Transmission Cost Estimation Guide

For MTEP21

February 9, 2021

Draft for Stakeholder Review

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 the region. Those projects are included in the MISO Transmission Expansion Plan (MTEP), an annual publication that is 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 in order to evaluate alternatives. MISO's transmission cost estimation guide for MTEP21 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 2021 US Dollars. All applicable taxes are included within the cost subcategories.

Disclaimer: This document is prepared for informational purposes only to support MISO planning staff in developing cost estimates and deriving benefit-to-cost ratios for solutions proposed for inclusion in the MISO Transmission Expansion Plan (MTEP). MISO's cost estimation approach is based on staff experience, vendor consultation, industry practice, and stakeholder feedback. MISO makes every effort to develop its cost estimates from the most accurate and appropriate assumptions and information available at that time. However, MISO cannot and does not guarantee the accuracy of information, assumptions, judgments, or opinions contained herein or derived therefrom. MISO may revise or terminate this document at any time at its discretion without notice. MISO's cost estimation assumptions are not an indication or a direction for how any particular project shall be designed or built.

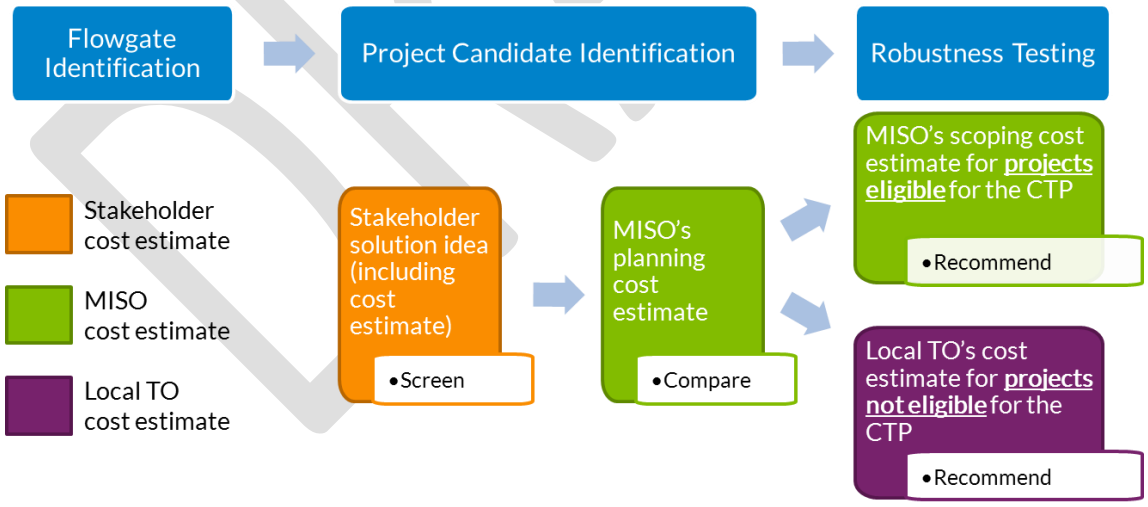
Executive Summary

In MISO's planning process, estimated project costs are necessary to evaluate alternatives and recommend projects. The MISO Transmission Expansion Plan (MTEP) may result in a project(s) to be eligible 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 MCPS, 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, a more refined scoping cost estimate is created. If the project is not eligible 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. If the project is eligible for the Competitive Transmission Process, 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.



