Transmission Cost Estimation Guide

For MTEP24

May 1, 2024

MISO

Purpose Statement

The MISO transmission planning process focuses on making the benefits of an economically efficient electricity market available to customers by identifying transmission projects that provide access to electricity at the lowest total electric system cost. As a part of this process, MISO identifies essential transmission projects that will improve the reliability and efficiency of energy delivery in its region. These projects are included in the annual MISO Transmission Expansion Plan (MTEP) publication, produced as a collaboration between MISO planning staff and stakeholders.

Certain types of projects, as identified in MTEP, require cost estimates to justify the business case for recommendation to MISO's Board of Directors. MISO provides cost estimates for these certain types of projects to evaluate alternatives. MISO's *Transmission Cost Estimation Guide* for MTEP24 describes the approach and cost data that MISO uses in developing its cost estimates. This document's assumptions and cost data are reviewed yearly with stakeholders.

All cost estimate data in this document are in 2024 U.S. dollars. Cost data was escalated from 2023 U.S. dollars to 2024 U.S. dollars at a rate of 5%. All applicable taxes are included within the cost subcategories.

Executive Summary

In MISO's planning process, estimated project costs are necessary to evaluate alternatives and recommend projects. The MISO Transmission Expansion Plan (MTEP) may recommend a project as a Market Efficiency Project (MEP) or in a portfolio of Multi-value Projects (MVP). Eligibility for MEPs and MVPs include a benefit-to-cost ratio requirement — MISO determines the benefits through its planning process, and costs are estimated.

Estimating project costs requires review and coordination throughout the planning process. At the onset of the planning study solicitation, stakeholders submit solution ideas that contain their cost estimate for a potential project. MISO utilizes stakeholders' cost estimate for initial screening of potential projects.

If a potential project passes the initial screening phase, MISO evaluates the costs of a potential project, and provides its planning cost estimate. MISO's planning cost estimates allow all potential projects' costs to be compared to each other using the same cost data and indicative assumptions.

If a potential project continues to show benefits in excess of cost, MISO creates a more refined scoping cost estimate. For projects ineligible for the Competitive Transmission Process (CTP), the local Transmission Owner will provide the cost estimate and will discuss and review the project scope of work with MISO. For eligible CTP projects, MISO will provide the scoping cost estimate. MISO's scoping cost estimate is specific for that individual potential project and MISO may adjust any of its cost estimate assumptions and/or any of its unit costs as necessary for that specific potential project. For any facility upgrades included in the project, MISO will discuss its estimate assumptions with the facility owner.

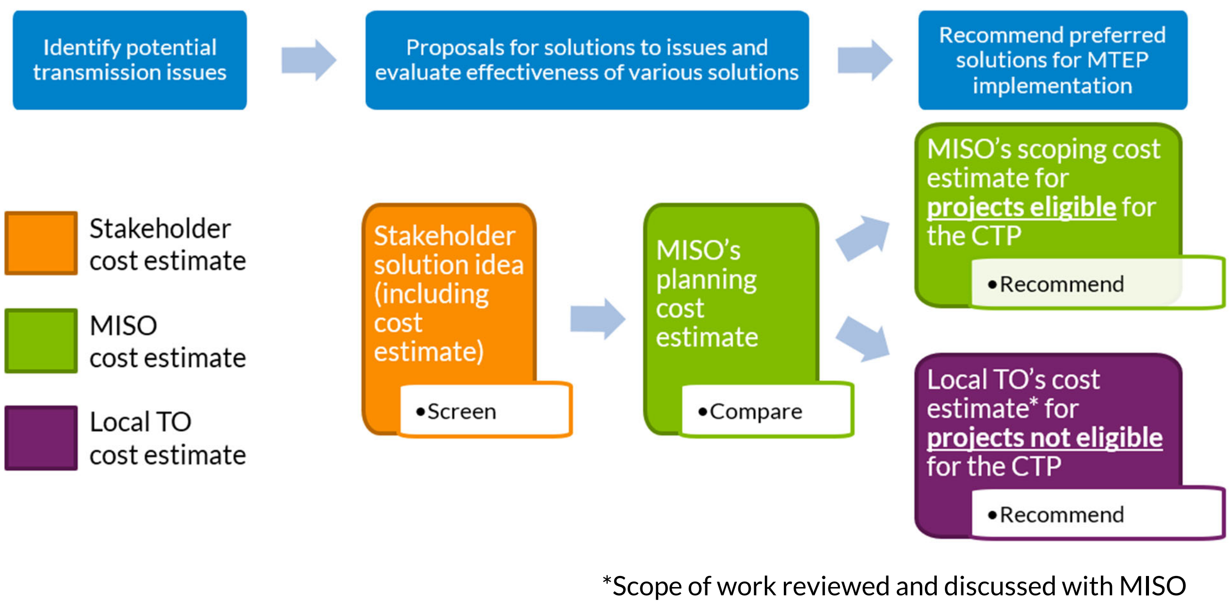


Figure 0-1: Overview of planning process and cost estimate development

Table of Contents

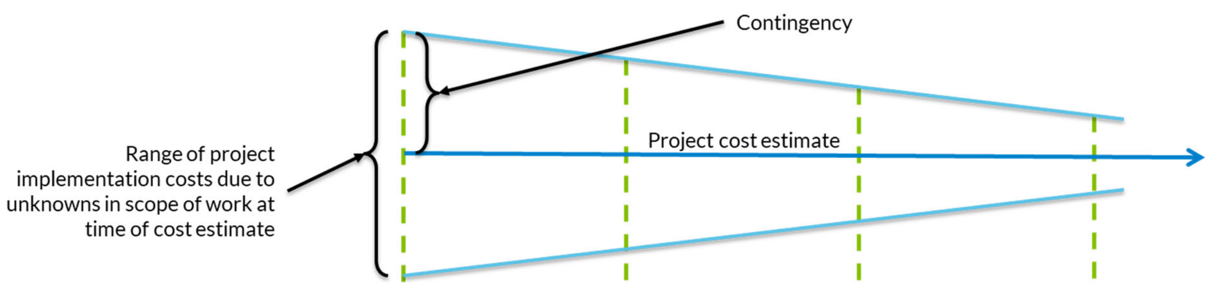
1. Capital Cost

Cost estimates that MISO provides are intended to be inclusive of all costs required to implement the project – the capital cost for a potential project. The capital cost estimate includes the project cost (as further described in this guide), contingency, and Allowance for Funds Used During Construction (AFUDC) (Figure 1-1).

Figure 1-1: Formula for the capital cost estimate

Contingency

Contingency is a cost adder to account for all the uncertainties/unpredictability and level of scope definition at the time of estimation. As more investigation is completed for a cost estimate (and a project), less contingency is carried as a cost in the cost estimate. MISO has three cost estimates types it provides, with different levels of contingency (Figure 1-2).



Cost estimate type	Exploratory cost estimate	Planning cost estimate	Scoping cost estimate	Competitive proposal
Level of design investigation	Generic $/mile per State	Desktop analysis	Desktop analysis and local outreach	Field analysis
Contingency adder (% of project cost)	30%	20%	15%	Observed: ~5%

Figure 1-2: Cost estimate types and related contingency adders

MISO researched industry practices for project cost estimating approaches and has included an instructive reference from the AACE (formerly the Association for the Advancement of Cost Engineering) International©. The cost estimates that MISO provides generally align with the classes in the table below as described:

- Class 5: MISO's exploratory cost estimate

- Class 4: MISO's planning cost estimate
- Class 3: MISO's scoping cost estimate
- Class 2: Not used for MISO cost estimate
- Class 1: Not used for MISO cost estimate

	Primary Characteristic	***Secondary Characteristic***		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Figure 1-3: Cost estimate classes and characteristics

AFUDC

AFUDC is a cost adder to account for the cost of debt and/or the cost of equity required to develop and place the project in service. AFUDC is assumed to be the same value for all the cost estimates MISO provides and is assumed to be 7.5% of the sum of the project cost and contingency.

2. Project Costs

Project costs are the costs to construct and install a project. Project cost estimates are categorized into smaller subcategories of cost that are then estimated for each individual project. Some cost category unit costs are common to all project types, while some are unique to the project type. This section describes the unit costs MISO uses in its cost estimates and in general, align with the cost categories MISO uses in its Request for Proposals in its Competitive Transmission Process and all costs include applicable taxes within their subcategory.

2.1 Common Cost Categories Among All Project Types

Project Management

Project management includes project implementation scheduling, project management activities, and resources for the project. Project management costs are estimated to be 5.5% of the project cost.

Administrative and General Overhead

Administrative and general overhead costs (A&G) are allocated to the project for the period prior to placing the project in service. A&G is estimated to be 1.5% of the project cost.

Engineering, Environmental Studies, and Testing and Commissioning

Engineering (including route and site evaluation), environmental studies, and testing and commissioning for the project comprise a cost category. Engineering, environmental studies, and testing and commissioning costs are estimated to be 3% of the project cost.

Right-of-Way, Land Acquisition, and Regulatory and Permitting

Right-of-way and land acquisition costs cover land easements on yet-to-be-installed projects and are typically charged to FERC plant accounts 350 and 359. MISO assumes that new right-of-way is required for all projects except transmission line rebuild projects. MISO has three categories of land costs: pasture, crop, and urban/suburban. MISO utilizes the annual USDA Land Values summary to estimate the value of pastureland. MISO assumes that cropland is three times more expensive per acre than pastureland and that suburban/urban land is five times more expensive than pastureland. Based on its desktop analysis, MISO will determine the land type encountered for each potential project and estimate accordingly. Regulatory and permitting costs include application to state commission boards for approval for construction including public outreach and open houses.

All land costs are based upon the acreage of land that the new transmission line would traverse or the site of the substation or HVDC converter station would require. The total land affected for a transmission line is the line length multiplied by the right-of-way width of the line. The right-of-way widths that MISO considers are intended to be indicative of right-of-way widths for transmission lines in each voltage class and correlate with the number of structures per mile that MISO assumes. Different project conditions (e.g., more transmission line structures per mile) could result in a wider or narrower right-of-way width than the indicative value MISO assumes.

Finally, certain states have unique circumstances to be accounted for in their cost estimates. Wisconsin projects involving transmission lines with nominal voltage of 345 kV and above have a one-time environmental impact fee in the amount of 5% of the total implementation cost of the transmission line —

MISO will include this additional cost in its cost estimate for projects in Wisconsin. Minnesota has a "buy the farm" statute where additional land may be required to be purchased in addition to the right-of-way required for the transmission line; MISO may consider additional land requirements for projects in Minnesota.

Table 2.1: Land costs

State	Right-of-Way cost per acre			Acquisition cost per acre	Regulatory and permitting cost per acre
	Pasture	Crop	Suburban and Urban		
Arkansas	$3,045	$9,135	$15,225	$14,247	$2,968
Illinois	$4,011	$12,033	$20,055	$14,247	$2,968
Indiana	$2,993	$8,978	$14,963	$14,247	$2,968
Iowa	$3,570	$10,710	$17,850	$14,247	$2,968
Kentucky	$3,570	$10,710	$17,850	$14,247	$2,968
Louisiana	$3,350	$10,049	$16,748	$14,247	$2,968
Michigan	$3,255	$9,765	$16,275	$14,247	$2,968
Minnesota	$2,205	$6,615	$11,025	$14,247	$9,914
Mississippi	$2,909	$8,726	$14,543	$14,247	$2,968
Missouri	$2,625	$7,875	$13,125	$14,247	$2,968
Montana	$840	$2,520	$4,200	$14,247	$2,968
North Dakota	$1,124	$3,371	$5,618	$14,247	$4,957
South Dakota	$1,407	$4,221	$7,035	$14,247	$3,977
Texas	$2,310	$6,930	$11,550	$14,247	$2,968
Wisconsin	$3,308	$9,923	$16,538	$14,247	$9,914

2.2 AC and HVDC Transmission Lines

This Transmission Cost Estimation Guide contains costs both for alternating current (AC) transmission lines and for high voltage direct current (HVDC) transmission lines. Both types of transmission lines rely on some similar project costs (e.g., land costs, conductor costs), and some unique costs dependent on the scope of work (e.g., structure costs).

