South's TDSIC Plan.

Q. What was the purpose of conducting the risk analysis in this manner?

A. Applying a risk-based approach to developing and optimizing capital budgets is recognized within the industry as good management practice under several industry asset management standards such as the International Organization of Standardization International Standard 55000 ("ISO 55000") and Publically Available Standard 55 ("PAS55"). Rather than the traditional approach of reliance on historic spending levels and priorities, adopting a risk-based approach enables utilities to both optimize the level of overall expenditure as well as targeting that expenditure on areas of the T&D system where system risk is reduced most, thereby maximizing the overall benefit to the system. The International Organization of Standardization International Standard 31000 ("ISO 31000") provides a standardized definition of risk (CoF x LoF) and an approach for risk assessment and management which has been adopted by the utility industry. By these standards, utilization of a risk-based approach is good management practice.

The reason for developing the baseline scenarios (Run-to-Failure, LoF 4+, and LoF 5) was to provide reference points to guide the optimization process when developing the optimized TDSIC Plan. The use of the Run-to-Failure Scenario was to provide a baseline reference, where we minimized the number of assumptions used to forecast one possible result. The LoF 4+ and LoF 5 scenarios provide additional baseline levels of asset replacement to serve as further reference points for this analysis.

Q. What were the results of the risk analysis?

A. Based on the risk analysis, the Black & Veatch and Vectren South team determined that the proposed TDSIC Plan would reduce the total T&D system risk by 40% over the seven years of the study period as compared to allowing the assets to "run to failure." This is driven by significant substation and circuit risk reduction, which represent 46% and 19%, respectively.

The TDSIC Plan Scenario requires a lower overall capital investment total than the age-based scenarios, thereby minimizing the amount requested under TDSIC cost recovery. Additionally, from a financial efficiency perspective, Vectren South's proposed TDSIC Plan Scenario achieves more risk reduction per dollar spent than the age-based scenarios. See below for graphs depicting the Risk Model results.

Please note that the costs depicted in the graphs below represent unit replacement costs that were systematically used for the development of cost scenarios and comparisons based on risk reduction per dollar of capital investment in the Risk Model. Vectren South undertook a more detailed cost estimating process for the projects in their final plan. Those costs can be found in the testimony of Lynnae K. Wilson.

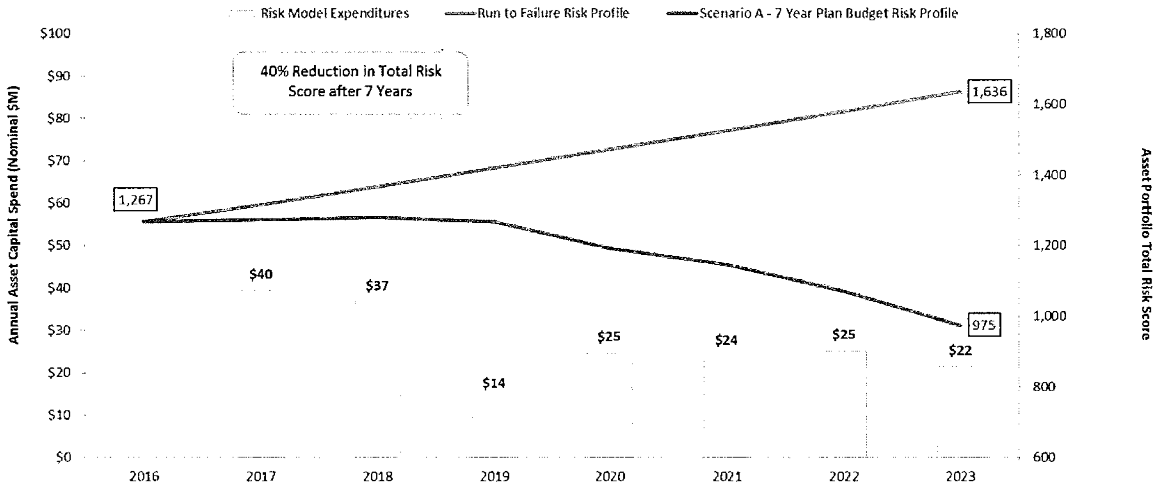


Figure 1 – Entire TDSIC Plan System Risk Profile – 2016 through 2023

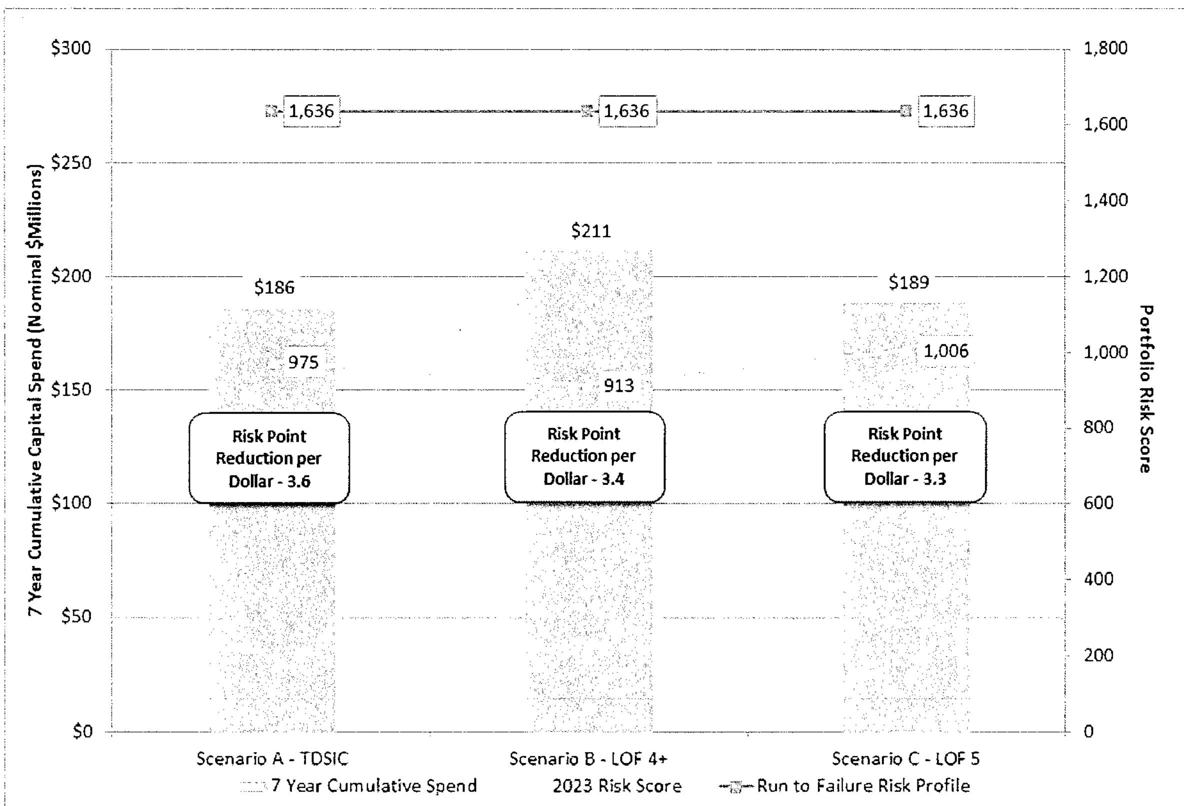


Figure 2 – Comparison of Risk Model Scenarios

Q. What conclusions can be made from the results of the risk analysis?

A. Based upon the risk analysis described above

1) The resulting TDSIC Plan is an optimized plan that prioritizes investment for eligible transmission and distribution improvements using risk reduction as a primary objective, while minimizing TDSIC recovery costs; and
2) By implementing the plan, total T&D system asset risk is significantly reduced, providing incremental benefits to Vectren South's system and customers in terms of improved service reliability.

III. CONCLUSION

Q. Does this conclude your testimony?

A. Yes.

VERIFICATION

I, William D. Williams, Associate Vice President of Asset Management for Black & Veatch Management Consulting, LLC, under penalty of perjury, affirm that the foregoing representations are true and correct to the best of my knowledge, information and belief.

Black & Veatch Management Consulting, LLC

By: W D Williams

William D. Williams
Associate Vice President, Asset Management

Dated: February 22, 2017

FINAL REPORT

LONG-TERM T&D CAPITAL PLAN BUSINESS CASE SUMMARY

BLACK & VEATCH PROJECT NO. 191896

PREPARED FOR

Vectren Corporation

21 FEBRUARY 2017

BLACK & VEATCH
Building a world of difference.

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1.0 Executive Summary

This report analyzes and quantifies the risk reduction Vectren Corporation (Vectren) will achieve through its TDSIC Investment Plan. Vectren and Black & Veatch utilized a risk-based planning approach to evaluate capital investments that affect the most critical, aging assets on Vectren's system. The investments are evaluated with respect to how they reduce risk on Vectren's T&D system. While risk reduction is a significant benefit and the focus of this document, it is not the only benefit of the TDSIC investment. Additional benefits are described and quantified elsewhere in Vectren's testimony and filing.

Vectren's Risk Model incorporates the key components required for an effectively prioritized investment plan. The Risk Model incorporates asset condition and health into the scoring of asset risk for substation assets. Asset health indices (AHI) have been developed for various asset classes and using the latest Vectren asset condition information available. Additionally, the Risk Model incorporates an asset criticality scoring of each asset based on established criteria. Vectren and Black & Veatch analyzed the Risk Model results for three investment plan scenarios, which used the Risk Model results within an iterative process to inform the TDSIC Investment Plan and refine replacement capital costs. The final TDSIC Investment Plan information was reinserted into the Risk Model to quantify the overall system risk reduction.

1.1 RISK MANAGEMENT OVERVIEW

Risk management is a systematic method for identifying, assessing, mitigating and monitoring the risks involved in any activity or process. It is a process that should be repeated many times during the life-cycle of the asset. In this report, risk is defined as the combination of the likelihood of an asset failing and the impact or consequence caused by its failure. Evaluating risk in this manner follows the ISO31000 risk management process, which is internationally accepted standard.

The basic framework for the risk assessment follows the process:

- Risk identification
- Risk assessment
- Develop risk mitigation measures
- Implement mitigation measures

One method for assessing risks is to use a risk matrix of likelihood and consequence. In Black & Veatch's risk model, both of these measures (likelihood and consequence) are divided into five levels defined as:

- Level 1 - Low
- Level 2 - Low - Medium
- Level 3 - Medium
- Level 4 - Medium - High
- Level 5 - High

Once scores for likelihood of failure and consequence of failure are clearly defined, these measures can then be plotted for each asset in a risk rating matrix or 'heat map' like that shown Figure 1-1.

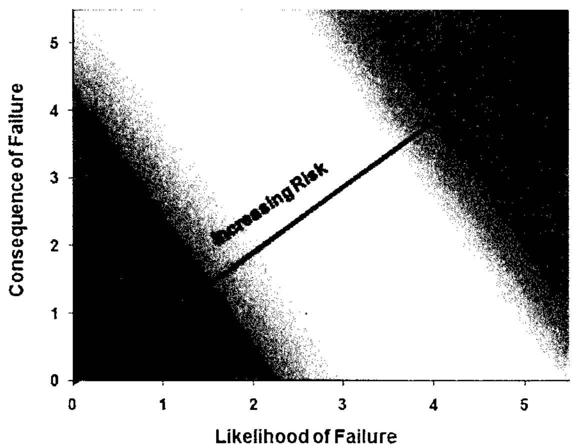

Figure 1-1 Example Risk Rating Matrix

1.2 T&D RISK MODEL OVERVIEW

The Vectren Risk Model focuses investment on high-risk assets in the T&D system. The model quantifies risk reduction achieved by replacement of these high-risk assets over the 7-year TDSIC investment planning period from 2017 through 2023. During Phase 1 of the project, Black & Veatch and Vectren worked in conjunction to identify assets for inclusion in the Risk Model. Asset classes without adequate, detailed data have not been included in the Risk Model, as development of likelihood of failure and consequence of failure require detailed manufacturing dates, installation dates, physical location, and customer and load impacts, among other attributes. Therefore, the Risk Model represents a tool that Vectren and Black & Veatch used in development of Vectren's TDSIC projects by identifying those assets which pose significant risks to the system, but the Risk Model is only one of several factors used in development of the TDSIC plan.