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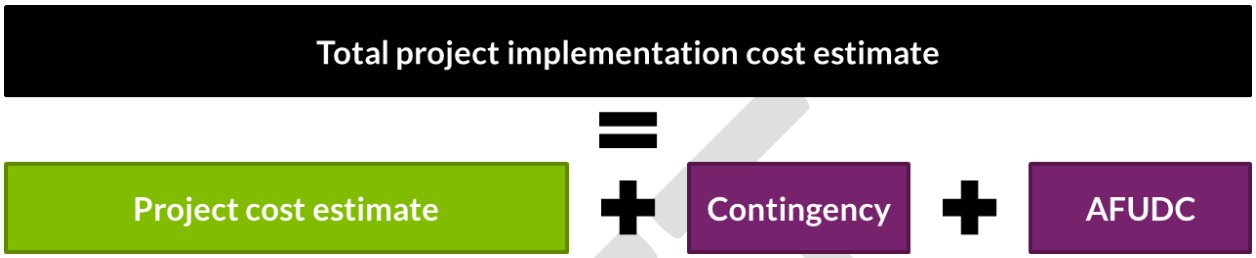
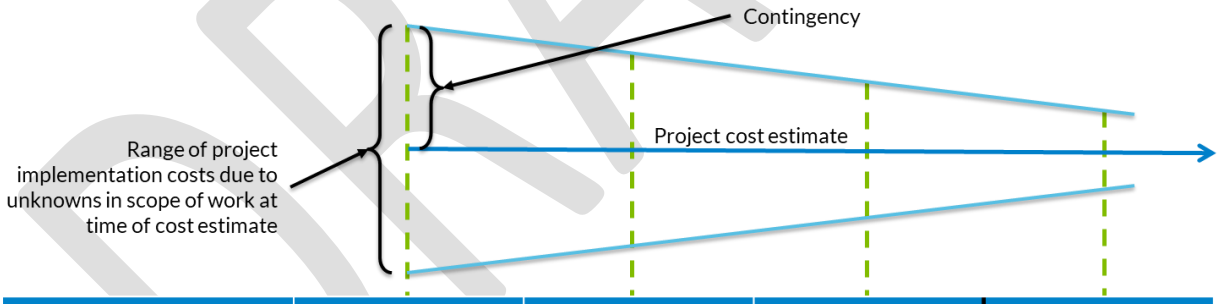
1. Total Project Implementation Cost

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



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 shown below.



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%

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

	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.

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 cost is the cost 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. All the unit costs MISO uses in its cost estimates are described below in this section 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 implementation scheduling and project management activities and resources for the project. Project management costs are estimated to be 5.5% of the project cost.

Administrative & General Overhead (A&G)

Projected overhead costs that will be allocated to the Project for the period prior to placing the project in service. Administrative & General Overhead (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. Engineering, environmental studies, and testing and commissioning costs are estimated to be 3.0% of the project cost.

Right-of-Way, land acquisition, and regulatory and permitting

Right-of-Way and land acquisition costs are costs to have an easement on the land for projects to be installed, 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. Pasture land values are based on USDA published values[1]. MISO utilizes the USDA pasture price as its initial cost for land value as it is a public resource that is updated yearly. MISO assumes that crop land is 3 times more expensive per acre than pasture land and that suburban/urban land is 5 times more expensive than pasture land. 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.

[1] United States Department of Aguriculture Land Values 2020 Summary - https://www.nass.usda.gov/Publications/Todays_Reports/reports/land0820.pdf

All land costs are based upon the acreage of land that the new transmission line would traverse or the substation or HVDC converter station would be sited. 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 MISO assumes. Different project conditions (e.g., more or less transmission line structures per mile) in different locations may have 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 345kV 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" statue 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.

Land costs

State – land	Right-of-Way cost per acre			Acquisition cost per acre	Regulatory & permitting cost per acre
	Pasture	Crop	Suburban & Urban		
Arkansas	$2,716	$8,149	$13,581	$12,608	$2,627
Illinois	$3,280	$9,840	$16,400	$12,608	$2,627
Indiana	$2,460	$7,380	$12,300	$12,608	$2,627
Iowa	$2,757	$8,272	$13,786	$12,608	$2,627
Kentucky	$3,126	$9,379	$15,631	$12,608	$2,627
Louisiana	$2,942	$8,825	$14,709	$12,608	$2,627
Michigan	$2,665	$7,995	$13,325	$12,608	$2,627
Minnesota	$1,722	$5,166	$8,610	$12,608	$8,773
Mississippi	$2,511	$7,534	$12,556	$12,608	$2,627
Missouri	$2,050	$6,150	$10,250	$12,608	$2,627
Montana	$697	$2,091	$3,485	$12,608	$2,627
North Dakota	$810	$2,429	$4,049	$12,608	$4,386
South Dakota	$1,076	$3,229	$5,381	$12,608	$3,520
Texas	$1,722	$5,166	$8,610	$12,608	$2,627
Wisconsin	$2,306	$6,919	$11,531	$12,608	$8,773

2.2 A/C and HVDC Transmission Lines

MISO's cost estimation guide contains costs both for alternating current (A/C) transmission lines and for high voltage direct current (HVDC) transmission lines. Both types of transmission lines rely on some similar project costs (i.e., land costs, conductor costs), and some unique costs dependent on the scope of work (i.e., structure costs).