MISO's AC and HVDC transmission line cost estimates are divided into smaller subcategories as shown below. The smaller subcategories of costs align with MISO's Request for Proposal for Competitive Transmission Projects. This Transmission Cost Estimation Guide includes estimated costs for AC transmission in voltage classes ranging from 69 kV to 765 kV, and HVDC transmission in voltage classes from ±250 kV to ±640 kV.

HVDC transmission has two major components: transmission lines and converter stations. With the advancement of technology, both components of HVDC transmission have many options and can be highly customized depending on the specific situation. For the purposes of creating a cost estimate, MISO assumes a bipole HVDC transmission system with a ground electrode return at each converter station. MISO makes an exception for the 765 kV interchangeable line described below, in which the metallic return provides a return path. Ground electrodes are assumed to be located at each end of the transmission line and connected by a ground electrode line.

Structures

Structure costs estimate the procurement and installation of structures (inclusive of its required foundation) for new, potential transmission line projects. Costs shown in tables 2.2-1 to 2.2-8 encompass cost subcategories of material, foundations, hardware, and installation typically charged to FERC plant accounts 354 and 355. All structures are designed for the highest applicable National Electric Safety Code (NESC) loading criteria in the MISO region.

MISO's transmission line cost estimates are comprised of four different structure types:

- Tangent structures are the most commonly used structures where the transmission line alignment is relatively straight and the line angle is between 0° and 2°. Tangent structures support the conductor using a suspension insulator assembly. The suspension insulator assembly consists of insulator and hardware to provide necessary electrical insulation and strength for load transfer. The optical groundwire (OPGW) shieldwire attaches to the shieldwire suspension assembly near the top of the structure.
- Running angle structures are used where the line alignment changes direction and the line angle is between 2° and 45°. Running angle structures support the conductor with a suspension insulator assembly similar to tangent structures. The OPGW shieldwire attaches to a shieldwire suspension assembly near top of structure.
- Non-angled deadend structures are partial deadend structures and not designed for full terminal loads. The line angle is between 5° to 45°. They are designed to withstand some unbalanced wire tensions in one direction of one or all wires on one face of the structure.
- Angled deadend structures are designed for full terminal loads for all wires and the line angle is between 0° and 90°

The steel weights and foundation sizes MISO considers for its steel pole and steel tower structure unit costs are intended as indicative for structures at different voltage classes and are not tied directly to any one structure design for that structure type.

The single- and double-circuit wood pole structures are included in this guide to address some of the project-specific needs involving wood pole construction. The wood pole structure costs that MISO considers for its unit costs are intended as an indicative value for the structures at different voltage classes and are not tied directly to any one structure design for that structure type.

All structure costs are comprised of the following unit costs (Tables 2.2-1 to 2.2-8):

- Material cost includes the cost of design, manufacture (material, labor, equipment) and delivery of the structure to the site (laydown yard) and is based on the estimated steel weight
- Installation costs are the costs to haul, assemble, and install the structure, insulators, and grounding assemblies. This cost includes access to the structure location, and restoration.
- Hardware cost includes material cost for insulator, line hardware and grounding assemblies

- Foundation cost includes material and installation of the foundations including the cost to procure and install anchor bolts and is based on the estimated foundation size

Steel structures are assumed to be supported on a concrete drilled pier foundation. Wood pole structures are assumed to be embedded directly in the ground and embedment cost is included in the installation cost. Drilled pier foundation size for a structure is indicated as concrete volume required per structure in cubic yards.

Interchangeable Transmission Lines (765 kV AC and ±640 kV HVDC)

Acquisition of new rights-of-way (ROW) for transmission lines has many regulatory, economic and environmental constraints. These constraints could create uncertainty in terms of time and cost for some projects, especially for extra high voltage lines with wider rights-of-ways. MISO acknowledges these constraints and therefore developed an interchangeable HVAC/HVDC transmission design for the purposes of creating a cost estimate in which transmission lines can be operated at 765 kV AC initially, and then if conversion to 640 kV DC is pursued later, the transmission line design would work with few modifications at ± 640 kV DC also. The outside phases act as direct current poles and center phase provides return path for the DC transmission, which would eliminate need for separate return path. In tables 2.2-7 and 2.2-8, the costs of interchangeable structure costs are provided under ±640 kV HVDC transmission line. The costs for interchangeable structures are higher than regular 765 kV transmission structures due to increased insulation and taller structures to achieve HVDC clearance requirements.

Table 2.2-1: AC transmission – steel pole – single circuit								
Tangent structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	7,000	7,900	8,400	9,300	11,100	22,300	35,100	52,800
Foundation size (Cu. Yd)	5.5	6.0	8.0	9.0	13.0	21.0	41.0	60.0
Material	$18,162	$20,498	$21,795	$24,130	$28,800	$57,860	$91,071	$136,997
Installation	$27,244	$30,746	$32,692	$36,195	$43,200	$86,790	$136,259	$205,493
Hardware	$4,783	$5,580	$5,979	$6,776	$7,970	$10,665	$11,676	$23,428
Foundation	$8,556	$9,334	$12,445	$14,001	$20,223	$32,668	$63,780	$93,336
Running angle structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	11,600	13,000	13,900	15,300	18,300	37,900	59,700	$149,000
Foundation size (Cu. Yd)	9.0	10.5	13.0	14.0	19.5	30.0	54.5	85.0
Material	$30,098	$33,730	$36,065	$39,698	$47,482	$98,336	$154,899	$386,602
Installation	$45,146	$50,595	$54,098	$59,547	$71,222	$147,504	$232,349	$579,895
Hardware	$4,783	$5,580	$5,979	$6,776	$7,970	$10,665	$11,676	$23,428
Foundation	$14,001	$16,335	$20,223	$21,779	$30,335	$46,668	$84,782	$132,225

Non-angled deadend structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	14,000	15,800	16,800	18,600	22,200	42,400	66,700	154,675
Foundation size (Cu. Yd)	11.0	12.0	15.0	16.5	22.5	33.5	60.0	160.0
Material	$36,325	$40,995	$43,590	$48,260	$57,601	$110,012	$173,061	$401,327
Installation	$54,487	$61,493	$65,385	$72,390	$86,401	$165,018	$259,592	$601,982
Hardware	$9,430	$11,002	$11,788	$13,359	$15,717	$38,332	$60,298	$93,712
Foundation	$17,112	$18,667	$23,334	$25,668	$35,002	$52,114	$93,337	$248,895
Angled deadend structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	20,400	23,000	24,500	27,100	32,400	48,100	80,700	154,675
Foundation size (Cu. Yd)	15.0	16.5	20.0	21.5	29.0	41.5	72.0	160.0
Material	$52,930	$59,676	$63,568	$70,314	$84,066	$124,801	$209,386	$401,327
Installation	$79,395	$89,515	$95,352	$105,471	$126,099	$187,202	$314,079	$601,982
Hardware	$9,430	$11,002	$11,788	$13,359	$15,717	$38,332	$60,298	$93,712
Foundation	$23,334	$25,668	$31,112	$33,446	$45,113	$64,559	$112,004	$248,895

Table 2.2-2: AC Transmission – steel tower – single circuit								
Tangent structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	6,100	6,900	7,300	8,100	10,100	20,300	27,000	34,320
Foundation size (Cu. Yd)	8.5	11.5	13.5	14.5	15.5	19.5	33.5	39.0
Material	$13,213	$14,946	$15,812	$17,545	$21,877	$43,971	$58,483	$89,049
Installation	$19,820	$22,419	$23,719	$26,318	$32,816	$65,957	$87,725	$133,570
Hardware	$4,783	$5,580	$5,979	$6,776	$7,970	$10,665	$11,676	$23,428
Foundation	$13,223	$17,890	$21,001	$22,557	$24,113	$30,335	$52,114	$60,668
Running angle structures								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	9,200	10,400	11,000	12,200	15,200	30,500	39,800	89,400
Foundation size (Cu. Yd)	16.0	19.0	19.5	22.0	24.5	39.0	72.5	81.0
Material	$19,928	$22,527	$23,827	$26,426	$32,924	$66,064	$86,209	$231,962
Installation	$29,891	$33,790	$35,740	$39,639	$49,386	$99,097	$129,313	$347,937
Hardware	$4,783	$5,580	$5,979	$6,776	$7,970	$10,665	$11,676	$23,428
Foundation	$24,890	$29,557	$30,335	$34,224	$38,113	$60,669	$112,783	$126,003
Non-angled deadend structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	10,400	11,700	12,400	13,800	17,200	34,500	45,900	108,273
Foundation size (Cu. Yd)	21.5	25.0	25.5	28.5	34.0	48.5	96.0	180.0
Material	$22,527	$25,343	$26,859	$29,891	$37,256	$74,729	$99,422	$280,929
Installation	$33,790	$38,015	$40,288	$44,837	$55,884	$112,094	$149,133	$421,387
Hardware	$9,430	$11,002	$11,788	$13,359	$15,717	$38,332	$60,298	$23,428
Foundation	$33,446	$38,890	$39,669	$44,336	$52,891	$75,448	$149,339	$248,895
Angled deadend structure								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Steel weight (lbs.)	13,400	15,200	16,100	17,800	22,200	44,700	59,400	108,273
Foundation size (Cu. Yd)	33.5	38.0	39.0	43.0	52.0	90.0	176.0	180.0

Material	$29,025	$32,924	$34,873	$38,556	$48,086	$96,822	$128,663	$280,929
Installation	$43,538	$49,386	$52,311	$57,833	$72,129	$145,234	$192,995	$421,387
Hardware	$9,430	$11,002	$11,788	$13,359	$15,717	$38,332	$60,298	$23,428
Foundation	$52,114	$59,113	$60,669	$66,891	$80,892	$140,005	$273,788	$248,895

Table 2.2-3: AC transmission – steel pole – double circuit						
Tangent structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	11,300	12,700	13,500	14,900	18,600	36,000
Foundation size (Cu. Yd)	8.0	10.0	14.5	17.5	23.0	46.5
Material	$29,319	$32,952	$35,027	$38,660	$48,260	$93,406
Installation	$43,979	$49,428	$52,541	$57,990	$72,390	$140,110
Hardware	$9,311	$10,863	$11,638	$13,190	$15,518	$20,881
Foundation	$12,445	$15,556	$22,557	$27,224	$35,779	$72,337
Running angle structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	15,000	16,800	17,900	19,700	24,600	47,700
Foundation size (Cu. Yd)	13.0	15.5	21.5	25.5	32.5	61.0
Material	$38,919	$43,590	$46,444	$51,114	$63,828	$123,764
Installation	$58,379	$65,385	$69,666	$76,671	$95,742	$185,645
Hardware	$9,311	$10,863	$11,638	$13,190	$15,518	$20,881
Foundation	$20,223	$24,113	$33,446	$39,669	$50,558	$94,893
Non-angled deadend structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	16,700	18,700	19,900	22,000	27,400	54,000
Foundation size (Cu. Yd)	15.5	18.5	25.0	29.5	37.0	68.5
Material	$43,330	$48,519	$51,633	$57,082	$71,093	$140,110
Installation	$64,995	$72,779	$77,450	$85,623	$106,639	$210,165
Hardware	$18,598	$21,699	$23,249	$26,348	$30,998	$76,240
Foundation	$24,113	$28,779	$38,890	$45,891	$57,558	$106,560
Angled deadend structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	26,000	29,200	31,100	34,300	42,800	84,600
Foundation size (Cu. Yd)	20.0	24.0	32.0	37.0	46.0	81.5
Material	$67,460	$75,763	$80,693	$88,996	$111,050	$219,505
Installation	$101,190	$113,645	$121,039	$133,493	$166,575	$329,258
Hardware	$18,598	$21,699	$23,249	$26,348	$30,998	$76,240
Foundation	$31,112	$37,335	$49,780	$57,558	$71,558	$126,783