Many of Vectren's planned T&D investment projects and programs under TDSIC replace aging infrastructure on its system. A number of these projects and programs, covering Vectren's major asset classes, are included in the Risk Model. These projects provide various types of benefits, but the risk modeling process focuses on the benefits associated with reduction of risk due to replacement of aging infrastructure. The following major substation and circuit projects and programs are included in the Vectren Risk Model:

- Breaker/transformer replacements
- Transmission overhead and underground circuit replacements
- Distribution overhead and underground circuit replacements
- Substation battery + charger system replacements

1.3 RUN-TO-FAILURE RISK MATRIX

Figure 1-2 illustrates the model results for the Run-To-Failure case where Vectren's assets are plotted in a 5 by 5 risk matrix, or 'heat map'. The matrix presents the number of assets in each region of the heat map whereby assets move up along the y-axis have a higher consequence of failure, and assets that move right along the x-axis in the heat map have a higher likelihood of failure. The combination of consequence and likelihood helps to quantify the risk associated with the assets. Therefore, assets in the upper, right-hand region of the heat map, known as the 'Red Zone', are the highest risk assets on Vectren's system. The goal of this study is to analyze scenarios that replace assets to reduce Vectren's system risk in a cost effective manner.

2023 ALL Assets Heat Map - Run to Failure

199 Red Zone Assets

Consequence of Failure	Likelihood of Failure: 1	2	3	4	5
5	13	2	0	0	1
4	30	29	20	8	19
3	78	47	64	26	125
2	156	90	190	47	140
1	85	54	102	20	51

Total Asset Records **1,397**

Figure 1-2 Example Asset Count Risk Matrix

1.4 SCENARIO FRAMEWORK

As mentioned above, Vectren and Black & Veatch developed three Risk Model Scenarios to evaluate their effects on the T&D system risk. The three scenarios are listed and described below:

- Scenario A – TDSIC 7 Year Plan – This scenario represents the impact on system risk reduction achieved by the TDSIC plan. The TDSIC plan was developed using input from the Risk Model, as well as other factors, including, but not limited to, planned outage scheduling, project costs, lead time for project engineering, procurement, and construction, and project / asset bundling efficiencies. Scenario A represents only the risk reduction achieved by projects that address Risk Model Assets.
- Scenario B – LOF >= 4 – This scenario is an age-based scenario that looks at only replacing assets due to their age, instead of risk. It includes assets that have a COF of 1 through 5 and a LOF of 4 and 5.
- Scenario C – LOF 5 - This scenario is a variation of Scenario B. It is an age-based scenario that looks at only replacing assets due to their age and includes assets that have a COF of 1 through 5, but a LOF of 5 only.

Sections 2.0, 3.0, and 4.0 of this report detail the T&D Risk Model approach used in the analysis and the scenario results. After Vectren and Black & Veatch used those results to inform the TDSIC Investment Plan, the finalized TDSIC Investment Plan was then incorporated into the Risk Model to provide final system risk reduction results.

1.5 SYSTEM RISK REDUCTION ACHIEVED THROUGH THE INVESTMENTS

Section 3.0 of this report describes in more detail how the different substation and circuit investments serve to reduce risk on the Vectren system. Figure 1-3 illustrates a comparison of the total capital expenditures and risk scores between the Run-To-Failure case and the three scenarios over the seven-year planning period. As the figure shows, increasing expenditures beyond the TDSIC plan yields greater risk reduction in the case of Scenario B, but the amount of risk reduction achieved per incremental capital dollar begins to decrease as the TDSIC expenditure level is surpassed. Additionally, comparison of Scenario A to Scenario C shows that focusing capital expenditures on only LOF 5 assets does not yield more risk reduction than Scenario A. Additionally, the age-based asset replacement scenarios require more capital investment and don't account for various appetites for risk at differing CoF levels, whereas Scenario A does. While the age-based scenarios address assets in the Red Zone, they also include assets with CoF 2 and 1. Therefore, expenditures in the Scenario A - TDSIC 7-Year Plan more prudently address the Red Zone asset region while minimizing necessary capital expenditures. Note that the expenditures in this figure represent risk model asset spending only.

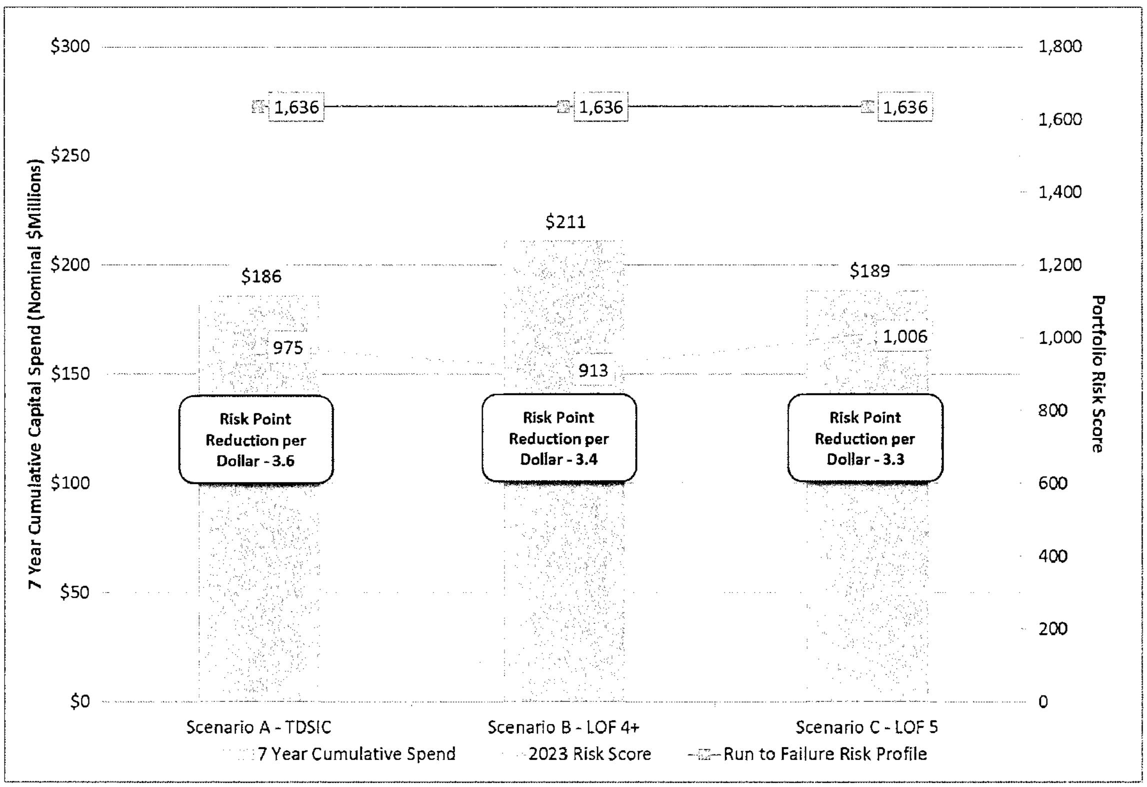

Figure 1-3 Comparison of TDSIC Investment Plan and Other Risk Profiles

2.0 Risk Model Approach

The Vectren Risk Model focuses investment on high-risk assets in the T&D system. The model quantifies risk reduction achieved by replacement of these high-risk assets over the 7-year TDSIC investment planning period from 2017 through 2023. This section describes the approach taken by Vectren and Black & Veatch in the development of the Risk Model and the application of the results to develop the TDSIC investment plan. Not all assets in Vectren's TDSIC plan are contained within the Risk Model. Therefore, the Risk Model represents a tool that Vectren and Black & Veatch used in development of Vectren's TDSIC projects by identifying those assets which pose significant risks to the system.

2.1 RISK MANAGEMENT OVERVIEW

Risk management is a systematic method for identifying, assessing, mitigating and monitoring the risks involved in any activity or process. It is a process that should be repeated many times during the life-cycle of the asset. In this report, risk is defined as the combination of the likelihood of an asset failing and the impact or consequence caused by its failure. Evaluating risk in this manner follows the ISO31000 risk management process, which is internationally accepted standard.

The basic framework for the risk assessment follows the process:

- Risk identification
- Risk assessment
- Develop risk mitigation measures
- Implement mitigation measures

One method for assessing risks is to use a risk matrix of likelihood and consequence. Once scores for likelihood of failure and consequence of failure are clearly defined, measures can then be plotted for each asset in a risk rating matrix or 'heat map' like that shown in Figure 2-1.

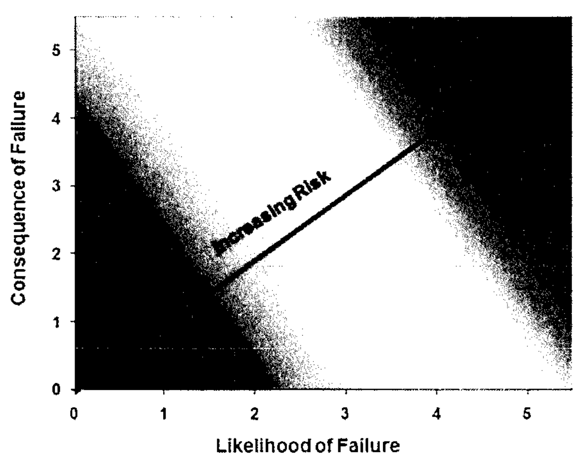

Figure 2-1 Example Risk Rating Matrix

Once the consequence and likelihood ratings are plotted, the risk rating matrix provides a systematic illustration of risk exposure. Risk rating levels can also be defined as in Figure 2-2.

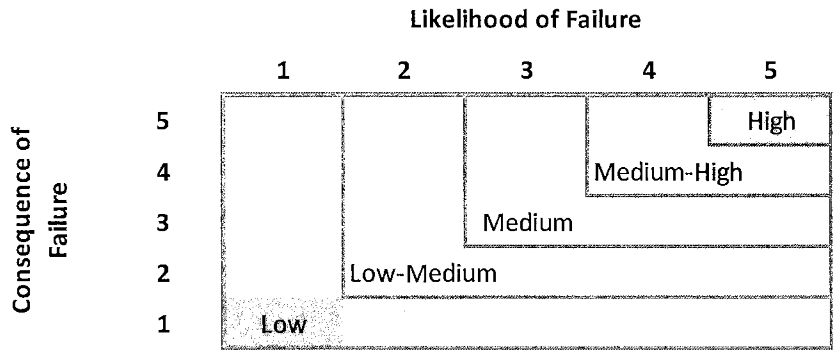

Figure 2-2 Risk Rating Levels in Risk Matrix

The Vectren Risk Model uses the methods described above for assessing risk using likelihood and consequence of failure. A scoring method using 1 to 5 scores has been developed, and identified risks have been captured in a risk register. The model has been configured so that it will evolve as risks are added to the risk register. The model will be re-run periodically and the results used to track risk reduction and provide inputs to regular updates that Vectren will submit to the IURC.

2.2 OVERVIEW OF T&D ASSETS FOR REPLACEMENT

Two voltage classes of T&D assets have been assessed for replacement under the Vectren T&D Risk Model framework and the risk matrix scoring approach summarized above. Figure 2-3 provides a view of the various assets modeled and how they relate to typical power system configurations. Further detail on the voltage classes with their associated subclasses is provided below.