MISO's A/C and HVDC transmission line cost estimates are sub-divided into smaller subcategories as shown below. The smaller subcategories of costs align with MISO's Request for Proposal for Competitive Transmission Projects. MISO's cost estimation guide includes estimated for costs for A/C transmission in voltage classes ranging from 69kV to 500kV, and HVDC transmission in voltage classes from ±250kV to ±600kV.

HVDC transmission has two major components – Transmission Line and Converter station. With the advancement of technology, both components of HVDC transmission have many options and customization for a specific need. For the purposes of creating a cost estimate, MISO will assume a bipole HVDC transmission line with a ground electrode return. Ground electrodes are assumed to be located at each end of the transmission line and connected by a ground electrode line.

Structures

Costs estimated to procure and install structures (inclusive of its required foundation) for new potential transmission line projects. Costs shown below 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 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 shieldwire (OPGW) is attached 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 and small angle structures. The shieldwire (OPGW) is attached to a shieldwire suspension assembly near top of structure.
- Non-Angled deadend structures are partial deadend structures and not designed for full terminal loads and 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 to be 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 the 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 to be 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 structures have the following unit costs as shown in the tables below:

- Material cost includes the cost of design, manufacture (material, labor, equipment) and delivery of the structure to site (laydown yard) and is based on the estimated steel weight.
- Installation cost is the cost 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.

A/C Transmission – Steel Pole – Single circuit							
Tangent structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	7,000	7,900	8,400	9,300	11,100	22,300	35,100
Foundation size (Cu. Yd)	5.5	6.0	8.0	9.0	13.0	21.0	41.0
Material	$16,072	$18,138	$19,286	$21,353	$25,486	$51,201	$80,590
Installation	$24,108	$27,208	$28,930	$32,029	$38,228	$76,801	$120,577
Hardware	$4,232	$4,937	$5,291	$5,996	$7,053	$9,437	$10,332
Foundation	$7,572	$8,259	$11,013	$12,389	$17,895	$28,908	$56,440
Running angle structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	11,600	13,000	13,900	15,300	18,300	37,900	59,700
Foundation size (Cu. Yd)	9.0	10.5	13.0	14.0	19.5	30.0	54.5
Material	$26,634	$29,848	$31,914	$35,129	$42,017	$87,018	$137,071
Installation	$39,950	$44,772	$47,872	$52,693	$63,025	$130,528	$205,607
Hardware	$4,232	$4,937	$5,291	$5,996	$7,053	$9,437	$10,332
Foundation	$12,389	$14,455	$17,895	$19,272	$26,844	$41,297	$75,024
Non-angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	14,000	15,800	16,800	18,600	22,200	42,400	66,700
Foundation size (Cu. Yd)	11.0	12.0	15.0	16.5	22.5	33.5	60.0
Material	$32,144	$36,277	$38,573	$42,706	$50,971	$97,350	$153,143
Installation	$48,216	$54,415	$57,859	$64,058	$76,457	$146,026	$229,715
Hardware	$8,345	$9,735	$11,821	$11,821	$13,908	$33,920	$53,358
Foundation	$15,142	$16,519	$22,714	$22,714	$30,973	$46,116	$82,595
Angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	20,400	23,000	24,500	27,100	32,400	48,100	80,700
Foundation size (Cu. Yd)	15.0	16.5	20.0	21.5	29.0	41.5	72.0
Material	$46,838	$52,808	$56,252	$62,222	$74,390	$110,438	$185,287
Installation	$70,258	$79,212	$84,378	$93,332	$111,586	$165,656	$277,931
Hardware	$8,345	$9,735	$10,431	$11,821	$13,908	$33,920	$53,358
Foundation	$20,649	$22,714	$27,532	$29,597	$39,921	$57,128	$99,113