Table 2.2-4: AC transmission – steel tower – double circuit						
Tangent structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	9,200	10,400	11,000	12,200	15,200	36,000
Foundation size (Cu. Yd)	13.0	17.0	19.5	21.0	22.0	31.5
Material	$19,928	$22,527	$23,827	$26,426	$32,924	$77,978
Installation	$29,891	$33,790	$35,740	$39,639	$49,386	$116,967
Hardware	$9,311	$10,863	$11,638	$13,190	$15,518	$20,881
Foundation	$20,223	$26,445	$30,335	$32,668	$34,224	$49,002
Running angle structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	13,800	15,600	16,500	18,300	22,800	53,100
Foundation size (Cu. Yd)	22.5	28.0	34.5	37.5	46.5	59.0
Material	$29,776	$33,790	$35,740	$39,639	$49,386	$115,017
Installation	$44,837	$50,686	$53,610	$59,459	$74,079	$172,526
Hardware	$9,311	$10,863	$11,638	$13,190	$15,518	$20,881
Foundation	$35,002	$43,557	$53,669	$58,336	$72,337	$91,781
Non-angled deadend structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	16,100	18,200	19,300	21,400	26,600	61,200
Foundation size (Cu. Yd)	28.5	34.5	43.0	48.5	70.5	86.5
Material	$34,873	$39,422	$41,805	$46,353	$57,617	$132,562
Installation	$52,311	$59,133	$62,708	$69,530	$86,425	$198,843
Hardware	$18,598	$21,699	$23,249	$26,348	$30,998	$76,240
Foundation	$44,336	$53,669	$66,891	$75,448	$109,671	$134,561
Angled deadend structure						
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Steel weight (lbs.)	21,200	23,900	25,300	28,100	35,000	79,200
Foundation size (Cu. Yd)	43.0	50.5	61.5	68.5	99.0	125.0
Material	$45,920	$51,769	$54,801	$60,866	$75,812	$171,551
Installation	$68,880	$77,653	$82,202	$91,299	$113,717	$257,326
Hardware	$18,598	$21,699	$23,249	$26,348	$30,998	$76,240
Foundation	$66,891	$78,559	$95,671	$106,526	$154,006	$194,452

Table 2.2-5: AC transmission – wood pole – single circuit							
Tangent structure							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Material	$5,106	$9,557	$9,677	$12,882	$13,951	N/A	N/A
Installation	$14,247	$14,841	$16,622	$23,745	$35,618	N/A	N/A
Hardware	$4,987	$5,640	$6,174	$6,827	$8,905	N/A	N/A
Running angle structure							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Material	$8,964	$16,741	$16,918	$22,558	$24,399	N/A	N/A
Installation	$24,933	$26,002	$29,089	$41,555	$62,332	N/A	N/A
Hardware	$8,727	$9,855	$10,805	$11,932	$15,613	N/A	N/A
Angled deadend structure							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Material	$10,211	$19,175	$19,353	$25,764	$27,901	N/A	N/A
Installation	$28,495	$29,682	$33,244	$47,491	$71,236	N/A	N/A
Hardware	$9,973	$11,280	$12,348	$13,654	$17,809	N/A	N/A

Table 2.2-6: AC transmission – wood pole – double circuit							
Tangent structure							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Material	$8,430	$15,791	N/A	N/A	N/A	N/A	N/A
Installation	$23,508	$24,517	N/A	N/A	N/A	N/A	N/A
Hardware	$8,252	$9,320	N/A	N/A	N/A	N/A	N/A
Running angle structure							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Material	$14,781	$27,604	N/A	N/A	N/A	N/A	N/A
Installation	$41,139	$42,920	N/A	N/A	N/A	N/A	N/A
Hardware	$14,426	$16,266	N/A	N/A	N/A	N/A	N/A
Angled deadend structure							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Material	$16,859	$31,641	N/A	N/A	N/A	N/A	N/A
Installation	$47,016	$48,975	N/A	N/A	N/A	N/A	N/A
Hardware	$16,791	$18,641	N/A	N/A	N/A	N/A	N/A

Table 2.2-7: HVDC transmission – steel pole – single circuit					
Tangent structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	14,773	19,943	21,938	26,325	54,550
Foundation size (Cu. Yd)	17.0	23.0	26.0	31.0	63.0
Material	$38,411	$51,854	$57,040	$68,448	$141,537
Installation	$57,617	$77,782	$85,560	$102,673	$212,305
Hardware	$5,183	$6,602	$7,182	$7,529	$29,286
Foundation	$26,498	$35,772	$39,855	$47,827	$98,003
Running angle structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	25,126	33,920	37,313	44,775	156,450
Foundation size (Cu. Yd)	23.0	31.0	34.0	41.0	90.0
Material	$65,331	$88,198	$97,017	$116,421	$405,929
Installation	$97,997	$132,296	$145,526	$174,631	$608,893
Hardware	$6,480	$8,253	$8,977	$9,411	$29,286
Foundation	$35,676	$48,162	$52,978	$63,574	$140,027
Non-angled deadend structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	28,072	37,898	41,688	50,025	162,409
Foundation size (Cu. Yd)	25.0	34.0	38.0	45.0	168.0
Material	$72,991	$98,539	$108,393	$130,072	$421,390
Installation	$109,487	$147,808	$162,589	$195,106	$632,084
Hardware	$10,222	$24,759	$26,931	$28,234	$117,140
Foundation	$39,276	$53,023	$58,325	$69,990	$261,341
Angled deadend structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	33,965	45,852	50,438	60,525	162,409
Foundation size (Cu. Yd)	30.0	41.0	45.0	54.0	168.0
Material	$88,312	$119,222	$131,144	$157,372	$421,390
Installation	$132,468	$178,832	$196,715	$236,059	$632,084
Hardware	$10,222	$24,759	$26,931	$28,234	$117,140
Foundation	$47,131	$63,627	$69,990	$83,988	$261,341

Table 2.2-8: HVDC transmission – steel tower – single circuit					
Tangent structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	10,227	15,341	16,875	20,250	36,036
Foundation size (Cu. Yd)	13.0	19.0	21.0	25.0	43.0
Material	$22,099	$33,149	$36,464	$43,756	$133,654
Installation	$33,149	$49,724	$54,696	$65,636	$200,482
Hardware	$5,183	$6,602	$7,182	$7,529	$19,211
Foundation	$19,737	$29,604	$32,565	$39,078	$79,400
Running angle structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	16,751	22,614	24,875	29,850	93,870
Foundation size (Cu. Yd)	31.0	41.0	45.0	54.0	90.0
Material	$36,196	$48,865	$53,750	$64,501	$237,622
Installation	$54,294	$73,297	$80,626	$96,752	$356,427
Hardware	$6,480	$8,253	$8,977	$9,411	$20,341
Foundation	$47,458	$64,069	$70,475	$84,571	$167,910
Non-angled deadend structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	19,318	26,080	28,688	34,425	113,687
Foundation size (Cu. Yd)	40.0	55.0	60.0	72.0	176.0
Material	$41,743	$56,353	$61,989	$74,387	$287,780
Installation	$62,615	$84,530	$92,984	$111,580	$431,669
Hardware	$10,222	$24,759	$26,931	$28,234	$99,898
Foundation	$62,842	$84,836	$93,320	$111,983	$325,745
Angled deadend structure					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Steel weight (lbs.)	25,000	33,750	37,125	44,550	113,687
Foundation size (Cu. Yd)	74.0	100.0	110.0	132.0	176.0
Material	$54,021	$72,929	$80,221	$96,265	$287,780
Installation	$81,031	$109,392	$120,331	$144,398	$431,669
Hardware	$10,222	$24,759	$26,931	$28,234	$99,898
Foundation	$115,209	$155,533	$171,086	$205,303	$325,745

Project-specific environmental circumstances of an individual project may lead to additional installation costs. MISO considers these additional costs for a new transmission line that traverses a forested area, wetland area, or mountainous terrain (Table 2.2-9).

Table 2.2-9: Additional structure installation costs	
Voltage class	69 kV – 765 kV
Forested clearing cost (per acre)	$5,995
Wetland (per acre)	Matting and construction difficulties: $69,975
	Wetland mitigation credits: $56,132
Mountainous terrain (per acre)	$7,794

Removal cost of existing transmission line and/or substation involves complete removal or retirement of existing transmission line or substation equipment. The removal costs include all plant, tools, equipment, machinery, skill, supervision and labor (Table 2.2-10).

Table 2.2-10: Transmission line removal/retirement							
$/mile							
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV
Wood pole – single circuit	$219,645	$255,611	$267,136	$281,978	$314,627	N/A	N/A
Wood pole – double circuit	$356,182	$409,609	N/A	N/A	N/A	N/A	N/A

Conductor

Costs estimated to procure and install conductor required for transmission line projects are typically charged to FERC plant account 356. Conductor costs are based upon the conductor selected and the length of the transmission line. MISO assumes conductor length adder of 4% for sag and wastage per conductor. Conductor type and size are based on economic planning model considerations for the required ampacity and based on MISO Business Practice Manual 029 to assign appropriate conductor type. See Section 3: Initial Assumptions for MISO's indicative conductor selection and ratings for different voltage classes.

Potential projects may involve reconductoring or upgrading the existing conductor size to allow more power transfer by increasing the ampacity of the existing circuit. In providing cost estimates for reconductoring project scope, MISO assumes that the existing structures — including foundations, insulators and hardware — are adequate to support the new conductor size and configuration. MISO will discuss these assumptions with the Transmission Owner. The costs of new conductor and installation are considered for the estimate of the retrofit projects.

MISO primarily considers Aluminum Conductor Steel Reinforce (ACSR) and Aluminum Conductor Steel Supported (ACSS) conductor types in its cost estimates (Tables 2.2-11 and 2.2-12). MISO also includes costs for representative High-Temperature Low Sag conductor sizes (e.g. Aluminum Conductor Composite Core (ACCC)) for any project with specific needs (Table 2.2-13). Where required, MISO will consider the cost for T2 as equivalent to two conductors of that size to the same cost when creating its cost estimate.