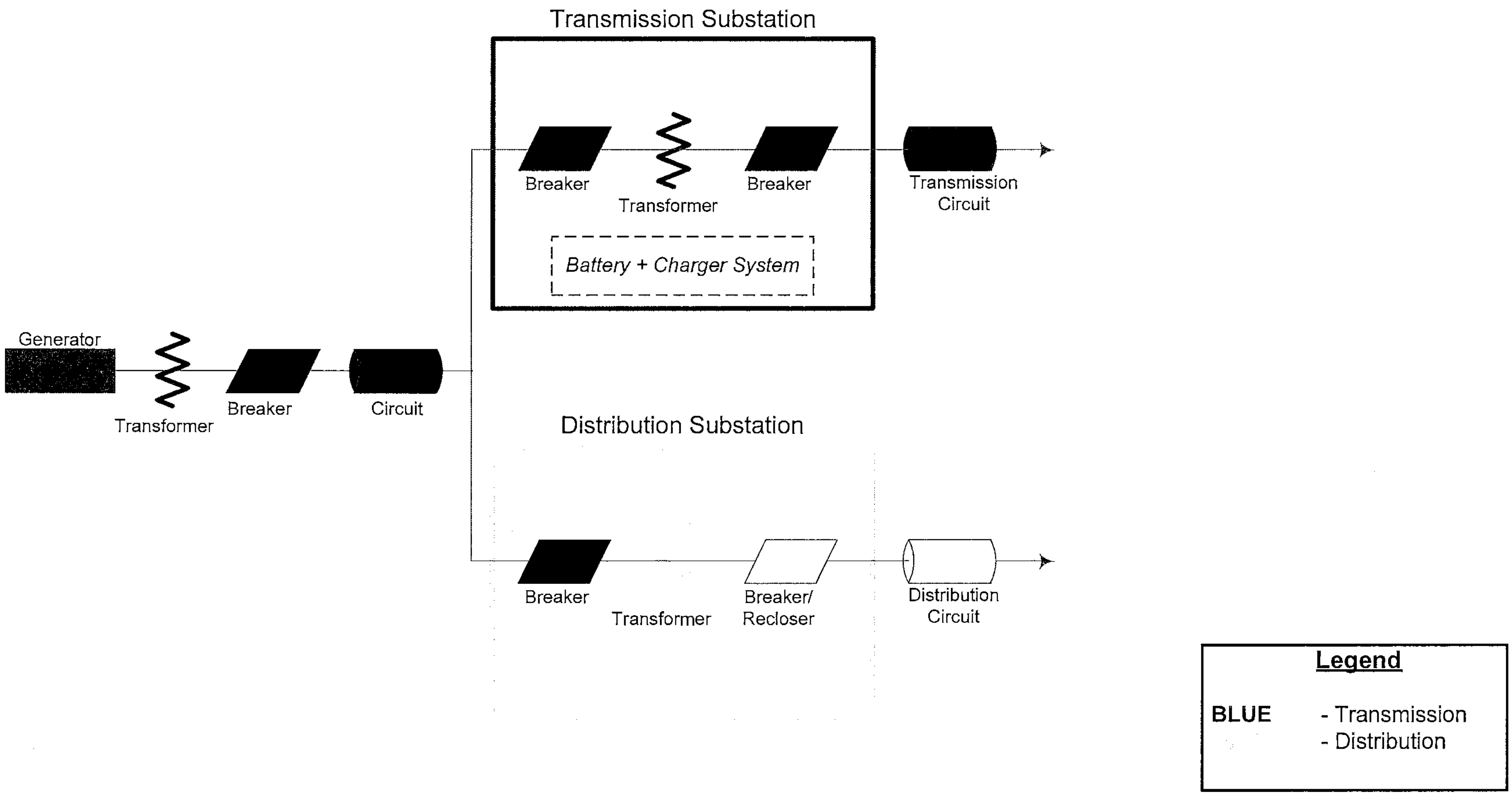

Figure 2-3 Asset Class Configurations

2.3 TRANSMISSION

Transmission assets are Vectren assets which operate at 69kV, 138 kV or 345kV. The consequence of failure criteria and likelihood of failure can sometimes differ between transmission and distribution voltage classes for the same asset.

For the purposes of the Vectren risk analysis, transmission assets would be those that deliver bulk power at 138kV or 345 kV to other assets that are closer to the end users of the power. The risk analysis evaluates transmission assets broken down into circuits and substation assets. The circuits consist of overhead & underground assets, while the substation assets consist of breakers, transformers and the battery and charger system. The count of each of these transmission asset categories included in the Risk Model is given in Table 2-1.

Table 2-1 Transmission Asset Counts

ASSET TYPE	COUNT
Transmission Circuits	128
Transmission Breakers	381
Transmission Transformers	44
Battery + Charger	118

2.4 DISTRIBUTION

The Vectren distribution assets are assets whose nominal operating voltage is 12 kV or 4 kV and whose function is to deliver power to the retail customer site where it is further reduced to a voltage consistent with the customer's utilization level (typically 240/120 volts). The count for each of the distribution assets identified and included in the risk analysis is given in Table 2-2.

Table 2-2 Distribution Asset Counts

ASSET TYPE	COUNT
Distribution Circuits	259
Distribution Breakers	314
Distribution Transformers	153

2.5 RISK SCORING: CONSEQUENCE OF FAILURE SCORING FACTORS

As mentioned above, risk is the combination of consequence of failure and likelihood of failure for a given asset. This section describes the development of the CoF scoring factors for the Vectren Risk Model. A consequence level (very low to very high) was attributed to each asset in the model across a number of consequence criteria.

The CoF weighting and rating scales were developed through a qualitative analysis involving inputs from subject matter experts: staff involved in the design, operation and maintenance of the assets in Vectren's system.

2.5.1 Consequence Criteria

The consequence criteria were determined for each asset within each asset category. The criteria used in the Risk Model consider a number of factors relating to the impact of an asset's failure to the Vectren system. Figure 2-4 below provides a summary of the criteria used to assess the CoF for the Risk Model assets. These categories represent a classification of the type of impacts that can be encountered with the failure of an asset.

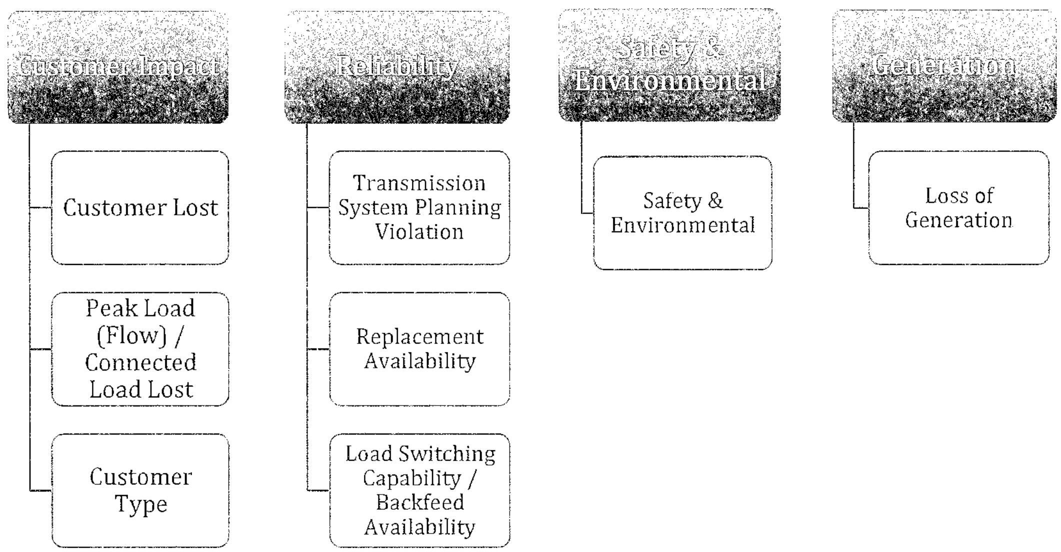

Figure 2-4 Consequence Criteria

2.5.2 Overall Asset CoF

The overall asset CoF is calculated by multiplying each criteria score by a weighting factor. The weighting factors for each asset type sum to 100%. The weighting factors were developed within several workshops involving Vectren subject matter experts and the Black & Veatch team. The CoF weighting factors are provided below in Table 2-3 and Table 2-4.

Table 2-3 Transmission Asset Weighting Factors

CRITERIA	TRANSFORMERS	CIRCUIT BREAKERS	CIRCUITS	BATTERY AND CHARGER
Safety & Environmental	25%	25%	25%	25%
Number of Customers Lost	10%	10%	10%	10%
Peak Flow	15%	-	-	-
Peak Load	-	15%	15%	20%
Customer Type	10%	10%	15%	10%
Transmission System Planning Violation	10%	10%	30%	10%

Replacement Availability	10%	10%	-	5%
Load Switching Capability	15%	15%	-	15%
Loss of Generation	5%	5%	5%	5%

Table 2-4 Distribution Asset Weighting Factors

CRITERIA	TRANSFORMERS	CIRCUIT BREAKERS	CIRCUITS
Safety & Environmental	25%	25%	25%
Number of Customers Lost	25%	25%	25%
Peak Load	10%	10%	10%
Customer Type	10%	10%	10%
Replacement Availability	15%	15%	-
Availability of Backfeed	-	-	25%
Load Switching Capability	10%	10%	-
Loss of Generation	5%	5%	5%

2.6 RISK SCORING: LIKELIHOOD OF FAILURE

After defining the CoF, Vectren and Black & Veatch began estimating the likelihood of failure for the assets. For this study, the risk event is predominately an age or deterioration-related asset failure that results in an outage and is either not repairable or the cost of repair coupled with the chronological age of the asset lends itself to asset replacement. This is referred to by some in the energy industry as 'end of life' failure. Survivor curves are used widely in the utility industry to forecast end of life LoF and deterioration of assets for asset management analyses. To develop LoF probabilities for Vectren T&D assets, survivor curves were developed and used as follows.

2.6.1 Overview of Survivor Curves and LoF Calculations / Approach

2.6.1.1 Survivor Curves

Survivor curves are widely used by utilities as part of depreciation studies to estimate the probable average service life of different assets and set depreciation rates in line with those lives. Referred to as 'Iowa' curves, Iowa Type Curves are a codified system commonly used in utility depreciation analyses. An example survivor curve for 138kV power transformers is shown in Figure 2-5.

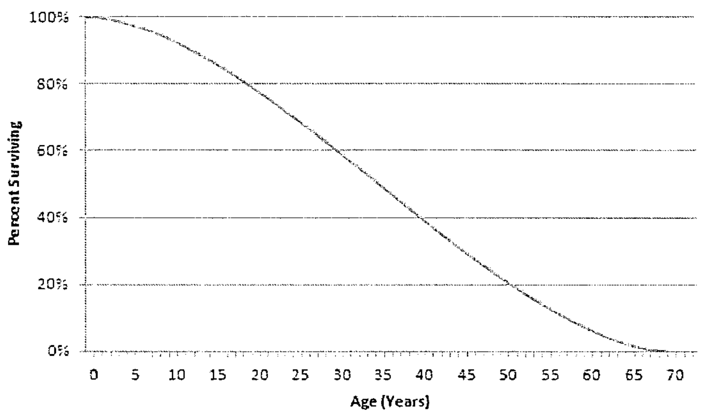

Figure 2-5 Example Survivor Curve

To select survivor curves for each asset, depreciable life estimates from a recent Black & Veatch depreciation rate survey of approximately 15 U.S. electric utilities were used. In addition to the asset life estimates from the Black & Veatch survey, survivor curve types were used based on Vectren's most recent depreciation study.