A/C Transmission – Steel Tower – Single circuit							
Tangent structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	6,100	6,900	7,300	8,100	10,100	20,300	27,000
Foundation size (Cu. Yd)	8.5	11.5	13.5	14.5	15.5	19.5	33.5
Material	$11,692	$13,226	$13,992	$15,526	$19,359	$38,910	$51,752
Installation	$17,539	$19,839	$20,989	$23,289	$29,039	$58,366	$77,628
Hardware	$4,232	$4,937	$5,291	$5,996	$7,053	$9,437	$10,332
Foundation	$11,701	$15,831	$18,584	$19,961	$21,337	$26,844	$46,116
Running angle structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	9,200	10,400	11,000	12,200	15,200	30,500	39,800
Foundation size (Cu. Yd)	16.0	19.0	19.5	22.0	24.5	39.0	72.5
Material	$17,634	$19,934	$21,084	$23,384	$29,135	$58,461	$76,287
Installation	$26,451	$29,901	$31,626	$35,077	$42,702	$87,692	$114,430
Hardware	$4,232	$4,937	$5,291	$5,996	$7,053	$9,437	$10,332
Foundation	$22,025	$26,155	$26,844	$30,285	$33,727	$53,686	$99,302
Non-angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	10,400	11,700	12,400	13,800	17,200	34,500	45,900
Foundation size (Cu. Yd)	21.5	25.0	25.5	28.5	34.0	48.5	96.0
Material	$19,934	$22,426	$23,768	$26,451	$32,968	$66,128	$87,979
Installation	$29,901	$33,639	$35,632	$39,667	$49,452	$99,192	$131,969
Hardware	$8,345	$9,735	$10,431	$11,821	$13,908	$33,920	$53,358
Foundation	$29,597	$34,414	$35,103	$39,233	$46,804	$66,764	$132,151
Angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	13,400	15,200	16,100	17,800	22,200	44,700	59,400
Foundation size (Cu. Yd)	33.5	38.0	39.0	43.0	52.0	90.0	176.0
Material	$25,684	$29,135	$30,860	$34,118	$42,552	$85,679	$113,855
Installation	$38,527	$43,702	$46,290	$51,177	$63,828	$128,519	$170,782
Hardware	$8,345	$9,735	$10,431	$11,821	$13,908	$33,920	$53,358
Foundation	$46,116	$52,310	$53,686	$59,193	$71,582	$123,892	$242,277

A/C Transmission – Steel Pole – Double circuit							
Tangent structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	11,300	12,700	13,500	14,900	18,600	36,000	50,300
Foundation size (Cu. Yd)	8.0	10.0	14.5	17.5	23.0	46.5	78.5
Material	$25,945	$29,159	$30,996	$34,210	$42,706	$82,656	$115,489
Installation	$38,917	$43,739	$46,494	$51,316	$64,058	$123,984	$173,233
Hardware	$8,239	$9,612	$10,298	$11,672	$13,732	$18,478	$20,244
Foundation	$11,013	$13,766	$19,961	$24,091	$31,661	$64,011	$108,062
Running angle structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	15,000	16,800	17,900	19,700	24,600	47,700	70,400
Foundation size (Cu. Yd)	13.0	15.5	21.5	25.5	32.5	61.0	99.0
Material	$34,440	$38,573	$41,098	$45,231	$56,482	$109,519	$161,638
Installation	$51,660	$57,859	$61,648	$67,847	$84,722	$164,279	$242,458
Hardware	$8,239	$9,612	$10,298	$11,672	$13,732	$18,478	$20,244
Foundation	$17,895	$21,337	$29,597	$35,103	$44,739	$83,971	$136,281
Non-angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	16,700	18,700	19,900	22,000	27,400	54,000	75,500
Foundation size (Cu. Yd)	15.5	18.5	25.0	29.5	37.0	68.5	109.0
Material	$38,343	$42,935	$45,690	$50,512	$62,910	$123,984	$173,348
Installation	$57,515	$64,403	$68,536	$75,768	$94,366	$185,976	$260,022
Hardware	$16,457	$19,201	$20,573	$23,316	$27,430	$67,466	$106,330
Foundation	$21,337	$25,467	$34,414	$40,609	$50,933	$94,296	$150,047
Angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	26,000	29,200	31,100	34,300	42,800	84,600	118,200
Foundation size (Cu. Yd)	20.0	24.0	32.0	37.0	46.0	81.5	127.0
Material	$59,696	$67,043	$71,406	$78,753	$98,269	$194,242	$271,387
Installation	$89,544	$100,565	$107,108	$118,129	$147,403	$291,362	$407,081
Hardware	$16,457	$19,201	$20,573	$23,316	$27,430	$67,466	$106,330
Foundation	$27,532	$33,038	$44,050	$50,933	$63,322	$112,191	$174,825