The formula for conductor costs includes the following unit costs:

- Material cost: the cost of manufacturing and deliver conductor to the site (laydown yard)
- Installation cost: the cost to haul conductor reels, install, and sag and clip conductor on transmission structures
- Accessories: the sleeves, spacers, and dampers material and installation cost required for a transmission line

Table 2.2-11: Conductor costs (<1,000 kcmil)

Conductor	Material cost per 1000 feet		Installation cost per 1,000 feet	Accessories cost per 1,000 feet
	ACSR	ACSS		
266.8 kcmil "Waxwing"	$640	$623	$870	$277
266.8 kcmil "Partridge"	$772	$798	$1,079	$277
336.4 kcmil "Merlin"	$683	$761	$989	$277
336.4 kcmil "Linnet"	$786	$911	$1,162	$277
336.4 kcmil "Oriole"	$981	$1,010	$1,367	$277
397.5 kcmil "Chickadee"	$842	$886	$1,186	$277
397.5 kcmil "Ibis"	$1,012	$1,079	$1,434	$277
397.5 kcmil "Lark"	$998	$1,198	$1,502	$277
477 kcmil "Pelican"	$987	$1,085	$1,421	$277
477 kcmil "Flicker"	$947	$1,135	$1,425	$277
477 kcmil "Hawk"	$1,179	$1,260	$1,673	$277
477 kcmil "Hen"	$1,313	$1,348	$1,828	$277
556.5 kcmil "Osprey"	$1,185	$1,198	$1,637	$277
556.5 kcmil "Parakeet"	$1,390	$1,384	$1,909	$277
556.5 kcmil "Dove"	$1,314	$1,447	$1,894	$277
636 kcmil "Kingbird"	$1,145	$1,348	$1,706	$277
636 kcmil "Rook"	$1,298	$1,559	$1,954	$277
636 kcmil "Grosbeak"	$1,486	$1,622	$2,132	$277
666.6 kcmil "Flamingo"	$1,533	$1,796	$2,253	$277
795 kcmil "Coot"	$1,517	$1,684	$2,194	$277
795 kcmil "Tern"	$1,434	$1,708	$2,151	$277
795 kcmil "Cuckoo"	$1,597	$1,921	$2,406	$277
795 kcmil "Condor"	$1,659	$1,921	$2,451	$277
795 kcmil "Drake"	$1,796	$1,807	$2,477	$277
900 kcmil "Canary"	$2,034	$1,983	$2,763	$277
954 kcmil "Rail"	$1,895	$1,928	$2,627	$277
954 kcmil "Cardinal"	$2,075	$2,138	$2,895	$277

2.2-12: Conductor costs (>1,000 kcmil)				
Conductor	Material cost per 1000 feet		Installation cost per 1,000 feet	Accessories cost per 1,000 feet
	ACSR	ACSS		
1,033.5 kcmil "Ortolan"	$2,078	$2,569	$3,177	$277
1,033.5 kcmil "Curlew"	$2,291	$2,170	$3,072	$277
1,113 kcmil "Bluejay"	$2,208	$2,757	$3,392	$277
1,192.5 kcmil "Bunting"	$2,059	$2,308	$2,993	$277
1,272 kcmil "Bittern"	$2,385	$2,470	$3,334	$277
1,272 kcmil "Pheasant"	$2,607	$2,855	$3,746	$277
1,351.5 kcmil "Dipper"	$2,580	$3,131	$3,905	$277
1,351.5 kcmil "Martin"	$3,197	$2,782	$4,126	$277
1,431 kcmil "Bobolink"	$2,924	$3,255	$4,236	$277
1,590 kcmil "Lapwing"	$3,016	$3,194	$4,262	$277
1,590 kcmil "Falcon"	$3,559	$3,563	$4,897	$277
1,780 kcmil "Chukar"	$3,879	$4,154	$5,513	$277
2,156 kcmil "Bluebird"	$4,569	$5,077	$6,613	$277
2,167 kcmil "Kiwi"	$4,138	$6,050	$6,932	$277
2,312 kcmil "Thrasher"	$4,740	$5,426	$6,963	$277
2,515 kcmil "Joree"	$5,038	$5,688	$7,350	$277

High-Temperature Low Sag Conductors (e.g. Aluminum Conductor Composite Core)

Alternatives to conventional ACSS and ACSR conductors include High- Temperature Low Sag (HTLS) conductors, an example of which being Aluminum Conductor Composite Core (ACCC) which is similar in construction to ACSS and ACSR conductor, except the ACCC uses a composite core of hybrid carbon and glass fibers rather than a steel core. The ACCC conductor is only available in a trapezoidal stranding configuration. This trapezoidal stranding configuration provides about one third more aluminum for a given diameter/size versus round wire conductor, and enables up to two times the power flow versus the comparably-sized round wire ACSR and ACSS conductors. The carbon composite core has a lower thermal expansion than the steel cores of other conductors, allowing higher temperature operation.

This ACCC conductor information provided (Tables 2.2-13) is intended for retrofitting/reconductoring projects, but ACCC conductors could be considered for new transmission line construction as well. ACCC conductors can be evaluated for ACSR conductor replacement as a same-size conductor or same-ampacity conductor replacement. However, conductor type and configuration should be analyzed and selected on a case-by-case basis. The structure and foundation data provided in previous tables are based on conventional ACSR and ACSS conductors. The ACCC conductors used in new projects have potential for fewer structures and foundations compared to conventional conductors, but such optimization is out of scope for this cost guide. Costs for representative ACCC conductor sizes commonly used in projects are based on discussions with ACCC stranders/suppliers. Other High-Temperature, Low Sag conductor options are available.

Table 2.2-13: ACCC conductor costs and round wire comparisons					
ACCC conductor size	Comparable ACSR/ACSS round wire conductor	Maximum amperage	Material cost per 1,000 feet	Installation cost per 1,000 feet	Accessories cost per 1,000 feet
821 kcmil	795 kcmil "Drake"	1,468	$3,800	$2,365	$277
1,026 kcmil		1,708	$5,090	$2,365	$277
1,011 kcmil	954 kcmil "Cardinal"	1,681	$4,680	$3,045	$277
1,222 kcmil		1,902	$5,190	$3,045	$277
1,300 kcmil	1,272 kcmil "Bittern"	1,975	$5,030	$3,145	$277
1,582 kcmil		2,228	$6,190	$3,145	$277
2,242 kcmil	2,156 kcmil "Bluebird"	2,785	$8,405	$7,215	$277
2,741 kcmil		3,130	$9,880	$7,215	$277

OPGW and Shieldwire

The costs estimated to procure and install OPGW and/or shieldwire required for transmission line projects (Table 2.2-14) are typically charged to FERC plant account 356. Unless otherwise specified by the solution idea, MISO assumes one OPGW and one steel shieldwire per transmission circuit. MISO assumes a conductor and shieldwire length adder of 4% for sag and wastage per conductor, OPGW, and shieldwire. OPGW and shieldwire are installed at the top of structures to protect the conductors below from direct lightning strikes and includes fiber optic cable.

The unit costs for the OPGW and shield wires include:

- Material cost: the cost of manufacturing and delivery of the OPGW or shieldwire to the site (laydown yard)
- Installation cost: the cost to haul the OPGW and shieldwire reels, install, and sag and clip conductor on transmission structures

Table 2.2-14: OPGW and shieldwire costs		
Wire type	Material cost per 1,000 feet	Installation cost per 1,000 feet
Shieldwire	$623	$936
OPGW	$2,819	$4,229

2.3 AC Substations

Substation cost estimates are sub-divided into cost categories. MISO provides cost estimates for both substation upgrades and for new substation sites. For planning cost estimates, MISO assumes size (acreage) requirements and equipment quantities based on general assumptions for the project area – see section 3 for initial assumptions. Both the size of the substation facilities and the equipment quantities are dependent upon the voltage class of the facility and the number of new line/transformer positions being considered. For scoping cost estimates that are upgrades of existing substations, MISO discusses its scope of work assumptions with the existing substation owner. If the substation is a new facility, MISO follows requirements in its Business Practice Manual 029 (BPM-029).

Site Work

Site work unit costs estimate the price to prepare the land for a substation including clearing, grading, grounding and physical security (Table 2.3-1). Additional costs may occur, depending on the terrain encountered for a specific substation site (e.g., forested area, or wetlands). MISO will add specialized site components costs (e.g. specialized gates, access protection, import/export of soil), if required, to its cost estimate and will call them out separately.

Table 2.3-1: Site work unit costs

Voltage class	69 kV – 765 kV
Level ground with light vegetation (per acre)	$403,539
Forested land (per acre)	+$5,995
Wetland (per acre)	+$69,975 for matting and construction difficulties
	+$56,132 for wetland mitigation credits

Access Road

Access road costs are estimated based on the length of the road. Access roads allow entry to the substation site from the nearest drivable public road. For the access road into a substation, MISO uses Google Earth to estimate the length of the access road required. Access road costs are estimated to be $593,636 per mile.

Electrical Equipment Material, Electrical Equipment Installation, Steel Structure Material, Steel Structure Installation, and Substation Foundation

Costs estimated to procure and install material and steel structures (Tables 2.3-2 to 2.3-6) are divided into the following subcategories:

- Material: the cost to procure and deliver electrical equipment materials to the site (laydown yard).
- Installation: the cost to assemble and place on foundation or steel structure.
- As applicable: the cost of jumpers, conduit, wiring, and grounding cost includes material and installation of the electrical jumpers and fittings to connect to adjacent electrical equipment, above grade conduit, landing control cables on terminal block in equipment, and the above grade ground grid connection
- Steel structure material: includes the cost of design, manufacture (material, labor, equipment) and delivery of the structure to the site (laydown yard) and is based on the estimated steel weight
- Steel structure installation: the cost to place the steel stand on the foundation
- Foundation: the cost includes material and installation for the foundations including the cost to procure and install anchor bolts and is based on the estimated foundation size

Table 2.3-2: Circuit breaker unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Foundation size (Cu. Yd)	3.6	4.5	5.3	6.7	8.0	8.8	19.8	39.6
Material cost	$47,491	$59,364	$62,332	$65,300	$112,791	$373,398	$491,531	$1,433,250
Installation cost	$8,905	$9,498	$10,092	$10,685	$11,873	$17,809	$23,745	$71,663
Jumpers, conduit, wiring, grounding	$9,498	$10,685	$11,873	$14,247	$17,809	$23,745	$29,682	$85,996
Foundation cost	$5,600	$7,001	$8,245	$10,423	$12,445	$13,689	$30,801	$61,601

Table 2.3-3: Disconnect switch (3-phase) unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Foundation size (Cu. Yd)	3.4	4.2	5.2	6.5	7.8	8.0	18.0	27.0
Steel stand weight (pounds)	1,500	1,750	2,000	2,500	3,500	4,000	5,000	7,500
Material cost	$11,873	$14,841	$17,809	$20,778	$23,745	$41,555	$59,364	$178,091
Installation cost	$7,124	$8,311	$9,498	$10,685	$11,873	$17,809	$23,745	$71,663
Jumpers, and grounding	$4,749	$5,343	$5,936	$7,124	$8,905	$11,873	$14,841	$42,998
Steel stand material cost	$3,892	$4,541	$5,189	$6,487	$9,081	$10,378	$12,973	$19,460
Steel stand installation cost	$4,476	$5,222	$5,968	$7,460	$10,443	$11,977	$14,919	$22,379
Foundation cost	$5,289	$6,534	$8,090	$10,112	$12,133	$12,445	$28,001	$42,002

Table 2.3-4: Bus support, bus, and fittings (3-phase) unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Foundation size (Cu. Yd)	3.1	3.9	4.8	6.0	7.2	9.6	14.4	21.6
Steel stand weight (pounds)	1,000	1,250	1,500	1,750	2,000	3,000	4,500	6,750
Material cost	$6,827	$8,548	$9,855	$10,359	$10,864	$12,853	$14,811	$22,218
Installation cost	$8,193	$10,258	$11,825	$12,431	$13,037	$15,423	$17,773	$26,660
Steel stand material cost	$2,595	$3,243	$3,892	$4,541	$5,189	$7,784	$11,676	$17,514
Steel stand installation cost	$2,984	$3,730	$4,476	$5,222	$5,968	$8,951	$13,427	$20,141
Foundation cost	$4,822	$6,067	$7,466	$9,334	$11,201	$14,934	$22,401	$33,602

Table 2.3-5: Voltage transformer (set of 3) unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Foundation size (Cu. Yd)	1.8	2.3	2.7	3.4	4.0	8.0	12.1	18.2
Steel stand weight (pounds)	1,250	1,350	1,425	1,500	1,750	2,000	2,500	3,750
Material cost	$23,745	$26,714	$29,682	$32,651	$41,555	$49,865	$94,982	$142,473
Installation cost	$2,375	$2,671	$2,969	$3,265	$3,562	$4,749	$5,936	$8,905
Jumpers, conduit, wiring, grounding	$7,124	$8,014	$8,905	$10,685	$13,357	$17,809	$22,258	$33,387
Steel stand material cost	$3,243	$3,503	$3,697	$3,892	$4,541	$5,189	$6,487	$9,730
Steel stand installation cost	$3,730	$4,029	$4,252	$4,476	$5,222	$5,968	$7,460	$11,189
Foundation cost	$2,800	$3,578	$4,200	$5,289	$6,222	$12,445	$18,823	$28,234

Table 2.3-6: Current transformer (set of 3) unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Foundation size (Cu. Yd)	1.8	2.3	2.7	3.4	4.0	8.0	12.1	18.2
Steel stand weight (pounds)	1,250	1,350	1,425	1,500	1,750	2,000	2,500	3,750
Material cost	$73,284	$91,598	$124,783	$137,249	$149,775	$249,595	$436,798	$655,197
Installation cost	$2,375	$2,671	$2,969	$3,265	$3,562	$4,749	$5,936	$8,905
Jumpers, conduit, wiring, grounding	$7,124	$8,014	$8,905	$10,685	$13,357	$17,809	$22,258	$33,387
Steel stand material cost	$3,243	$3,503	$3,697	$3,892	$4,541	$5,189	$6,487	$9,730
Steel stand installation cost	$3,730	$4,029	$4,252	$4,476	$5,222	$5,968	$7,460	$11,189
Foundation cost	$2,800	$3,578	$4,200	$5,289	$6,222	$12,445	$18,823	$28,234

Deadend structure unit cost is the cost associated with one angled deadend structure. The unit cost utilized for a deadend structure installed in a substation is same unit cost is used for transmission line estimates (Tables 2.2-1 to 2.2-8).