2.6.1.2 LoF Calculations Using Survivor Curves

Survivor curves can be used to calculate age-based LoF percentages. Black & Veatch is using this approach in identifying LoF percentages for the Vectren T&D Risk Model. An important concept to understand when using survivor curves and explaining them is that the survivor curve percentages on the y-axis show the 'percent surviving' among a given asset population. Calculating the LoF for a given asset age is derived by looking forward along the curve and disregarding the portion of the curve to the left of age 35 (see Figure 2-6 below).

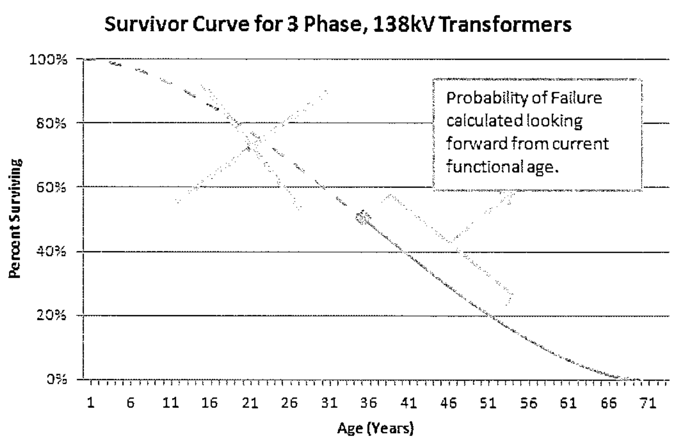

Figure 2-6 138 kV Transformer Survivor Curve

The Vectren Risk Model combines CoF scoring factors with an age-based LoF to arrive at a risk score for each asset in the Risk Model. In order to generate the LoF percentages for the Risk Model, a survivor curve model calculates the discrete failure probabilities by year, and then sums the cumulative LoF for the next 10 years for each individual asset. The age of each specific asset is incorporated in these calculations. Table 2-5 shows example calculations of a 10-year cumulative LoF, while Figure 2-7 described in the next paragraph visually demonstrates the calculations.

Table 2-5 Example LOF Calculations

Current Age of Asset

35

Age	Forecast Year	Discrete LoF	Cumulative LoF
36	1	3.9%	3.9%
37	2	3.9%	7.8%
38	3	3.9%	11.7%
39	4	3.9%	15.6%
40	5	3.9%	19.5%
41	6	3.9%	23.4%
42	7	3.8%	27.2%
43	8	3.8%	31.0%
44	9	3.8%	34.7%
45	10	3.7%	**38.5%**

Building upon the survivor curve example in Figure 2-6, Figure 2-7 focuses on the LoF calculations. It highlights how discrete annual LoF percentages are calculated for each year in the future. Each blue vertical line is illustrative of this annual calculation. These are then summed over the next 10 years to arrive at a 10 year cumulative LoF for each asset that is loaded into the Risk Model.

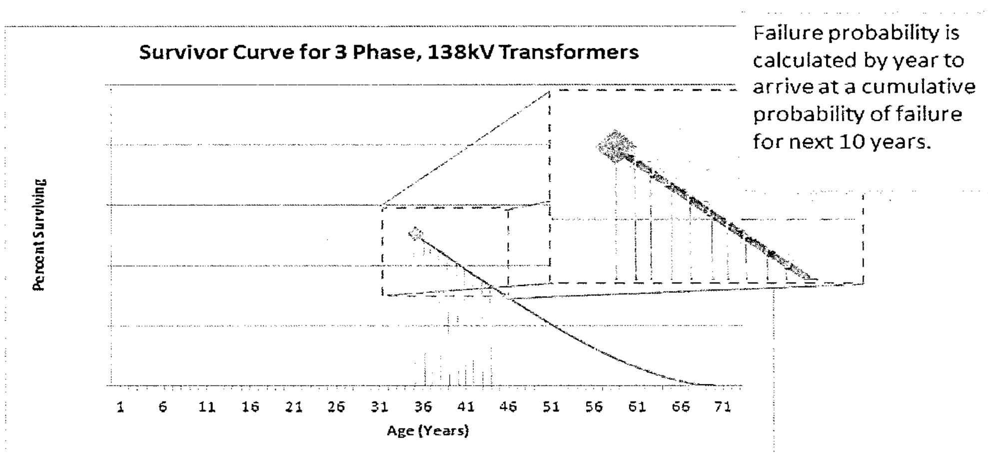

Figure 2-7 Discrete Annual LoF Percentages are Summed into a 10 Year Cumulative Value for Use in the Risk Model

2.6.2 Effective Age and Asset Condition

Where the relevant data are available, an asset's LoF should incorporate an asset's health and condition. This allows for an enhancement to the LoF component of the analysis because assets that are older, but have good health can have their LoF reduced, while assets that are younger, but in poor health condition, can have an increased LoF. The concept of adjusting an asset's chronological age to more closely resemble its health creates an asset's effective age. Scenario A, Scenario B, and Scenario C in this study incorporate asset health and effective age.

The condition of an asset can be influenced by many factors such as:

- Operating Conditions
- Service History
- Quality of Maintenance
- Number of Operations
- Loadings
- Exposure
- Latent Defects and Patent Defects
- Environmental Effects
- Demand Cycles

The asset health index (AHI) methodology described below estimates the impact of the factors listed above on asset health using available asset condition information.

2.6.2.1 Asset Health Index (AHI)

The AHI is an indexed score of an asset's relative health based on a number of measures that incorporate the asset condition information. These measures are gathered from Vectren's maintenance and testing programs and include information and data from analytical testing as well as visual inspections. Additionally, these measures are asset specific and can vary from asset class to asset class.

For Vectren's AHI, an asset is scored for each appropriate measure based on a condition rating scale for that measure. The concept is similar to that of CoF with criteria, scoring definitions, and weighting factors.

2.6.2.2 Effective Age Estimation

As assets age, their condition, and therefore their AHI score is expected to degrade. Based on the calculated condition rating (or AHI score) of an asset based on condition data, Figure 2-8 and Figure 2-9 is used to estimate the effective age of an asset by comparing the condition rating to the survivor curve. Doing this, we can estimate that an asset with a condition rating of 'poor' is like an asset that is at 90 to 100% of its service life, regardless of its age.

For example, a 32-year old power transformer may have a condition rating of 'good' based on its condition data. As a result, its estimated effective age would be approximately 30% of its service life. This means the asset's condition is better than we would expect, given its age. Using a service life of 35 years, we would estimate that the effective age of this power transformer is 11 years old (35 * 0.30). Figure 2-8 graphically illustrates this example.

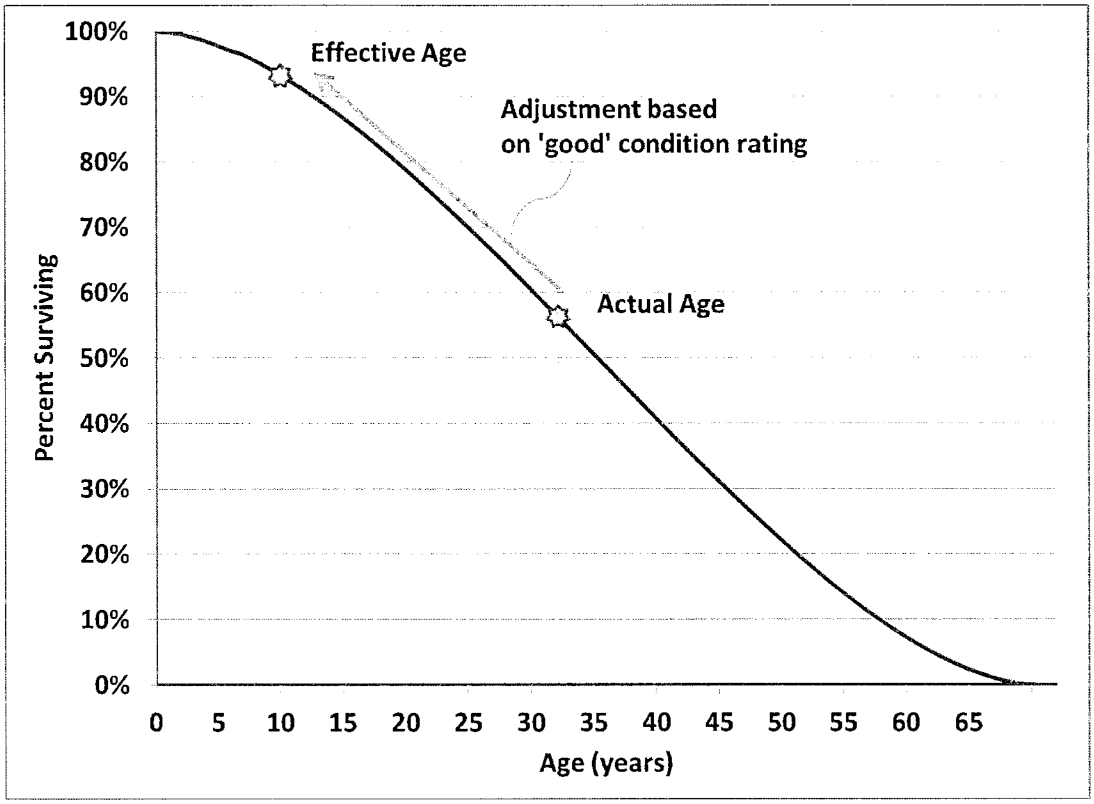

Figure 2-8 Example Effective Age Estimate – Good Condition

Likewise, a 10-year old power transformer may have a condition rating of 'poor' based on its condition data. As a result, its estimated effective age would be approximately 90% of its service life. Using a service life of 35 years, we would estimate that the effective age of this power transformer is 32 years old (35 * 0.90). This means the asset's condition is better than we would expect, given its age. Figure 2-9 graphically illustrates this example.