A/C Transmission – Steel Tower – Double circuit							
Tangent structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	9,200	10,400	11,000	12,200	15,200	36,000	41,900
Foundation size (Cu. Yd)	13.0	17.0	19.5	21.0	22.0	31.5	48.5
Material	$17,634	$19,934	$21,084	$23,384	$29,135	$69,003	$80,312
Installation	$26,451	$29,901	$31,626	$35,077	$43,702	$103,505	$120,468
Hardware	$8,239	$9,612	$10,298	$11,672	$13,732	$18,478	$20,244
Foundation	$17,895	$23,402	$26,844	$28,908	$30,285	$43,363	$66,764
Running angle structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	13,800	15,600	16,500	18,300	22,800	53,100	62,900
Foundation size (Cu. Yd)	22.5	28.0	34.5	37.5	46.5	59.0	87.5
Material	$26,349	$29,901	$31,626	$35,077	$43,702	$101,779	$120,564
Installation	$39,677	$44,852	$47,440	$52,615	$65,553	$152,670	$180,846
Hardware	$8,239	$9,612	$10,298	$11,672	$13,732	$18,478	$20,244
Foundation	$30,973	$38,544	$47,492	$51,622	$64,011	$81,218	$120,451
Non-angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	16,100	18,200	19,300	21,400	26,600	61,200	71,200
Foundation size (Cu. Yd)	28.5	34.5	43.0	48.5	70.5	86.5	126.5
Material	$30,860	$34,885	$36,993	$41,018	$50,986	$117,305	$136,473
Installation	$46,290	$52,327	$55,490	$61,528	$76,478	$175,958	$204,709
Hardware	$16,457	$19,201	$20,573	$23,316	$27,430	$67,466	$106,330
Foundation	$39,233	$47,492	$59,193	$66,764	$97,049	$119,074	$174,137
Angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Steel weight (lbs.)	21,200	23,900	25,300	28,100	35,000	79,200	92,200
Foundation size (Cu. Yd)	43.0	50.5	61.5	68.5	99.0	125.0	236.0
Material	$40,635	$45,810	$48,494	$53,861	$67,086	$151,807	$176,724
Installation	$60,953	$68,716	$72,741	$80,792	$100,629	$227,710	$265,087
Hardware	$16,457	$19,201	$20,573	$23,316	$27,430	$67,466	$106,330
Foundation	$59,193	$69,518	$84,660	$94,265	$136,281	$172,072	$324,672

A/C Transmission – Wood Pole – Single circuit							
Tangent structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Material	$4,518	$8,457	$8,563	$11,399	$12,345	N/A	N/A
Installation	$12,608	$13,133	$14,709	$21,013	$31,519	N/A	N/A
Hardware	$4,413	$4,991	$5,463	$6,041	$7,880	N/A	N/A
Running angle structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Material	$7,932	$14,814	$14,971	$19,962	$21,591	N/A	N/A
Installation	$22,063	$23,009	$25,741	$36,772	$55,158	N/A	N/A
Hardware	$7,722	$8,721	$9,561	$10,559	$13,816	N/A	N/A
Angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Material	$9,035	$16,968	$17,126	$22,799	$24,690	N/A	N/A
Installation	$25,215	$26,266	$29,418	$42,025	$63,038	N/A	N/A
Hardware	$8,825	$9,981	$10,927	$12,083	$15,759	N/A	N/A