Removal cost of existing substation equipment includes all plant, tools, equipment, machinery, skill, supervision and labor. For any substation equipment that is required to be removed, MISO will utilize its installation cost for that item and consider it equivalent as the cost of removal.

Power transformer unit cost is the cost associated with one power transformer (Table 2.3-7). Power transformer cost varies based on the low-side voltage winding and high-side voltage winding. Unit cost includes all material, shipping, foundation, and installation costs with that transformer. For a scoping cost estimate, MISO will discuss power transformer pricing with vendors.

Table 2.3-7: Power transformer ($/MVA)								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
69 kV	$5,606	$4,564	$5,050	$5,317	$5,896	$7,239	$9,336	$13,135
115 kV	$4,564	$6,209	$5,050	$5,317	$5,896	$6,880	$8,444	$10,807
138 kV	$5,050	$5,050	$6,880	$5,606	$5,896	$6,880	$8,444	$10,807
161 kV	$5,317	$5,317	$5,606	$7,622	$6,209	$7,239	$8,884	$10,807
230 kV	$5,896	$5,896	$5,896	$6,209	$8,444	$7,239	$8,884	$10,807
345 kV	$7,239	$6,880	$6,880	$7,239	$7,239	$10,286	$9,336	$11,340
500 kV	$9,336	$8,444	$8,444	$8,884	$8,884	$9,336	$13,784	$12,510
765 kV	$13,135	$10,807	$10,807	$10,807	$10,807	$11,340	$12,510	$18,475

Grid supporting devices unit costs are the costs associated to procure and install devices to support the grid (Table 2.3-8). Unit costs include all material, shipping, foundation, and installation costs. Additional substation upgrades to add a bus position for interconnection of grid supporting devices are not included in the costs shown in Table 2.3-8 and will be included in a cost estimate if needed.

Certain grid supporting devices are nominally rated less than transmission voltage (i.e., less than 69 kV). In order to connect those devices to the transmission system, they must be stepped-up to a transmission voltage. Energy storage costs are focused on transmission applications, which historically tend to be smaller with less economies of scale than large wholesale installations. MISO researches energy storage costs annually in order to stay up-to-date with market costs, which historically have declined year-over-year. For a scoping cost estimate, MISO will discuss grid supporting device pricing with vendors.

Table 2.3-8: Grid supporting devices unit costs

Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Reactor ($/MVAr)	$16,117	$16,117	$16,117	$16,117	$16,117	$19,950	$24,806	$35,831
Capacitor bank ($/MVAr)	$11,873	$11,873	$11,873	$11,873	$11,873	$11,873	$11,873	$11,873
Static VAr Compensator ($/MVAr)	$114,185	$114,185	$114,185	$114,185	$114,185	$114,185	$114,185	$114,185
STATCOM ($/MVAr)	$226,013	$226,013	$226,013	$226,013	$226,013	$226,013	$226,013	$226,013
Synchronous condenser ($/MVAr)	$169,500/MVAr + $169,500/MW ($169.5/kw) (step-up to 69 kV)							
Energy storage (lithium ion)	Battery system: $236,000/MWh ($236/kwh) + Inverter: $71,500/MW ($71.5/kw) + $169,500/MW ($169.5/kw) (step-up to 69 kV)							
APFC (Advanced Power Flow Control) / SSSC (Static Series Synchronous Condensers)	$159,750/MVAr							

Control Enclosure and Communication System

The cost of the control enclosure and communication system is estimated for one control enclosure of approximately 500 square feet (Table 2.3-9). Material and installation costs include the cost to procure and deliver one control enclosure to the site (laydown yard); the offload and placement of the control enclosure on the foundation; and wiring of the AC/DC systems to field equipment. A control enclosure includes AC panels, DC panels, a cable tray, and all other typical components. Relay panels are considered separately. Battery and battery charger costs includes the material and installation cost for the batteries in the control enclosure and their associated battery charger. Communication equipment costs account for communication equipment placed inside the substation (e.g., fiber patch panel, remote terminal unit, human machine interface). Station service power is the cost to provide station service power to the control enclosure. Foundation size is the amount of cubic yards of concrete required for the foundation. Foundation cost is the combination of the material and installation cost for the foundation and is based on the estimated foundation size.

Table 2.3-9: Control enclosure unit costs

Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Foundation size (Cu. Yd)	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Material and installation cost	$356,182	$356,182	$356,182	$356,182	$356,182	$356,182	$356,182	$356,182
Battery and battery charger	$118,727	$118,727	$118,727	$118,727	$118,727	$118,727	$118,727	$118,727
Communication equipment	$118,727	$118,727	$118,727	$118,727	$118,727	$178,091	$178,091	$178,091
Station service power	$130,600	$130,600	$130,600	$130,600	$130,600	$154,345	$154,345	$154,345
Foundation cost	$28,001	$28,001	$28,001	$28,001	$28,001	$28,001	$28,001	$28,001

Relay Panels

Relay panel estimated unit costs are for one relay panel per voltage class (Table 2.3-10). Material cost is the cost to procure and deliver one relay panel to the site (laydown yard). Procurement of the relay panel includes all the relays and devices in the panel, and all the internal wiring for the devices in each individual relay panel. Installation cost includes placement of relay panel in a control enclosure; wiring from field equipment; and inter-panel wiring to other relay panels inside the control enclosure.

Table 2.3-10: Relay panel unit costs

Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Material cost	$22,262	$27,752	$34,727	$39,180	$43,336	$57,880	$72,424	$90,529
Installation cost	$44,523	$55,505	$69,456	$78,360	$86,671	$115,760	$144,847	$181,060

Control Cable, Conduit, and Cable Trench

Control cable unit costs are the costs associated with 1,000 feet of control cable (Table 2.3-11). Material cost is the cost to procure and deliver 1,000 feet of control cable to the site (laydown yard). Installation cost includes placing and pulling the control cable in conduit and/or in a cable trench and bringing the control cable to its end point where it will be landed. The final wiring of landing on terminal blocks is included in other unit costs.

Table 2.3-11: Control cable unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Material cost per 1,000 feet	$3,562	$3,562	$3,562	$3,562	$3,562	$4,749	$4,749	$4,749
Installation cost per 1,000 feet	$5,936	$5,936	$5,936	$5,936	$5,936	$5,936	$5,936	$5,936

Conduit unit cost is the cost associated with 1,000 feet of conduit (Table 2.3-12). Material cost is the cost to procure and deliver 1,000 feet of conduit to the site (laydown yard). Included in the material cost is the conduit along with applicable fittings and connectors. Installation cost includes excavation, placement of conduit, and utilizing all applicable fittings and connectors.

Table 2.3-12: Conduit unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Material cost per 1,000 feet	$3,562	$3,562	$3,562	$3,562	$3,562	$3,562	$3,562	$3,562
Installation cost per 1,000 feet	$47,491	$47,491	$47,491	$47,491	$47,491	$47,491	$47,491	$47,491

Cable trench unit cost is the cost associated with 1 foot of cable trench inclusive of a lid/cover (Table 2.3-13). Material cost is the cost to procure and deliver 1 foot of cable trench to the site (laydown yard). Installation cost includes excavation, and placement of cable trench. Placement of control cables in cable trench is included in the control cable installation cost.

Table 2.3-13: Cable trench unit costs								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Material cost per foot	$59	$59	$59	$59	$59	$59	$59	$59
Installation cost per foot	$237	$237	$237	$237	$237	$237	$237	$237

2.4 HVDC Converter Stations

Converter stations are required at each endpoint of an HVDC transmission line in order to interconnect with the AC transmission system. MISO includes in its guide two converter station design types — line-commutated converter thyristor valve technology (LCC) and voltage-source converter transistor technology (VSC).

In addition to only a converter station, there would also be AC substation equipment needed to interconnect. Typical interconnection voltages are 230 kV AC for a ±250 kV HVDC transmission line; 345 kV AC for a ±400 kV HVDC transmission line; 500 kV AC for a ±500 kV and ±600 kV HVDC transmission line; and 765 kV AC for a ±640 kV HVDC transmission line. For the purposes of creating a cost estimate, as shown in tables 2.4-1 and 2.4-2, MISO assumes a new four-position, breaker-and-a-half substation for the AC substation costs connected with a new converter station.

At each converter station, MISO assumes the installation of a ground electrode except in the instance of an interchangeable transmission line. Historically, HVDC electrodes have been installed to provide a low-resistance path during both monopolar and bipolar operations, using earth as a conductive medium. Although this return path option in HVDC is less expensive, there are environmental and regulatory implications. For the purpose of the cost estimate, MISO assumes that those concerns are permitted by respective authorities and addressed by the developer.

The ground electrode is a structure with a conductor, or a group of conductors embedded in the soil directly or surrounded by conductive medium providing an electric path to ground. The electrodes are generally located relatively close to the converter stations. MISO's unit cost of a ground electrode includes the engineering study, permitting, material, labor and land. In addition to the ground electrode, there is also the ground electrode line, which is an electrical connection between conversions and ground electrode. The cost of overhead ground electrode line includes supporting structures, foundations, conductor material and labor. MISO assumes 20 miles of ground electrode line at each of the HVDC transmission line.

LCC stations are composed of thyristor valves and are located indoors to provide a safe, clean and controlled operating environment. The cost of a bipolar converter station valve hall includes land and land acquisition, the building, and DC switching station equipment including DC filters, converter transformer, insulation, control devices and services. LCC stations require AC filters which are included in the converter station costs. Reactive power compensation is assumed to be a Static Var Compensator, which the costs are shown in section 3.2.

Table 2.4-1: Converter station line commutated converter (LCC) – one end

Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Power Transfer	500 MW	1,500 MW	2,000 MW	2,400 MW	3,000 MW
Assumed Reactive Power Need	167 MVAR	500 MVAR	667 MVAR	800 MVAR	1,000 MVAR
Ground electrode line length	20 miles	20 miles	20 miles	20 miles	20 miles
Valve hall	$34.7M	$127.4M	$173.7M	$214.3M	$267.9M
AC filters	$3.5M	$12.7M	$17.4M	$21.4M	$26.8M
Reactive power	$19.1M	$57.1M	$76.2M	$91.4M	$114.2M
AC Substation	$12.4M	$18.2M	$26.4M	$26.4M	$35.3M
Ground electrode	$3.1M	$4.2M	$4.3M	$4.5M	$4.7M
Ground electrode line	$4.6M	$11.6M	$13.9M	$17.4M	$18.8M

Voltage source converter (VSC) stations are composed of insulated-gate bipolar transistor (IGBT) valves and are located indoors to provide a safe, clean and controlled operating environment. The cost of a bipolar converter station valve hall includes land and land acquisition, building, and DC switching station equipment including DC filters, converter transformer, insulation, control devices and services. It is assumed that VSC converter stations do not require any additional reactive power support and they can inherently provide power with a 0.95 leading to a 0.95 lagging power factor.