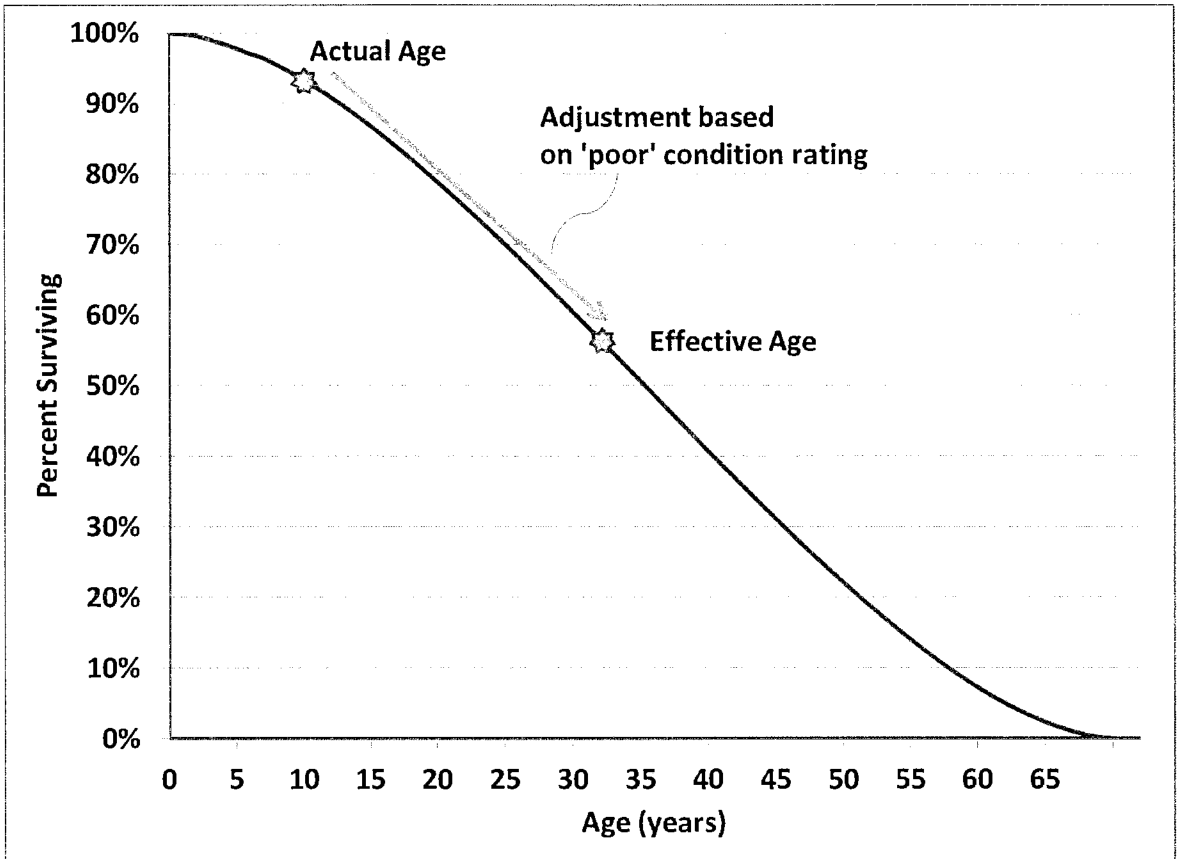

Figure 2-9 Example Effective Age Estimate – Poor Condition

2.6.2.3 Likelihood of Failure Scoring for Overhead Circuit Assets

For circuit assets, detailed condition data was not available. Therefore, AHI was not developed for circuit assets.

2.6.2.4 Likelihood of Failure Scoring for Transformers, Circuit Breakers, and Batteries and Chargers

AHI and effective ages are used in conjunction with the asset-appropriate survivor curves to generate a likelihood of failure score for transformers and circuit breakers. Detailed condition data for batteries was not available. Therefore, batteries do not have an AHI in the Risk Model.

3.0 Run-to-Failure Analysis

This section demonstrates how the Risk Model quantifies the impact of a Run-to-Failure case. It demonstrates the level of risk that Vectren carries due to its aging infrastructure without proactive replacement of the assets. In a Run-to-Failure situation, for modeling purposes, Vectren would repair assets as they fail, but not proactively replace them. This Run-to-Failure analysis establishes the baseline from which risk reduction can be measured. Implementing a proactive replacement strategy is a prudent way to manage and reduce the risk on the system and maintain reliable service.

3.1 RUN-TO-FAILURE CASE

For the Run-to-Failure case, the Risk Model examines the aging of existing assets with zero replacements over a seven-year time period. This analysis identifies the increase in risk exposure to Vectren if no assets were replaced within this time frame.

3.1.1 Assumptions

The analysis assumes the following:

- Assets will age seven years.
- CoF ratings are assumed to remain static over the analysis period (it is noted that the weighting of these criteria will need to be reviewed annually or whenever any of Vectren's strategic initiatives or imperatives change).
- Assets are repaired in such a manner to restore service but not extend useful or expected service life.
- For simplicity, this analysis does not include any new assets for system growth, increased capacity or the like.

3.1.2 Red Zone

The Risk Model prioritizes assets for proactive replacement if they have a high consequence and likelihood of failure. In the Risk Model, Black & Veatch has defined an area with high consequence and likelihood on the heat matrix as the 'Red Zone'. The Red Zone is used as a guide when developing the TDSIC plan. In this study, the Red Zone includes assets that have a CoF of greater than, or equal to 3 and a LoF of greater than, or equal to 3. The exception is that assets with both a CoF and LoF of 3 are not included in the Red Zone. The Red Zone region is highlighted in Figure 3-1 below.

Likelihood of Failure

Consequence of Failure	1	2	3	4	5
5				Red Zone	
4					
3					
2					
1					

Figure 3-1 Red Zone Target Region

3.1.3 Run-to-Failure Risk Assessment

Figure 3-2 is a summary of the asset risk ratings for all assets modeled in the risk analysis as defined in Section 2.3 in 2017. The numbers within each box represent the number of assets that fall within the given risk ratings. As the matrix shows, there are a significant number of assets with high LoF ratings of 4 and 5 – an indicator of an aging system.

Figure 3-3 shows the collection of assets, but 7 years later, in 2023. The figure shows how assets move into the higher LoF regions as the study period progresses. In this case, Vectren's system moves from having 158 assets in the red zone to 199 over the 7-year period. Additionally, the entire system risk score grows from 1,316 to 1,636 from 2017 to 2023 due to the increase in likelihood of failure for the Risk Model assets over the same period.

2017 ALL Assets Heat Map

158 Red Zone Assets

Likelihood of Failure

Consequence of Failure	1	2	3	4	5
5	14	1	0	1	0
4	47	27	12	5	15
3	112	66	37	24	101
2	198	200	80	48	97
1	100	114	40	30	28

Total Asset Records **1,397**

Figure 3-2 2017 Risk Rating Matrix – Run-to-Failure

2023 ALL Assets Heat Map - Run to Failure

Consequence of Failure	Likelihood of Failure: 1	2	3	4	5 (199 Red Zone Assets)
5	13	2	0	0	1
4	30	29	20	8	19
3	78	47	64	26	125
2	156	90	190	47	140
1	85	54	102	20	51

Total Asset Records 1,397

Figure 3-3 2023 Risk Rating Matrix – Run-to-Failure

3.1.4 Run-to-Failure Case Summary

Figure 3-4 shows the increase in total risk score from the current year to the seven year case. This illustrates a 29 percent increase in total system risk for the run to failure risk profile.

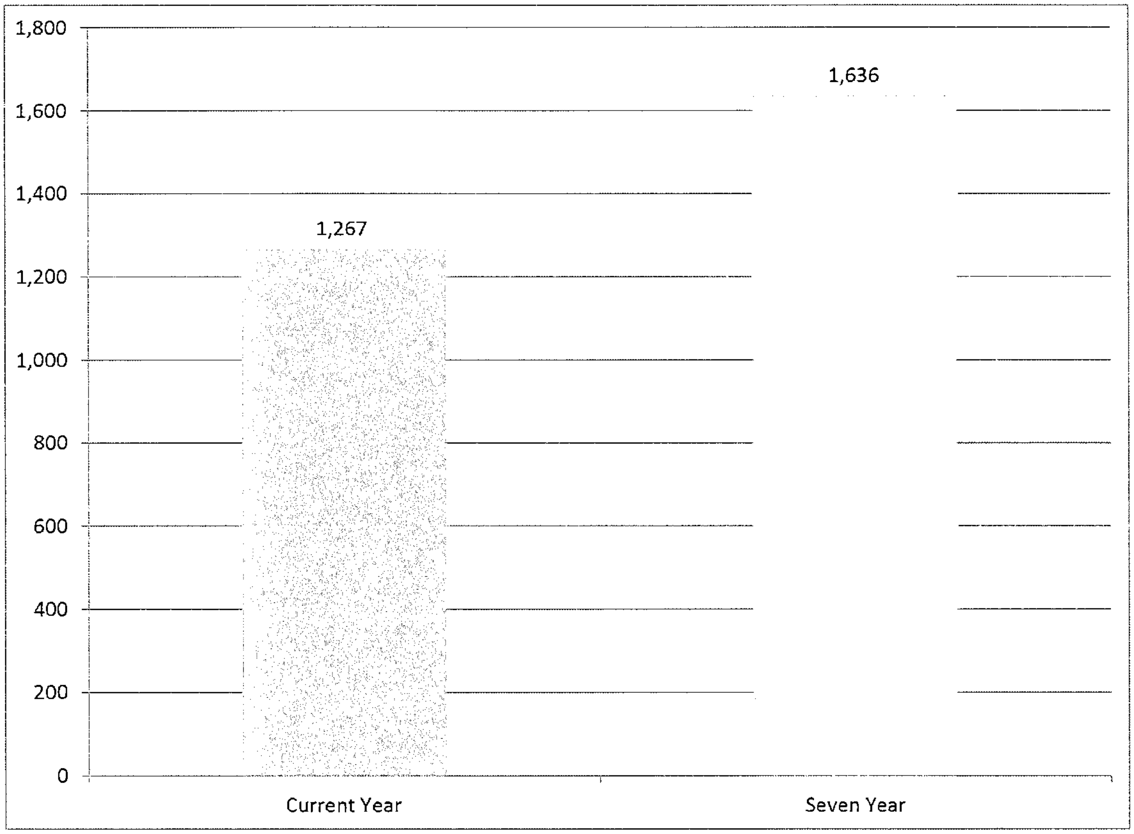

Figure 3-4 Total Risk Score of Assets in Current Year (2016), Seven Years (2023)

3.2 USE OF THE RISK ASSESSMENT MODEL

For the purposes of capital planning, the development of this risk assessment model is to facilitate informed decision making in the capital planning process. It is not intended to be an absolute or final decision maker. Proper capital planning involves the evaluation of multiple criteria, including operational, planning, technical, and financial perspectives, as well as long term system risk.

The risk assessment model is intended to allow Vectren to refine their capital planning process through the consideration of

- Overall systematic asset risk;
- the potential reduction in systematic asset risk associated with capital replacements;
- how systematic asset risk is balanced across the Vectren system, in terms of the separate transmission and distribution systems, as well as across asset classes; and
- provide relative comparisons of risk between assets and asset classes.

Utilization of the risk assessment results in this manner provides an improved decision making process for capital planning that far exceeds the information available in more simplified capital planning processes, such as those based on asset age.

4.0 Risk Model Scenario Results

4.1 OVERVIEW

This section presents the asset replacement plan scenarios, building upon the analysis presented in Sections 1 through 3 of this report. Each of these scenarios demonstrates various asset replacement expenditures that either reduce the number of assets beyond a certain point of the survivor curve or reduce system-wide asset risk. This section focuses on the level of risk reduction for Vectren's system and does not detail the assets replaced by the Risk Model.

4.2 SCENARIO FRAMEWORK

As discussed, Black & Veatch and Vectren have developed three scenarios that are used in analyzing the effects of proactive replacement on Vectren's system-level risk. The three scenarios are listed and described below:

- Scenario A – TDSIC 7 Year Plan – This scenario represents the impact on system risk reduction achieved by the TDSIC plan, which is a risk-based strategy. The TDSIC plan was developed using input from the Risk Model, as well as other factors.
- Scenario B – LoF >= 4 – This scenario is an age-based scenario that looks at only replacing assets due to their effective age, instead of risk. It includes assets that have a CoF of 1 through 5 and a LoF of 4 and 5.
- Scenario C – LoF 5 - This scenario is a variation of Scenario B. It is an age-based scenario that looks at only replacing assets due to their effective age and includes assets that have a COF of 1 through 5, but a LOF of 5 only.

4.2.1 Age-Based Replacement Scenarios

While Scenario A utilizes a risk-based investment plan strategy, Scenarios B and C utilize an age-based replacement strategy. The age-based replacement scenarios represent the use of a different asset targeting strategy to provide comparisons to Vectren's TDSIC plan. The age-based scenarios are driven primarily by the LoF in the Risk Model. Due to the number of assets in the LoF 4 and 5 regions in Vectren's system, the model was constrained in the age-based replacement scenarios by the number of projects that can be scheduled for each asset class during the seven-year period. This provides a more realistic comparison of the three scenarios since Scenarios B and C represent replacement scenarios that are potentially feasible, at least from a number of projects perspective. It should be noted, however, that the project replacement schedules chosen by the Risk Model in Scenarios B and C have not been evaluated for technical or operational feasibility. The scenarios are designed to be a tool for comparison. Scenario C replaces assets only in the LoF 5 region of the heat matrix and utilizes project constraints that closely resemble the number of projects in the TDSIC plan. Scenario B replaces assets that are in the LoF 4 and LoF 5 regions of the heat matrix. Due to the expanded number of assets eligible for replacement in Scenario B compared to Scenario C, the project constraints were expanded so that Scenario B represents a very aggressive replacement strategy. Although potentially feasible, Scenario B replacement levels would likely strain Vectren's resources over the seven-year TDSIC period and make implementation of the plan difficult.