A/C Transmission – Wood Pole – Double circuit							
Tangent structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Material	$7,460	$13,974	N/A	N/A	N/A	N/A	N/A
Installation	$20,802	$21,695	N/A	N/A	N/A	N/A	N/A
Hardware	$7,302	$8,247	N/A	N/A	N/A	N/A	N/A
Running angle structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Material	$13,080	$24,427	N/A	N/A	N/A	N/A	N/A
Installation	$36,404	$37,980	N/A	N/A	N/A	N/A	N/A
Hardware	$12,765	$14,394	N/A	N/A	N/A	N/A	N/A
Angled deadend structure							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Material	$14,919	$27,999	N/A	N/A	N/A	N/A	N/A
Installation	$41,650	$43,338	N/A	N/A	N/A	N/A	N/A
Hardware	$14,858	$16,495	N/A	N/A	N/A	N/A	N/A

HVDC Transmission – Steel Pole – Single circuit				
Tangent structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	14,773	19,943	21,938	26,325
Foundation size (Cu. Yd)	17.0	23.0	26.0	31.0
Material	$33,990	$45,886	$50,475	$60,570
Installation	$50,986	$68,830	$75,713	$90,856
Hardware	$4,587	$5,843	$6,355	$6,663
Foundation	$23,448	$31,655	$35,268	$42,322
Running angle structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	25,126	33,920	37,313	44,775
Foundation size (Cu. Yd)	23.0	31.0	34.0	41.0
Material	$57,812	$78,047	$85,851	$103,022
Installation	$86,718	$117,069	$128,777	$154,532
Hardware	$5,734	$7,303	$7,944	$8,328
Foundation	$31,570	$42,618	$46,880	$56,257
Non-angled deadend structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	28,072	37,898	41,688	50,025
Foundation size (Cu. Yd)	25.0	34.0	38.0	45.0
Material	$64,590	$87,198	$95,917	$115,101
Installation	$96,886	$130,796	$143,876	$172,651
Hardware	$9,046	$21,909	$23,831	$24,984
Foundation	$34,756	$46,920	$51,612	$61,935
Angled deadend structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	33,965	45,852	50,438	60,525
Foundation size (Cu. Yd)	30.0	41.0	45.0	54.0
Material	$78,148	$105,500	$116,051	$139,260
Installation	$117,222	$158,250	$174,075	$208,890
Hardware	$9,046	$21,909	$23,831	$24,984
Foundation	$41,706	$56,304	$61,935	$74,322

HVDC Transmission – Steel Tower – Single circuit				
Tangent structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	10,227	15,341	16,875	20,250
Foundation size (Cu. Yd)	13.0	19.0	21.0	25.0
Material	$19,556	$29,333	$32,267	$38,720
Installation	$29,333	$44,001	$48,401	$58,082
Hardware	$4,587	$5,843	$6,355	$6,663
Foundation	$17,465	$26,197	$28,817	$34,580
Running angle structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	16,751	22,614	24,875	29,850
Foundation size (Cu. Yd)	31.0	41.0	45.0	54.0
Material	$32,030	$43,241	$47,564	$57,077
Installation	$48,045	$64,861	$71,346	$85,616
Hardware	$5,734	$7,303	$7,944	$8,328
Foundation	$41,996	$56,695	$62,364	$74,837
Non-angled deadend structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	19,318	26,080	28,688	34,425
Foundation size (Cu. Yd)	40.0	55.0	60.0	72.0
Material	$36,969	$49,867	$54,855	$65,826
Installation	$55,480	$74,801	$82,282	$98,738
Hardware	$9,046	$21,909	$23,831	$24,984
Foundation	$55,609	$75,072	$82,579	$99,095
Angled deadend structure				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Steel weight (lbs.)	25,000	33,750	37,125	44,550
Foundation size (Cu. Yd)	74.0	100.0	110.0	132.0
Material	$47,804	$64,535	$70,988	$85,186
Installation	$71,705	$96,802	$106,482	$127,779
Hardware	$9,046	$21,909	$23,831	$24,984
Foundation	$101,950	$137,632	$151,396	$181,674

Project specific environmental circumstances of an individual project may lead to additional installation costs. Where a new transmission line traverses a forested area, wetland area, or mountainous terrain, the following additional costs are considered.