Table 2.4-2: Converter station voltage source converter (VSC) – one end					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Power Transfer	500 MW	1,500 MW	2,000 MW	2,400 MW	3,000 MW
Ground electrode line length	20 miles	20 miles	20 miles	20 miles	20 miles
Valve hall	$83.4M	$266.4M	$359.1M	$440.2M	$535.7M
AC Substation	$12.4M	$18.2M	$26.4M	$26.4M	$35.3M
Ground electrode	$3.1M	$4.2M	$4.3M	$4.5M	$4.7M
Ground electrode line	$4.6M	$11.6M	$13.9M	$17.4M	$18.8M

3. Initial Assumptions

To create a cost estimate, MISO makes initial assumptions about the scopes of work for potential projects. As more information becomes known, scope of work assumptions is refined. The assumptions are not an indication of how a potential project should be built, but merely an instrument to provide a cost estimate.

3.1 AC and HVDC Transmission Lines

Line Length

The transmission line length is a consideration for determining its cost estimate for a potential project. For exploratory and planning cost estimates, the line length is determined by the straight-line distance between the two substations plus a 30% line length adder. This 30% line length adder accounts for routing constraints that will be determined upon further development of the potential transmission line project. For scoping cost estimates, the line length is determined by a MISO-created proxy route based upon a desktop study. For new potential projects, MISO considers new right-of-way. For retrofit/reconductor projects, MISO assumes an adequate existing right-of-way. MISO does not share its assumed proxy route information with stakeholders, as the route could be perceived as a MISO-endorsed or preferred route. MISO's proxy route is merely an instrument to support the MISO's transmission line cost estimate. MISO utilizes Google Earth to determine route length, land types, and terrain types encountered.

Right-of-Way Width

The right-of-way widths that MISO assumes are intended to be indicative of right-of-way widths for transmission lines in each voltage class (Table 3.1-1). Different project conditions in different locations may have a wider or narrower right-of-way width than the indicative value MISO assumes.

Table 3.1-1: Right-of-way width

AC Transmission (single and double circuit)								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Feet	80	90	95	100	125	175	200	225

HVDC transmission (single circuit)					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Feet	130	180	200	215	225

Structures Per Mile

MISO makes indicative assumptions about the quantity of structures per mile required in transmission line cost estimates (Tables 3.1-2, 3.1-3 and 3.1-4). The indicative assumptions are not connected to any specific project. For AC transmission, MISO assumes a steel pole structure type for 69 kV – 765 kV. For HVDC, MISO assumes a steel pole structure type for 250 kV, and a steel tower structure for 400 kV – 600 kV.

Table 3.1-2: Structures per mile – AC transmission steel tower and steel pole (single circuit/double circuit)								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Tangent structures	9/9.5	8.5/9	8/8.5	7/7.5	5/7	4.5/6	3.0/N/A	3.5/N/A
Running angle structures	1/1	1/1	1/1	1/1	1/1	1/1	1/N/A	0.25/N/A
Non-angled deadend structures	0.25/0.25	0.25/0.25	0.25/0.25	0.25/0.25	0.25/0.25	0.25/0.25	0.25/N/A	0.125/N/A
Angled deadend structures	0.25/0.25	0.25/0.25	0.25/0.25	0.25/0.25	0.25/0.25	0.25/0.25	0.25/N/A	0.125/N/A

Table 3.1-3: Structures per mile – AC transmission wood pole (single circuit/double circuit)								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Tangent structures	15.5/18.5	13.5/16.5	13.5/N/A	10.5/N/A	7.5/N/A	N/A	N/A	N/A
Running angle structures	1/1	1/1	1/N/A	1/N/A	1/N/A	N/A	N/A	N/A
Angled deadend structures	0.5/0.5	0.5/0.5	0.5/N/A	0.5/N/A	0.5/N/A	N/A	N/A	N/A

Table 3.1-4: Structures per mile – HVDC transmission steel tower and steel pole (single circuit)					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Tangent structures	4.5	4.0	3.5	3.0	3.5
Running angle structures	0.5	0.5	0.5	0.5	0.25
Non-angled structures	0.25	0.25	0.25	0.25	0.125
Angled structures	0.25	0.25	0.25	0.25	0.125

Conductor Selection

Conductor selection for MISO's exploratory cost estimates are shown in tables 3.1-5 and 3.1-6. The conductor selected is intended to be typical for a circuit in the voltage class. Specific solution ideas may necessitate different conductors from those shown.

Table 3.1-5: Conductor selection per circuit – AC Transmission								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Conductor size	477 kcmil	795 kcmil	795 kcmil	795 kcmil	795 kcmil	795 kcmil	954 kcmil	795 kcmil
Conductor type	ACSS	ACSS	ACSS	ACSS	ACSS	ACSS	ACSR	ACSR
Conductor quantity	1	1	1	1	1	2	3	6
Amp rating	1,175	1,650	1,650	1,650	1,650	3,000	3,000	5,000
Power rating (MVA)	140	329	394	460	657	1,792	2,598	6,625

Table 3.1-6: Conductor selection per circuit – HVDC Transmission					
Voltage class	± 250 kV	± 400 kV	± 500 kV	± 600 kV	± 640 kV
Conductor size	1,590 kcmil	1,590 kcmil	1,590 kcmil	1,590 kcmil	795 kcmil
Conductor type	ACSR	ACSR	ACSR	ACSR	ACSR
Conductor quantity per pole	1	2	2	2	6
Power transfer	500 MW	1,500 MW	2,000 MW	2,400 MW	6,000 MW

Land and Terrain Type

A significant cost driver for transmission line projects is the land and terrain types encountered. MISO's cost estimates account for differences between states in MISO's footprint by using different assumptions for each state's unique land and terrain (Table 3.1-7). The indicative assumptions are not tied to any specific project and are intended for the sole purpose of providing MISO's exploratory cost estimate.

Table 3.1-7: Land and terrain type per state						
State	Land type (pasture, crop, and suburban/urban land sum to 100% per state)			Terrain type (level ground, forested, and wetland terrain sum to 100% per state)		
	Pasture-land	Cropland	Suburban/ Urban	Level ground	Forested	Wetland
Arkansas	25%	65%	10%	40%	55%	5%
Illinois	25%	65%	10%	55%	40%	5%
Indiana	25%	65%	10%	80%	15%	5%
Iowa	10%	80%	10%	80%	15%	5%
Kentucky	25%	65%	10%	65%	25%	10%
Louisiana	25%	65%	10%	55%	25%	20%
Michigan	25%	65%	10%	50%	40%	10%
Minnesota	10%	80%	10%	70%	25%	5%
Mississippi	25%	65%	10%	55%	25%	20%
Missouri	25%	65%	10%	40%	55%	5%
Montana	70%	20%	10%	85%	10%	5%
North Dakota	70%	20%	10%	90%	5%	5%
South Dakota	50%	40%	10%	90%	5%	5%
Texas	65%	25%	10%	50%	30%	20%
Wisconsin	25%	65%	10%	70%	25%	5%

3.2 AC Substations

MISO's substation exploratory cost estimates use indicative assumptions for the ratings and quantity of equipment required for substation upgrades and for new substations (Tables 3.2-1 through 3.2-5). The indicative assumptions for substation equipment are not tied to any specific project and are intended for the sole purpose of providing MISO's exploratory cost estimate.

Table 3.2-1: Initial assumptions – bus ratings								
Voltage class	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Amp rating	1,200	3,000	3,000	3,000	3,000	3,000	3,000	4,000
Power rating (MVA)	143	598	717	837	1195	1,793	2,598	5,300

Table 3.2-2: Substation upgrade – add 1 position (ring/breaker-and-a-half/double-breaker bus)								
Scope of work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Land required (acre)	0.4/0.5/0.6	0.5/0.6/0.7	0.5/0.6/0.8	0.6/0.7/0.8	0.6/0.8/0.9	0.8/0.9/1.1	1.3/1.6/1.9	1.6/2.0/2.3
Access road (mile)	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Circuit breakers (each)	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2
Disconnect switches (each)	2/4/4	2/4/4	2/4/4	2/4/4	2/4/4	2/4/4	2/4/4	2/4/4
Voltage transformers (set of 3)	1/1/2	1/1/2	1/1/2	1/1/2	1/1/2	1/1/2	1/1/2	1/1/2
Bus support, bus, and fittings (3-phase)	4/4/6	4/4/6	4/4/6	4/4/6	4/4/6	6/6/8	8/8/10	12/12/14
Deadend structure	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1
Control enclosure	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Relay panel(s)	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2	1/2/2
Cable trench (foot), conduit (10 feet), control cable (100 feet)	50 / 70 / 90	50 / 70 / 100	50 / 80 / 100	50 / 80 / 110	60 / 80 / 110	60 / 90 / 120	70 / 110 / 140	88 / 131 / 175

Table 3.2-3: Substation upgrade – add 2 positions (ring/breaker-and-a-half/double-breaker bus)								
Scope of work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Land required (acre)	0.8/1.0/1.2	0.9/1.1/1.4	1.0/1.3/1.5	1.1/1.4/1.7	1.2/1.5/1.8	1.5/1.9/2.3	2.5/3.1/3.8	3.1/3.9/4.7
Access road (mile)	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Circuit breakers (each)	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4
Disconnect switches (each)	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8
Voltage transformers (set of 3)	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2
Bus support, bus, and fittings (3-phase)	8/8/12	8/8/12	8/8/12	8/8/12	8/8/12	12/12/16	16/16/20	20/20/24
Deadend structure	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2
Control enclosure	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Relay panel(s)	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4	2/3/4
Cable trench (foot), conduit (10 feet), control cable (100 feet)	90 / 135 / 180	95 / 143 / 190	100 / 150 / 200	105 / 158 / 210	110 / 165 / 220	120 / 180 / 240	140 / 210 / 280	175 / 263 / 350

Table 3.2-4: New substation – 4 positions (ring/breaker-and-a-half/double-breaker bus)								
Scope of work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Land required (acre)	1.6/2.0/2.4	1.8/2.3/2.7	2.0/2.5/3.0	2.2/2.8/3.3	2.4/3.0/3.6	3.0/3.8/4.5	5.0/6.3/7.5	6.2/7.8/9.4
Access road (mile)	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1
Circuit breakers (each)	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8	4/6/8
Disconnect switches (each)	8/12/16	8/12/16	8/12/16	8/12/16	8/12/16	8/12/16	8/12/16	8/12/16
Voltage transformers (set of 3)	4/6/6	4/6/6	4/6/6	4/6/6	4/6/6	4/6/6	4/6/6	4/6/6
Bus support, bus, and fittings (3-phase)	12/14/16	12/14/16	12/14/16	12/14/16	12/14/16	14/16/20	20/24/32	28/32/48
Deadend structure	4/4/4	4/4/4	4/4/4	4/4/4	4/4/4	4/4/4	4/4/4	4/4/4
Control enclosure	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1
Relay panel(s)	6/8/10	6/8/10	6/8/10	6/8/10	6/8/10	6/8/10	6/8/10	6/8/10
Cable trench (foot), conduit (10 feet), control cable (100 feet)	180 / 270 / 360	190 / 290 / 380	200 / 300 / 400	210 / 320 / 420	220 / 330 / 440	240 / 360 / 480	280 / 420 / 560	350 / 525 / 700