4.2.2 Scenario A – TDSIC Seven Year Asset Replacement Plan Overview

In Scenario A, the TDSIC Risk Model seven year asset replacement plan represents the Risk Model's quantification of risk reduction based on the number of replacements and amount of capital investment in the TDSIC plan. Scenario A represents only the risk reduction achieved by TDSIC projects that address Risk Model Assets. It represents a risk-based, optimized replacement plan that has been developed with consideration of various inputs as well as system and operational constraints. These inputs and constraints include:

- Asset risk, model prioritization
- System reliability / planned outage scheduling
- Project costs and available budget
- Resources available by asset class
- MISO coordination for transmission projects
- Lead time for engineering, procurement, and construction
- Project allocations between transmission and distribution
- Project and asset bundling/work efficiencies
- Worst performing distribution circuits
- Asset condition and health

4.2.2.1 Scenario A – TDSIC Workplan Projects

In Scenario A, the TDSIC projects that affect Risk Model assets are reflected in the Risk Model in terms of number of projects and schedule of replacements. The types of TDSIC projects in Vectren's plan that replace Risk Model assets and are reflected in Scenario A include:

- 12kV Circuit Rebuild / Looping
- 4kV Substation and Circuit Conversions
- Breaker/Switchgear Replacements
- System Protection/Control Upgrades
- Transmission Line Rebuilds
- Underground Network Upgrades
- Underground Replacement / Looping

It should be noted that not all projects within each of these categories cause Risk Model asset replacements. In the 12kV Circuit Rebuild / Looping project category, for instance, looping projects add system capabilities that increase reliability, but do not necessarily replace existing assets. Per the inputs and constraints mentioned in Section 4.2.1, the number of projects completed in Scenario A by asset class per year may vary. Table 4-1 presents the Scenario A - TDSIC annual number of asset replacement projects. It should be noted that Vectren's plan includes many circuit projects that rebuild the most deteriorated portions of the circuit, but the entire circuit is not rebuilt. Therefore, a number of the circuit projects in the table include partial rebuilds.

Table 4-1 Scenario A – TDSIC Workplan Annual Asset Replacements

ASSET	2017	2018	2019	2020	2021	2022	2023
Transmission Transformers	-	1	-	-	-	-	-
Transmission Circuit Breakers	5	5	3	13	8	4	13
Transmission Overhead Circuits	1	1	1	1	2	1	1
Transmission Underground Circuits	-	-	-	1	1	-	-
Distribution Transformers	3	4	6	13	7	11	11
Distribution Circuit Breakers	9	9	15	23	20	31	31
Distribution Overhead Circuits	25	20	16	18	16	14	16
Transmission Batteries & Chargers	2	1	2	1	2	2	2

4.2.2.2 Scenario A – TDSIC Workplan Asset Condition and Health

As described in earlier sections of this report, the scenarios in this report consider asset condition and health when projecting LoF, where appropriate data are available. Using asset condition and health provides a more appropriate risk management strategy for Vectren's critical and higher cost assets as it prevents old assets that are in good condition from being replaced too early and it highlights younger assets that are in poor health, possibly due to environmental, loading, or other factors, that otherwise would be overlooked in a replacement plan based solely on physical age.

4.2.2.3 Scenario A – TDSIC Workplan Risk Appetite

From an asset management strategy perspective, not all deteriorated assets should be treated equally. While proactive replacement strategies can differ slightly from utility to utility, in general, assets with very low CoF are not prioritized for proactive replacement. Additionally, it is recognized that utilities have multiple competing demands for expenditures that typically exceed available budgets. For instance, a utility may accept the notion of allowing a distribution breaker with a CoF score of 1 to move well into the LoF 5 region before proactively replacing it. Depending on the breaker, it may even be allowed to run to failure if the CoF is low enough. Conversely, the appetite for risk for a breaker that has a CoF 5 is much lower because an unplanned or irreparable failure of the asset can cause serious impacts to the system.

Utilizing the Red Zone in the manner described in this report, as opposed to just age-based replacements, allows for appropriate representation of the changes in appetite for risk depending upon an asset's CoF. Figure 4-1 illustrates how differing asset management strategies can be applied as assets move around the risk matrix. High CoF and high LoF areas indicate higher risk assets that should be proactively replaced and/or included in a proactive monitoring strategy. High LoF areas with low CoF, such as CoF 2, LoF 5, tend to fall within the realm of an economic-based strategy from an asset management perspective. This means that utilities may sometimes target this area for proactive replacement if it provides economic and other additional benefits.

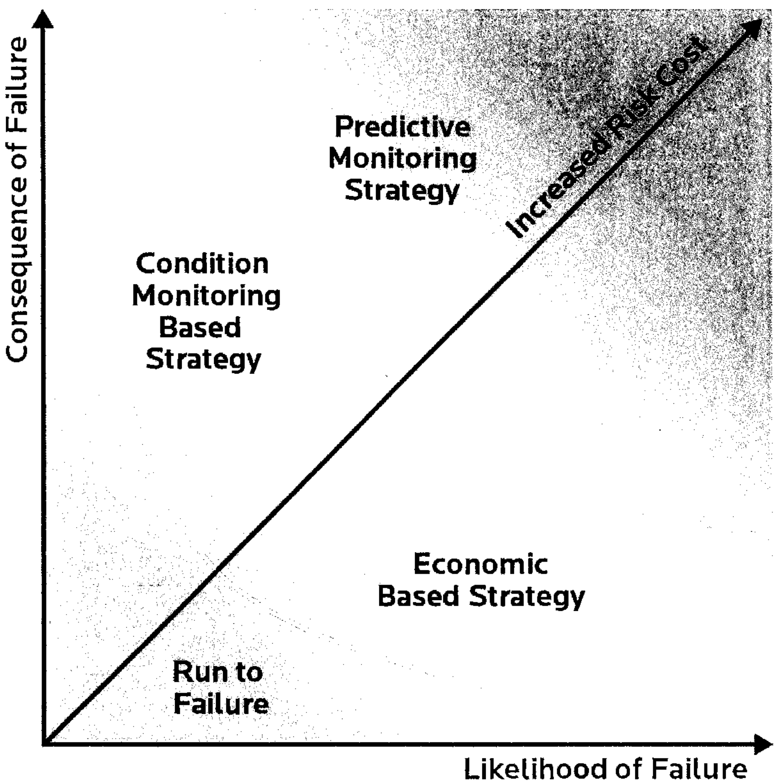

Figure 4-1 Predictive Monitoring Strategy

4.2.3 Scenario B - LoF >= 4 Asset Replacements Overview

Scenario B - LoF >=4 asset replacement scenario is derived from a LoF-based analysis of system-wide asset replacements in Vectren's service territory using asset-specific survivor curves and condition data. This case limits asset investment and replacements to the LoF 4 and LoF 5 regions of the heat matrix, but does not limit replacements based on an asset's CoF. As described in Section 4.2.1, this scenario assumes aggressive, non-optimized asset replacements. Figure 4-2 highlights the LoF >=4 target region.

2023 ALL Assets Heat Map - Run to Failure

Consequence of Failure	Likelihood of Failure: 1	2	3	4	5
5	13	2	0	0	1
4	30	29	20	8	19
3	78	47	64	26	125
2	156	90	190	47	140
1	85	54	102	20	51

Total Asset Records 1,397

Figure 4-2 Scenario B - LOF >=4 Case Target Region

4.2.4 Scenario C - LoF 5 Asset Replacements Overview

Scenario C - LoF 5 scenario is a variant of Scenario B above. The primary differences are that the asset investments and replacements are limited to only the LoF 5 region of the heat matrix. Figure 4-3 below highlights the LoF 5 target region.

2023 ALL Assets Heat Map - Run to Failure

Consequence of Failure	Likelihood of Failure: 1	2	3	4	5
5	13	2	0	0	1
4	30	29	20	8	19
3	78	47	64	26	125
2	156	90	190	47	140
1	85	54	102	20	51

Total Asset Records 1,397

Figure 4-3 Scenario C - LOF 5 Case Target Region

4.3 SCENARIO EXPENDITURES

This section outlines the annual levels of expenditures for all the three scenarios associated with risk model assets only. For each of the scenarios, the annual expenditures by substations and circuits are shown; followed by annual expenditure by voltage class and further broken into individual assets by voltage class included in the risk model.

4.3.1 Scenario A – TDSIC Workplan Risk Model Expenditures

As discussed above, the TDSIC Risk Model Scenario incorporates various factors to develop an optimized investment plan. It should be noted that the TDSIC Workplan Risk Model Scenario has the least amount of total capital expenditures among the three scenarios. Figure 4-4 shows the total annual expenditures by substations and circuits.

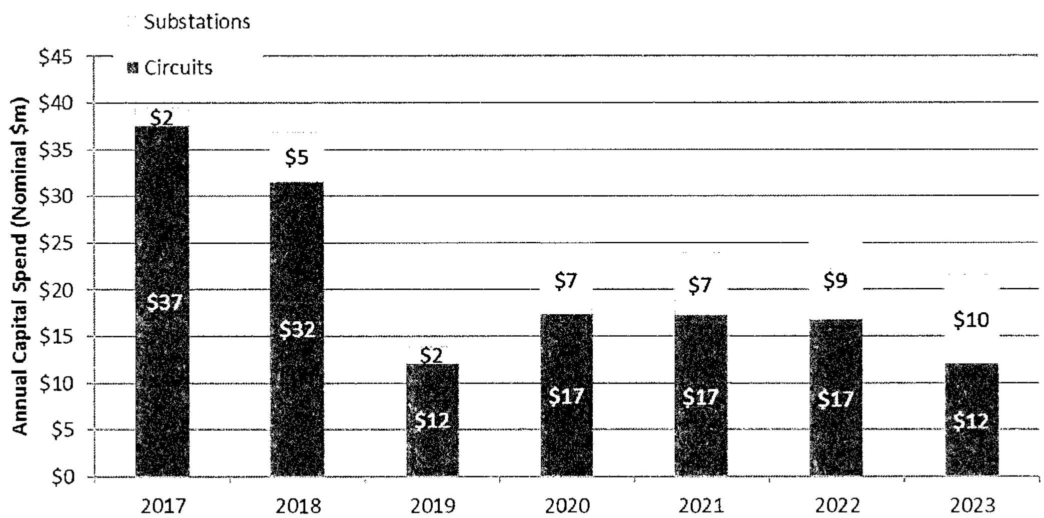

Figure 4-4 Scenario A – TDSIC Workplan Risk Model Expenditures

Table 4-2 provides the total TDSIC Workplan Risk Model Scenario expenditures broken down by voltage class. Note the totals may not equal to the sum of the annual values due to rounding.