Additional structure installation costs	
Voltage class	69kV – 600kV line
Forested clearing cost (per acre)	$5,305
Wetland (per acre)	Matting & construction difficulties: $61,921 Wetland mitigation credits: $49,672
Mountainous terrain (per acre)	$6,897

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.

Transmission line removal/retirement $/mile							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Wood pole – single circuit	$194,366	$226,192	$236,391	$249,524	$278,416	N/A	N/A
Wood pole – double circuit	$315,188	$362,466	N/A	N/A	N/A	N/A	N/A

Conductor

Costs estimated to procure and install conductor required for transmission line projects 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 Business Practice Manual 029 to assign appropriate conductor type. See initial assumptions to see MISO's indicative conductor selection and ratings for different voltage classes.

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

MISO primarily considers ACSR (Aluminum Conductor Steel Reinforce), ACSS (Aluminum Conductor Steel Supported) conductor types in its cost estimates. Where required, MISO would consider the cost for T2 to be equivalent to two conductors of that size to the same cost when creating its cost estimate.

Conductors have the following unit costs as shown in the tables below:

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

Conductor costs (<1000 kcmil)				
Conductor	Material cost per 1000 feet		Installation cost per 1000 feet	Accessories cost per 1000 feet
	ACSR	ACSS		
266.8 kcmil "Waxwing"	$566	$552	$770	$245
266.8 kcmil "Partridge"	$683	$706	$954	$245
336.4 kcmil "Merlin"	$604	$673	$875	$245
336.4 kcmil "Linnet"	$696	$806	$1,028	$245
336.4 kcmil "Oriole"	$868	$894	$1,210	$245
397.5 kcmil "Chickadee"	$745	$784	$1,050	$245
397.5 kcmil "Ibis"	$895	$955	$1,269	$245
397.5 kcmil "Lark"	$884	$1,060	$1,329	$245
477 kcmil "Pelican"	$873	$960	$1,257	$245
477 kcmil "Flicker"	$838	$1,004	$1,261	$245
477 kcmil "Hawk"	$1,043	$1,115	$1,481	$245
477 kcmil "Hen"	$1,162	$1,192	$1,617	$245
556.5 kcmil "Osprey"	$1,049	$1,060	$1,449	$245
556.5 kcmil "Parakeet"	$1,230	$1,225	$1,689	$245
556.5 kcmil "Dove"	$1,163	$1,281	$1,676	$245
636 kcmil "Kingbird"	$1,013	$1,192	$1,509	$245
636 kcmil "Rook"	$1,148	$1,379	$1,729	$245
636 kcmil "Grosbeak"	$1,315	$1,435	$1,887	$245
666.6 kcmil "Flamingo"	$1,356	$1,590	$1,994	$245
795 kcmil "Coot"	$1,343	$1,490	$1,942	$245
795 kcmil "Tern"	$1,269	$1,512	$1,903	$245
795 kcmil "Cuckoo"	$1,413	$1,700	$2,129	$245
795 kcmil "Condor"	$1,468	$1,700	$2,169	$245
795 kcmil "Drake"	$1,590	$1,599	$2,192	$245
900 kcmil "Canary"	$1,800	$1,755	$2,445	$245
954 kcmil "Rail"	$1,677	$1,706	$2,325	$245
954 kcmil "Cardinal"	$1,836	$1,892	$2,561	$245