Table 3.2-5: New substation – 6 positions (ring/breaker-and-a-half/double-breaker bus)								
Scope of work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Land required (acre)	2.0/2.5/3.0	2.3/2.8/3.4	2.5/3.1/3.8	2.8/3.4/4.1	3.0/3.8/4.5	3.8/4.7/5.6	6.3/7.8/9.4	7.8/9.8/11.7
Access road (mile)	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1
Circuit breakers	6/9/12	6/9/12	6/9/12	6/9/12	6/9/12	6/9/12	6/9/12	6/9/12
Disconnect switches (each)	12/18/24	12/18/24	12/18/24	12/18/24	12/18/24	12/18/24	12/18/24	12/18/24
Voltage transformers (set of 3)	6/8/8	6/8/8	6/8/8	6/8/8	6/8/8	6/8/8	6/8/8	6/6/8
Bus support, bus, and fittings (3-phase)	14/16/20	14/16/20	14/16/20	14/16/20	14/16/20	16/20/24	24/32/40	32/48/60
Deadend structure	6/6/6	6/6/6	6/6/6	6/6/6	6/6/6	6/6/6	6/6/6	6/6/6
Control enclosure	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1	1/1/1
Relay panel(s)	8/11/14	8/11/14	8/11/14	8/11/14	8/11/14	8/11/14	8/11/14	8/11/14
Cable trench (foot), conduit (10 feet), control cable (100 feet)	270 / 410 / 540	290 / 430 / 570	300 / 450 / 600	320 / 470 / 630	330 / 500 / 600	360 / 540 / 720	420 / 630 / 840	525 / 788/ 1050

4. Exploratory Costs

In the planning process, exploratory cost estimates allow quick assessment of many different project ideas to check potential viability. MISO provides high-level, exploratory cost estimates for projects with low levels of scope definition. MISO does not recommend using exploratory cost estimates for any solution idea in the regular planning cycle due to the breadth of the assumptions used to derive the unit costs and lower level of granularity regarding specific project components. The exploratory cost estimates provided in sections 4.1, 4.2 and 4.3 are based on the assumptions and cost data shown in this guide. Before a potential project is recommended for approval to MISO's Board of Directors, MISO completes a thorough scoping cost estimate, the details of which are shared with stakeholders for their review and comment. MISO provides its exploratory cost estimate in a $/mile cost as defined by its voltage class and, in most cases, by the state in which the potential project would be developed.

4.1 AC and HVDC Transmission Lines

Table 4.1-1: Exploratory cost estimate – AC transmission new single circuit transmission line $/mile

Location	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Arkansas	$1.7M	$1.9M	$2.0M	$2.1M	$2.2M	$3.5M	$4.4M	$5.5M
Illinois	$1.8M	$2.0M	$2.0M	$2.1M	$2.2M	$3.6M	$4.5M	$5.6M
Indiana	$1.7M	$1.9M	$2.0M	$2.0M	$2.1M	$3.4M	$4.3M	$5.4M
Iowa	$1.7M	$1.9M	$2.0M	$2.1M	$2.2M	$3.5M	$4.4M	$5.6M
Kentucky	$1.8M	$2.0M	$2.1M	$2.2M	$2.3M	$3.7M	$4.6M	$5.8M
Louisiana	$2.0M	$2.2M	$2.3M	$2.4M	$2.6M	$4.1M	$5.1M	$6.3M
Michigan	$1.8M	$2.0M	$2.1M	$2.2M	$2.3M	$3.7M	$4.6M	$5.8M
Minnesota	$1.8M	$2.0M	$2.1M	$2.1M	$2.3M	$3.6M	$4.5M	$5.7M
Mississippi	$2.0M	$2.2M	$2.3M	$2.4M	$2.6M	$4.1M	$5.0M	$6.3M
Missouri	$1.7M	$1.9M	$2.0M	$2.0M	$2.2M	$3.5M	$4.4M	$5.5M
Montana	$1.6M	$1.8M	$1.9M	$1.9M	$2.0M	$3.2M	$4.1M	$5.2M
North Dakota	$1.6M	$1.8M	$1.9M	$1.9M	$2.0M	$3.3M	$4.1M	$5.2M
South Dakota	$1.6M	$1.8M	$1.9M	$1.9M	$2.0M	$3.3M	$4.1M	$5.2M
Texas	$1.9M	$2.2M	$2.3M	$2.3M	$2.5M	$4.0M	$4.9M	$6.1M
Wisconsin	$1.8M	$2.0M	$2.1M	$2.2M	$2.3M	$3.7M	$4.6M	$5.8M

Includes contingency (30%) and AFUDC (7.5%)

Table 4.1-2: Exploratory cost estimate – AC transmission new double circuit transmission line $/mile						
Location	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV
Arkansas	$2.5M	$2.8M	$2.9M	$3.0M	$3.6M	$5.8M
Illinois	$2.5M	$2.8M	$3.0M	$3.0M	$3.6M	$5.9M
Indiana	$2.4M	$2.7M	$2.9M	$3.0M	$3.5M	$5.8M
Iowa	$2.5M	$2.8M	$2.9M	$3.0M	$3.6M	$5.8M
Kentucky	$2.6M	$2.9M	$3.0M	$3.1M	$3.7M	$6.0M
Louisiana	$2.8M	$3.1M	$3.3M	$3.3M	$4.0M	$6.4M
Michigan	$2.6M	$2.9M	$3.0M	$3.1M	$3.7M	$6.0M
Minnesota	$2.5M	$2.8M	$3.0M	$3.1M	$3.6M	$6.0M
Mississippi	$2.7M	$3.1M	$3.2M	$3.3M	$4.0M	$6.4M
Missouri	$2.5M	$2.8M	$2.9M	$3.0M	$3.5M	$5.8M
Montana	$2.3M	$2.6M	$2.8M	$2.8M	$3.3M	$5.5M
North Dakota	$2.4M	$2.7M	$2.8M	$2.9M	$3.4M	$5.6M
South Dakota	$2.4M	$2.7M	$2.8M	$2.9M	$3.4M	$5.6M
Texas	$2.7M	$3.0M	$3.2M	$3.3M	$3.9M	$6.3M
Wisconsin	$2.6M	$2.9M	$3.0M	$3.1M	$3.7M	$6.0M

Includes contingency (30%) and AFUDC (7.5%)

Table 4.1-3: Exploratory cost estimate – AC transmission rebuild and reconductor transmission line $/mile								
Scope of Work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Rebuild – single circuit	$1.5M	$1.7M	$1.8M	$1.8M	$1.9M	N/A	N/A	N/A
Rebuild – double circuit	$2.3M	$2.6M	N/A	N/A	N/A	N/A	N/A	N/A
Reconductor – per circuit	$.33M	$.39M	$.39M	$.39M	$.39M	$.62M	$.83M	$1.14M

Includes contingency (30%) and AFUDC (7.5%)

Table 4.1-4: Exploratory cost estimate – HVDC transmission new bipole transmission line $/mile					
Location	**250 kV**	**400 kV**	**500 kV**	**600 kV**	**640 kV**
Arkansas	$2.3M	$2.7M	$2.8M	$3.0M	$5.5M
Illinois	$2.3M	$2.7M	$2.9M	$3.1M	$5.6M
Indiana	$2.2M	$2.6M	$2.7M	$2.9M	$5.4M
Iowa	$2.3M	$2.7M	$2.8M	$3.0M	$5.5M
Kentucky	$2.4M	$2.9M	$3.0M	$3.2M	$5.8M
Louisiana	$2.7M	$3.3M	$3.5M	$3.7M	$6.3M
Michigan	$2.4M	$2.9M	$3.0M	$3.2M	$5.8M
Minnesota	$2.4M	$2.8M	$2.9M	$3.1M	$5.7M
Mississippi	$2.7M	$3.2M	$3.4M	$3.7M	$6.2M
Missouri	$2.3M	$2.6M	$2.8M	$2.9M	$5.5M
Montana	$2.1M	$2.3M	$2.5M	$2.6M	$5.1M
North Dakota	$2.1M	$2.4M	$2.5M	$2.7M	$5.2M
South Dakota	$2.1M	$2.4M	$2.5M	$2.7M	$5.2M
Texas	$2.6M	$3.1M	$3.3M	$3.5M	$6.1M
Wisconsin	$2.4M	$2.9M	$3.0M	$3.2M	$5.8M

Includes contingency (30%) and AFUDC (7.5%)

4.2 AC Substations

Substations have a variety of layouts and arrangements. MISO's exploratory cost estimates for substations capture the most common substation arrangements that are estimated in MISO's planning process. The arrangements selected for the exploratory indicative cost estimates are not an all-inclusive list for substation arrangements. Exploratory cost estimates are provided for both substation upgrades and new substations. Bus ratings per voltage class are included in the indicative assumptions and are aligned with the line ratings assumed by MISO for its transmission line project cost estimates. The 765 kV substations include shunt reactors for every line position.

Table 4.2-1: Exploratory cost estimate – substation upgrade								
Scope of work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
Add 1 position (ring bus)	$1.3M	$1.5M	$1.7M	$1.8M	$2.2M	$3.4M	$5.3M	$17.4M
Add 1 position (breaker-and-a-half bus)	$1.7M	$2.0M	$2.3M	$2.6M	$3.0M	$4.9M	$7.3M	$21.9M
Add 1 position (double-breaker bus)	$2.0M	$2.3M	$2.6M	$2.9M	$3.4M	$5.4M	$8.0M	$22.7M
Add 2 positions(ring bus)	$2.5M	$3.0M	$3.3M	$3.7M	$4.3M	$6.8M	$10.6M	$26.7M
Add 2 positions (breaker-and-a-half bus)	$3.2M	$3.7M	$4.1M	$4.6M	$5.4M	$8.6M	$13.0M	$31.7M
Add 2 positions (double-breaker bus)	$4.0M	$4.6M	$5.2M	$5.8M	$6.8M	$10.7M	$15.9M	$37.3M

Includes contingency (30%) and AFUDC (7.5%)

Table 4.2-2: Exploratory cost estimate – new substation								
Scope of work	69 kV	115 kV	138 kV	161 kV	230 kV	345 kV	500 kV	765 kV
4 positions (ring bus)	$7.5M	$8.3M	$9.1M	$9.8M	$11.1M	$15.8M	$22.9M	$47.5M
4 positions (breaker-and-a-half bus)	$8.9M	$10.0M	$11.0M	$11.9M	$13.6M	$19.8M	$28.7M	$58.8M
4 positions (double-breaker bus)	$10.3M	$11.5M	$12.7M	$13.9M	$15.9M	$23.7M	$34.6M	$71.3M
6 positions (ring bus)	$9.4M	$10.6M	$11.6M	$12.6M	$14.5M	$21.1M	$30.8M	$63.0M
6 positions (breaker-and-a-half bus)	$11.4M	$12.9M	$14.2M	$15.5M	$18.0M	$26.9M	$39.3M	$80.8M
6 positions (double-breaker bus)	$13.4M	$15.2M	$16.8M	$18.4M	$21.3M	$32.3M	$47.4M	$97.3M

Includes contingency (30%) and AFUDC (7.5%)

4.3 HVDC Converter Stations

Table 4.2-3: Exploratory cost estimate – HVDC transmission converter Station (one end)

Scope of work	250 kV	400 kV	500 kV	600 kV	640 kV
Line Commutated Converter	$119M	$355M	$479M	$577M	$718M
Voltage Source Converter	$159M	$461M	$620M	$750M	$914M

Includes contingency (30%) and AFUDC (7.5%)

5. Costs Over Time

MISO's yearly MTEP report may identify and recommend certain types of projects to its Board that are justified on a benefit-to-cost ratio requirement. In order to evaluate alternatives in the planning process, MISO estimates the net present value of costs over time of differing solution ideas that may also be differing technology types (e.g., energy storage project vs. transmission line project) (Figure 5-1).