Table 4-2 Scenario A – TDSIC Workplan Risk Model Expenditures ($Millions)

PROJECT	2017	2018	2019	2020	2021	2022	2023	TOTAL
Distribution	$31.4	$22.8	$12.2	$21.0	$13.3	$15.5	$14.1	$130.3
Transmission	$8.1	$14.2	$1.7	$3.8	$10.7	$9.8	$7.6	$55.9
Total	$39.5	$36.9	$13.9	$24.8	$24.0	$25.3	$21.7	$186.2

4.3.2 Scenario B - LoF >= 4 Asset Replacement Expenditures

Using the LoF-based analysis discussed in Section 3.0 of this report, the LoF >= 4 scenario was derived by identifying the assets that would require replacement under the LoF >= 4 region. Figure 4-5 shows the total expenditures by substation and circuit assets for the next seven years.

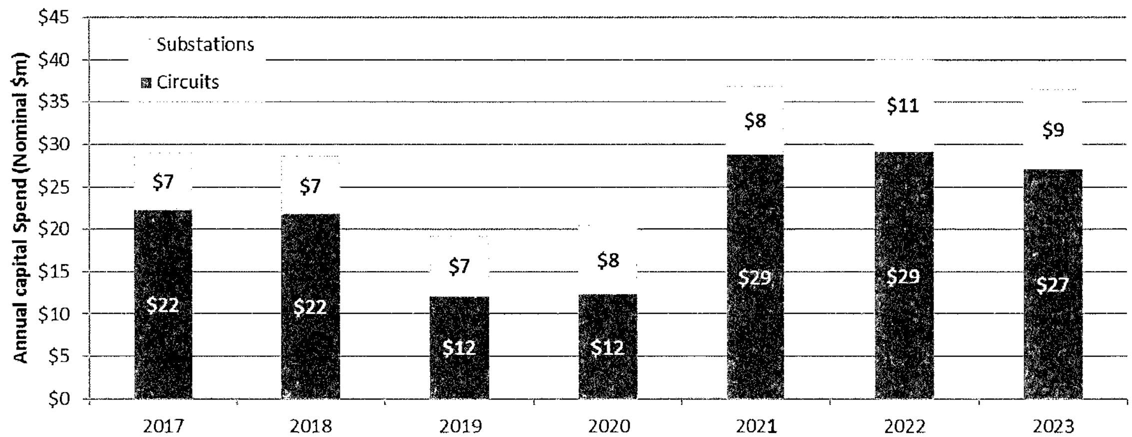

Figure 4-5 Scenario B - LoF >= 4 Expenditures Summary

Table 4-3 provides the annual expenditures for the LoF >= 4 Scenario by voltage class. Note the totals may not equal to the sum of the annual values due to rounding.

Table 4-3 Scenario B - LoF >= 4 Expenditures ($Millions)

PROJECT	2017	2018	2019	2020	2021	2022	2023	TOTAL
Distribution	$6.5	$6.8	$5.2	$6.5	$8.8	$7.3	$7.7	$48.8
Transmission	$22.6	$21.8	$14.2	$14.1	$28.2	$32.8	$28.8	$162.5
Total	$29.0	$28.7	$19.3	$20.7	$37.0	$40.1	$36.6	$211.4

4.3.3 Scenario C - LoF 5 Asset Replacement Expenditures

The LoF = 5 asset replacement scenario is a variant of the LoF >= 4 scenario and uses the same basic assumptions. Whereas the LoF >= 4 scenario assumes asset replacement occurs at a point where assets are LoF 4 or higher, the LoF = 5 scenario assumes asset replacement occurs at a point where assets reach LoF 5. The Figure 4 6 summarizes the total expenditures by asset and project for the next seven years for this scenario. Figure 4-6 shows the total expenditures by substation and circuit assets for the next seven years.

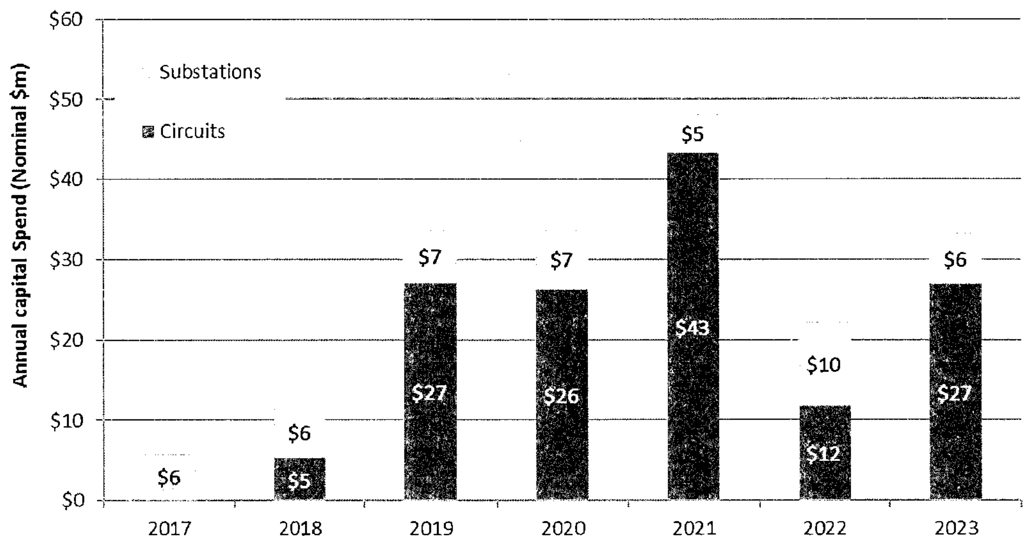

Figure 4-6 Scenario C - LoF 5 Expenditures Summary

Table 4-4 provides the total LoF 5 Scenario expenditures broken down by voltage class. Note the totals may not equal to the sum of the annual values due to rounding.

Table 4-4 Scenario C - LoF 5 Expenditures ($Millions)

PROJECT	2017	2018	2019	2020	2021	2022	2023	TOTAL
Distribution	$4.3	$6.6	$5.5	$5.3	$4.2	$9.1	$6.9	$41.8
Transmission	$1.5	$5.1	$28.2	$28.5	$44.1	$13.0	$26.4	$146.7
Total	$5.9	$11.7	$33.7	$33.7	$48.2	$22.2	$33.3	$188.6

4.4 SCENARIO EXPENDITURE SUMMARY

This section summarizes results for the annual levels of expenditures for Scenario A, B and C. Figure 4-7 summarizes the total, 7-year plan expenditures for each of the three scenarios described above. As shown in the figure, the Scenario B – LoF >=4 has the highest level of expenditures with approximately $211 million. Scenario C has the next highest level of expenditures with approximately $189 million, while Scenario A, the TDSIC – 7 Year Plan has approximately $186 million in total investment. It should be reiterated that these costs represent expenditures for risk model assets only.

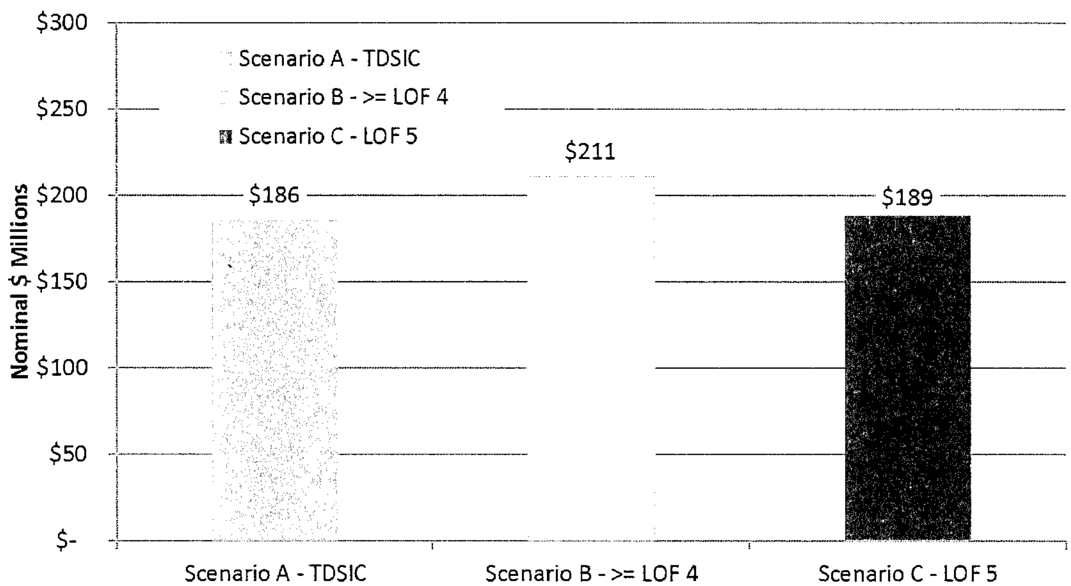

Figure 4-7 Total 7-Year Expenditures by Scenario

4.5 SCENARIO RISK PROFILES

This section explores the relationship between the capital expenditures and portfolio risk reduction for Vectren. For each of the three scenarios described above, the corresponding portfolio risk profile is calculated and illustrated from three different perspectives. Risk profiles are provided by substations, circuits, and total system profile, which includes substations and circuits. Breaking down the risk profiles by substations and circuits provides insight into the drivers of the total portfolio risk for each scenario.

4.5.1 Scenario A – TDSIC Workplan Model Risk Profile

4.5.1.1 Scenario A – TDSIC Workplan Risk Model Total Portfolio Risk Reduction

Figure 4-8 shows the Risk Model 7 Year plan Scenario expenditures and the associated risk profile for the total portfolio of assets. The figure shows that the overall risk reduction of the TDSIC Workplan Risk Model Scenario is 40% with approximately $186 million in expenditures over the seven-year period.

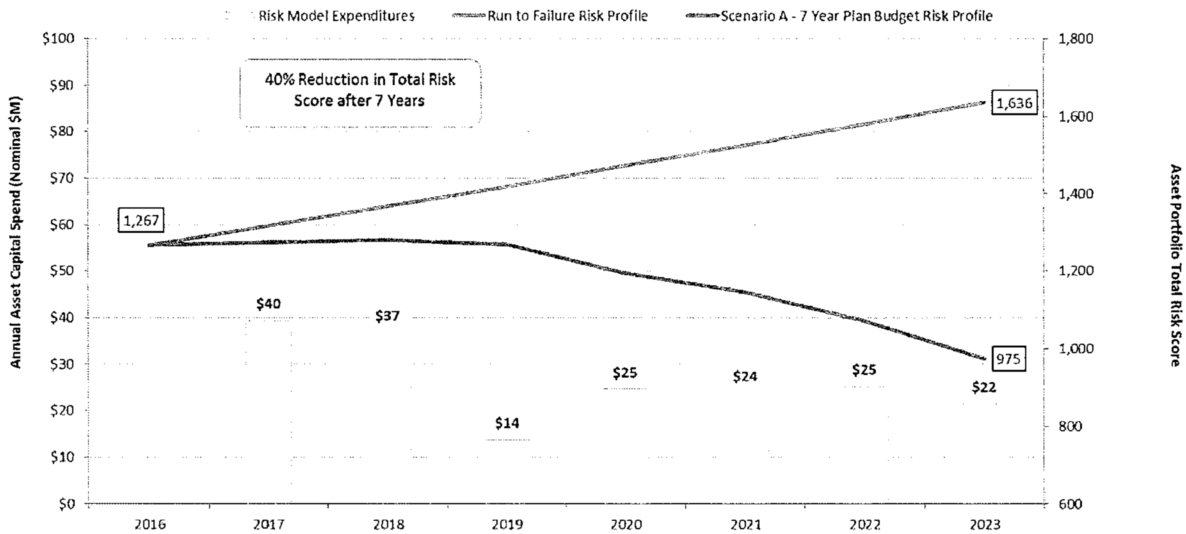

Figure 4-8 Scenario A - TDSIC Risk Model Expenditures and Risk Reduction for Total Portfolio of Assets

Figure 4-9 shows the resulting risk matrix in 2023 for the TDSIC Workplan Risk Model Scenario expenditures shown in Figure 4-8 above. The investment plan associated with Scenario A results in having 31 assets remaining in the Red Zone after the end of the study period.

2023 ALL Assets Scenario Heat Map

31 Red Zone Assets

Consequence of Failure	Likelihood of Failure: 1	2	3	4	5
5	14	2	0	0	0
4	64	33	5	4	0
3	219	52	47	15	7
2	243	105	153	40	82
1	119	57	87	19	30

Total Asset Records 1,397

Figure 4-9 Scenario A - TDSIC Workplan 2023 Risk Model Total Portfolio Risk Rating Matrix

4.5.2 Scenario B - LoF >= 4 Scenario Expenditures and Risk Profile

4.5.2.1 Scenario B - LoF >= 4 Total Portfolio Risk Reduction

Figure 4-10 below summarizes the total portfolio expenditures and risk reduction for the LoF >=4 Scenario. The figure shows that the overall risk reduction of the LoF >=4 Scenario is 44% with approximately $211 million in expenditures over the seven-year period.

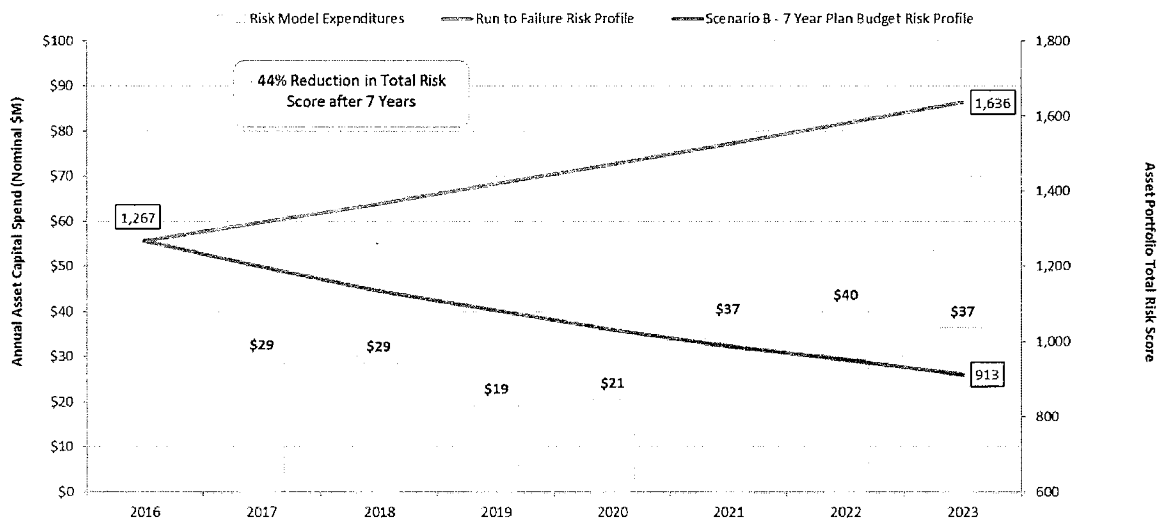

Figure 4-10 Scenario B - LoF >= 4 Capital Expenditures and Risk Reduction for Portfolio of Assets

Figure 4-11 shows the resulting risk rating matrix in 2023 for Scenario B expenditures shown in Figure 4-10 above. The LoF >= 4 expenditures significantly reduce the number of assets in the LoF 4 and LoF 5 regions, but some still remain due to the constraints described earlier in this section. There are no Red Zone assets in the LoF 4 or 5 regions, but there are 20 assets still remaining in the Red Zone due to the LoF 3 region.

2023 ALL Assets Scenario Heat Map

Consequence of Failure		Likelihood of Failure 1	2	3	4	5 (20 Red Zone Assets)
	5	14	2	0	0	0
	4	57	29	20	0	0
	3	228	48	64	0	0
	2	257	99	190	13	64
	1	107	55	102	15	33

Total Asset Records 1,397

Figure 4-11 Scenario B - 2023 LoF >= 4 Scenario Total Portfolio Risk Rating Matrix

4.5.3 Scenario C - LOF 5 Scenario Expenditures and Risk Profile

4.5.3.1 Scenario C - LoF 5 Total Portfolio Risk Reduction

Figure 4-12 below summarizes the total portfolio expenditures and risk reduction for the LoF 5 scenarios. The figure shows that the overall risk reduction of the LoF 5 scenario is 39% with approximately $189 million in expenditures over the seven-year period.

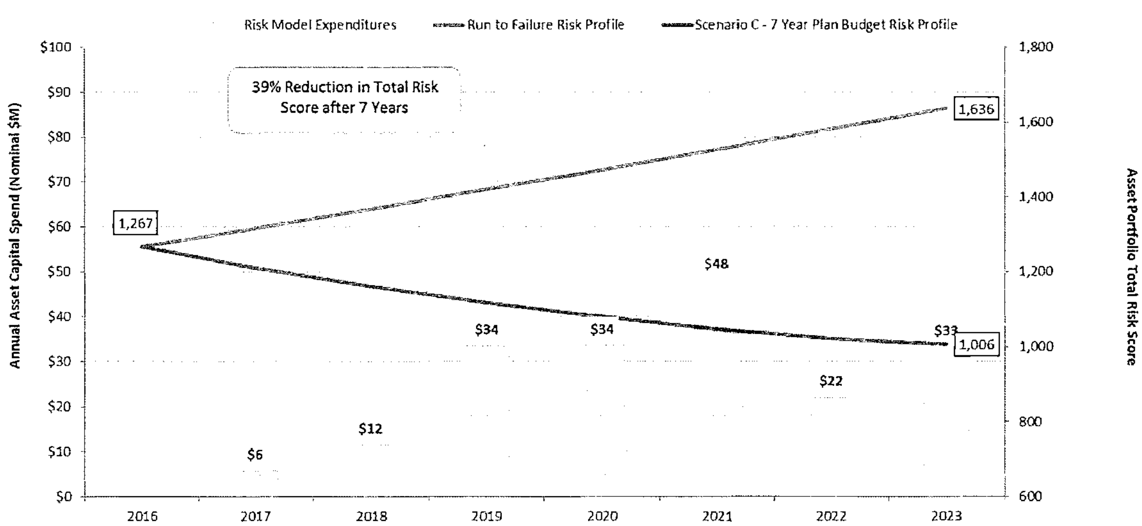

Figure 4-12 Scenario C - LoF 5 Capital Expenditures and Risk Reduction for Portfolio of Assets

Figure 4-13 shows the resulting risk rating matrix in 2023 for the LoF 5 expenditure levels shown in Figure 4-12. The LoF 5 expenditures replace a significant amount of assets in the LoF 5 region by 2023, but some LoF 5 assets remain due to the constraints described earlier in this section.

2023 ALL Assets Scenario Heat Map

Consequence of Failure	Likelihood of Failure 1	2	3	4	5 (54 Red Zone Assets)
5	14	2	0	0	0
4	49	29	20	8	0
3	203	47	64	26	0
2	236	91	190	47	59
1	114	54	102	20	22

Total Asset Records **1,397**

Figure 4-13 Scenario C - 2023 LOF 5 Scenario Total Portfolio Risk Rating Matrix

4.5.4 Budget Expenditures and Risk Summary

Figure 4-14 shows a summary of the three scenarios and corresponding risk results for each scenario at the end of the study period. The red line at the top of the figure shows the Run-to-Failure level of total risk score. The green line shows the risk score that corresponds with the scenario investments. The figure visually shows the expenditures (turquoise bars) that result in the reduced risk score in the green line by the year 2023 (scenario vs. Run-to-Failure). It also illustrates the points of risk reduction achieved per dollar of capital investment. This provides another way to compare the scenarios on spending efficiency, although this is just one of several ways to compare the plans.

The bar chart includes the total seven year spend for each scenario in nominal dollars. The bars correspond to the left side vertical axis. The lines in the figure show asset risk profiles for each of the expenditures and the Run-to-Failure case. The right side vertical axis corresponds to the lines in the figure.

As the figure shows, increasing expenditures beyond the TDSIC plan yields greater risk reduction in the case of Scenario B, but the amount of risk reduction achieved per incremental capital dollar begins to decrease. Additionally, comparison of Scenario A to Scenario C shows that focusing capital expenditures on only LoF 5 assets does not yield more risk reduction than Scenario A. Additionally, the age-based asset replacement scenarios require more capital investment and don't account for various appetites for risk at differing CoF levels, whereas Scenario A does. While the age-based scenarios address assets in the Red Zone, they also include assets with CoF 2 and 1. Therefore, expenditures in the Scenario A - TDSIC 7-Year Plan more prudently address the Red Zone asset region while minimizing necessary capital expenditures.

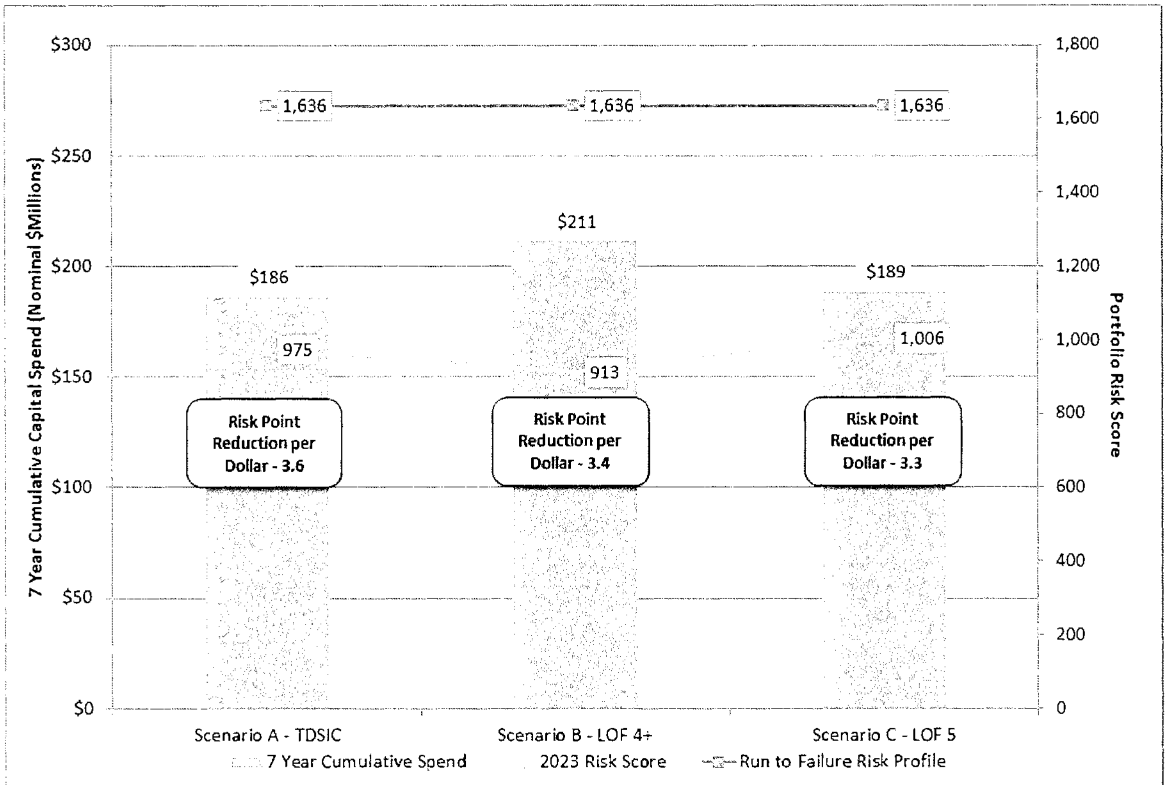

Figure 4-14 Budget Expenditures and Risk Summary