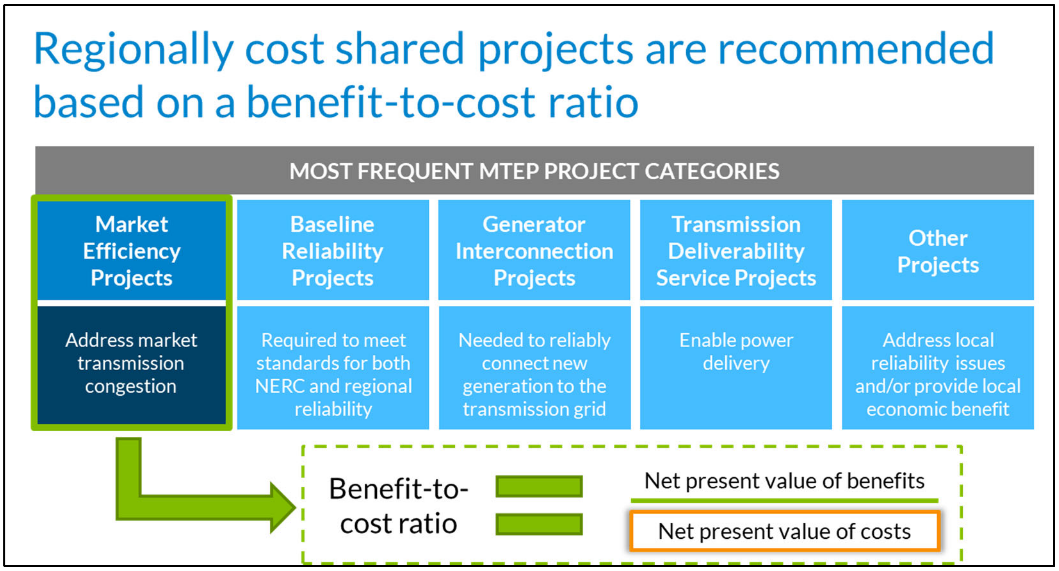


Figure 5-1: Calculation of benefit-to-cost ratio for Market Efficiency Projects

In order to estimate costs over time, MISO estimates depreciation costs, expense factors, and return factors for transmission projects (Figure 5-2). Expense factors and return factors vary by state to account for differences in taxes (e.g., income taxes and property taxes).

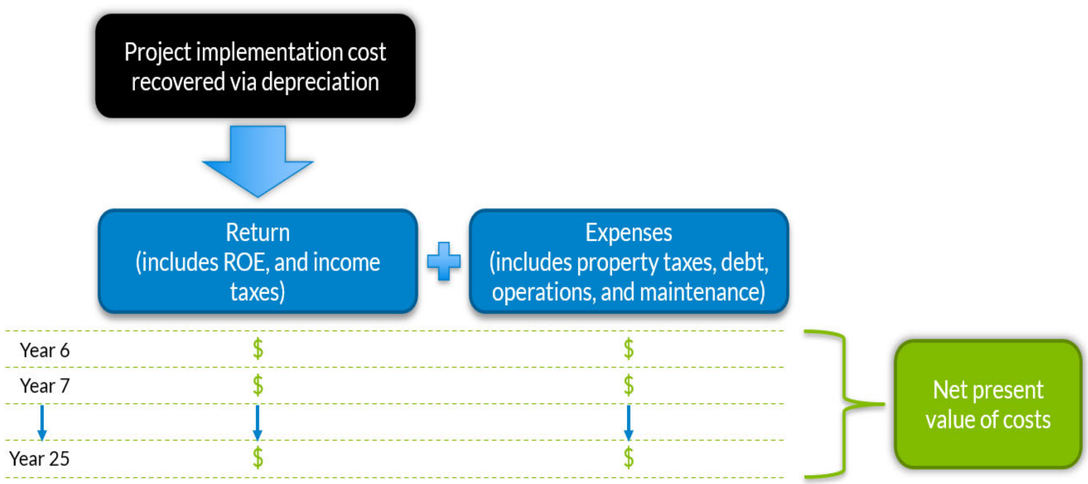


Figure 5-2: Calculation of net present value of costs

In its estimate of costs over time, MISO makes assumptions about the cost inputs in Figure 5-3.

Year #	Gross Plant Project Cost ISD Yr.$ (PI)	Net Plant Project Cost ISD Yr.$ (PI)	Annual Depreciation Factor	Return Factor subject to decrease in net plant	Expense Factor	Annual Cost to be Recovered	Present Value Discount Rate	Net Present Value Cost

Figure 5-3: Cost inputs for calculation of net present value cost

Year(s)

MISO defines the Project Costs to be used in the benefit-to-cost ratio as the present value of the annual revenue requirements projected for the first 20 years of the project's life (Attachment FF Section II.C.7). For example, if a project takes five years to construct, then the first 20 annual revenue requirement years start at year six and end at year 25.The present value cost calculation is over the same period for which the project benefits are determined.

Gross Plant (Nominal Cost Estimate)

The nominal cost to construct the project is also the amount used for the annual revenue requirements calculation. The present year project cost estimate is converted to nominal cost by factoring in a construction spend per year and an annual inflation rate of 2.5%. Figure 5-4 shows an example of a $100 million project expressed as a nominal cost estimate at an assumed five-year project development time span.

Example: Project cost $100M, Contingency $20M, AFUDC $9M
Present year capital cost = $129M
Nominal capital cost = $149.8M

Estimated 5-year project spend						
Year	1	2	3	4	5	Subtotal
Costs incurred per year	1%	4%	35%	35%	25%	100%
Present year capital cost	$1.3M	$5.1M	$45.2M	$45.2M	$32.2M	$129.0M
Convert to nominal dollars at 2.5% inflation rate (shown below) AFUDC calculated at 7.5% annually based on cumulative cost. Nominal cost = present year cost * (1 + inflation rate) ^ (project year)						
Nominal project implementation cost	$1.3M	$5.3M	$47.4M	$52.3M	$43.5M	$149.8M

Figure 5-4: Example of conversion from present year capital cost to nominal capital cost

Table 5-1 shows estimated annual spend for projects with in-service dates of 5 to 8 years from the present year, based on a year-end in-service date.

Table 5-1: Estimated annual spend for projects with in-service dates of 5 to 8 years from present

Year	1	2	3	4	5	6	7	8
5-year	1%	4%	35%	35%	25%			
6-year	1%	4%	10%	30%	35%	20%		
7-year	1%	1%	3%	15%	30%	30%	20%	
8-year	1%	1%	3%	5%	15%	25%	30%	20%

Net Plant and Annual Depreciation Factor

The net plant is the gross plant, less depreciation, and is based on a 40-year asset life which assumes 2.5% depreciation per year.

Return Factor and Expense Factor (by State)

The return factor accounts for the cost of equity and income taxes. The return factor changes annually as it is a factor of net gross plant, which is reduced annually as a result of depreciation. The expense factor accounts for property taxes, the cost of debt, and operations and maintenance.

For energy storage installations, in addition to the expense factor, MISO will assume replacement of the inverters every 10 years after project is in service, and replacement of the battery system every 15 years after the project is in service. Both factors are based on Attachment Os and GGs provided by MISO Transmission Owners and vary by state (Table 5-1).

Table 5.2: Expense factor and return factor (by state)		
State	**Expense Factor**	**Return Factor (adjusted for the first year of depreciation)**
Arkansas	2.96%	8.10%
Illinois	3.69%	8.29%
Indiana	3.16%	8.23%
Iowa	3.42%	8.44%
Kentucky	3.08%	8.07%
Louisiana	2.76%	8.19%
Michigan	3.62%	8.07%
Minnesota	3.28%	8.31%
Mississippi	2.96%	8.01%
Missouri	3.20%	8.08%
Montana	3.15%	8.12%
North Dakota	3.50%	8.02%
South Dakota	3.42%	7.70%
Texas	3.74%	7.70%
Wisconsin	3.71%	8.19%

Present Value Discount Rate

MISO calculates the present value discount rate annually as the after-tax weighted average cost of capital of the Transmission owners that make up the Transmission Provider Transmission System. MISO's estimated costs over time will use the same discount rate as used to determine benefits.

Net Present Value Cost

Appling the discount rate to the first 20 years of the annual revenue requirement results in the net present value cost to be used in the benefit-to-cost ratio. Net Present Value Cost is calculated per year by multiplying the annual cost to be recovered by the Present Value Discount Rate for their respective years.

Example – Estimating Project Costs Over Time

For example, if estimating the costs over time for a project that had a nominal cost estimate of $100 million, and using a discount rate of 6.9%, based on the approach described in this section, the net present value of cost over the first 20 years of in-service life would be $96.2 million (Table 5-2).

Table 5-3: Methodology for calculating a project's net present value cost

Year #	Gross Plant Project Cost ISD Yr.$ (PI)	Net Plant Project Cost ISD Yr.$ (PI)	Annual Depreciation Factor	Return Factor subject to decrease in net plant	Expense Factor	Annual Cost to be Recovered	Present Value Discount Rate	Net Present Value Cost
MTEP Year							1.000	
1							0.935	
2							0.875	
3							0.819	
4							0.766	
5				8.42%			0.716	
6	$100,000,000	$97,500,000	2.50%	8.21%	3.41%	$14,123,772	0.670	$9,464,212
7	$100,000,000	$95,000,000	2.50%	8.00%	3.41%	$13,913,259	0.627	$8,721,374
8	$100,000,000	$92,500,000	2.50%	7.79%	3.41%	$13,702,746	0.586	$8,035,001
9	$100,000,000	$90,000,000	2.50%	7.58%	3.41%	$13,492,232	0.549	$7,400,899
10	$100,000,000	$87,500,000	2.50%	7.37%	3.41%	$13,281,719	0.513	$6,815,179
11	$100,000,000	$85,000,000	2.50%	7.16%	3.41%	$13,071,206	0.480	$6,274,237
12	$100,000,000	$82,500,000	2.50%	6.95%	3.41%	$12,860,693	0.449	$5,774,733
13	$100,000,000	$80,000,000	2.50%	6.74%	3.41%	$12,650,179	0.420	$5,313,571
14	$100,000,000	$77,500,000	2.50%	6.53%	3.41%	$12,439,666	0.393	$4,887,884
15	$100,000,000	$75,000,000	2.50%	6.32%	3.41%	$12,229,153	0.368	$4,495,011
16	$100,000,000	$72,500,000	2.50%	6.10%	3.41%	$12,018,640	0.344	$4,132,492
17	$100,000,000	$70,000,000	2.50%	5.89%	3.41%	$11,808,126	0.322	$3,798,044
18	$100,000,000	$67,500,000	2.50%	5.68%	3.41%	$11,597,613	0.301	$3,489,554
19	$100,000,000	$65,000,000	2.50%	5.47%	3.41%	$11,387,100	0.281	$3,205,064
20	$100,000,000	$62,500,000	2.50%	5.26%	3.41%	$11,176,587	0.263	$2,942,762
21	$100,000,000	$60,000,000	2.50%	5.05%	3.41%	$10,966,073	0.246	$2,700,967
22	$100,000,000	$57,500,000	2.50%	4.84%	3.41%	$10,755,560	0.230	$2,478,127
23	$100,000,000	$55,000,000	2.50%	4.63%	3.41%	$10,545,047	0.216	$2,272,800
24	$100,000,000	$52,500,000	2.50%	4.42%	3.41%	$10,334,533	0.202	$2,083,656
25	$100,000,000	$50,000,000	2.50%	4.21%	3.41%	$10,124,020	0.189	$1,909,459
								$96,195,027