Conductor costs (>1000 kcmil)				
Conductor	Material cost per 1000 feet		Installation cost per 1000 feet	Accessories cost per 1000 feet
	ACSR	ACSS		
1033.5 kcmil "Ortolan"	$1,839	$2,274	$2,811	$245
1033.5 kcmil "Curlew"	$2,028	$1,921	$2,718	$245
1113 kcmil "Bluejay"	$1,954	$2,440	$3,002	$245
1192.5 kcmil "Bunting"	$1,822	$2,042	$2,648	$245
1272 kcmil "Bittern"	$2,111	$2,185	$2,951	$245
1272 kcmil "Pheasant"	$2,307	$2,527	$3,315	$245
1351.5 kcmil "Dipper"	$2,283	$2,770	$3,456	$245
1351.5 kcmil "Martin"	$2,829	$2,462	$3,651	$245
1431 kcmil "Bobolink"	$2,588	$2,881	$3,749	$245
1590 kcmil "Lapwing"	$2,669	$2,826	$3,772	$245
1590 kcmil "Falcon"	$3,150	$3,153	$4,333	$245
1780 kcmil "Chukar"	$3,432	$3,676	$4,878	$245
2156 kcmil "Bluebird"	$4,043	$4,492	$5,851	$245
2167 kcmil "Kiwi"	$3,661	$5,354	$6,134	$245
2312 kcmil "Thrasher"	$4,194	$4,801	$6,162	$245
2515 kcmil "Joree"	$4,458	$5,034	$6,504	$245

OPGW and shieldwire

Costs estimated to procure and install Optical Groundwire (OPGW) and/or shieldwire required for transmission line projects 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 conductor and shieldwire length adder of 4% for sag and wastage per conductor, OPGW, and shieldwire. Optical Groundwire (OPGW) and shieldwire are installed at the top of structures to protect the conductors below from direct lightning strikes and includes fiber optic cable. OPGW and shield wires have the following unit costs as shown in the tables below:

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

OPGW and shieldwire costs		
Wire	Material cost per 1000 feet	Installation cost per 1000 feet
Shieldwire	$551	$828
OPGW	$2,495	$3,742

2.3 A/C Substations

Substation cost estimates are sub-divided in to the cost categories as shown in the table below. 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 for initial assumptions in this guide. 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

Costs estimated to prepare the land for a substation including clearing, grading, grounding and physical security. Depending on the terrain encountered for a specific substation site (e.g., forested area, or wetlands), additional costs may be required. Where specialized site components are required (e.g. specialized gates, access protection, import/export of soil) MISO will add those costs to its cost estimate and will call them out separately.

Site work unit costs	
Voltage class	69kV – 500kV
Level ground with light vegetation (per acre)	$357,095
Forested land (per acre)	+$5,305
Wetland (per acre)	+$61,921 for matting and construction difficulties
	+$49,672 for wetland mitigation credits

Access Road

Access roads 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 $538,125 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. Costs are divided into the following subcategories:

- Material cost is the cost to procure and deliver electrical equipment materials to site (laydown yard).
- Installation cost is the cost to assemble and place on foundation or steel structure.
- As applicable, 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 cost includes the cost of design, manufacture (material, labor, equipment) and delivery of the structure to site (laydown yard) and is based on the estimated steel weight.
- Steel structure installation cost is the cost to place the steel stand on the foundation.
- 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.

Circuit breaker unit costs

Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Foundation size (Cu. Yd)	3.6	4.5	5.3	6.7	8.0	8.8	19.8
Material cost	$42,025	$52,531	$55,158	$57,784	$99,809	$330,422	$434,959
Installation cost	$7,880	$8,405	$8,931	$9,456	$10,506	$15,759	$21,013
Jumpers, conduit, wiring, grounding	$8,405	$9,456	$10,506	$12,608	$15,759	$21,013	$26,266
Foundation cost	$4,956	$6,195	$7,296	$9,223	$11,013	$12,113	$27,256

Disconnect switch (3-phase) unit costs							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Foundation size (Cu. Yd)	3.4	4.2	5.2	6.5	7.8	8.0	18.0
Steel stand weight (pounds)	1500	1750	2000	2500	3500	4000	5000
Material cost	$10,506	$13,133	$15,759	$18,386	$21,013	$36,772	$52,531
Installation cost	$6,304	$7,354	$8,405	$9,456	$10,506	$15,759	$21,013
Jumpers, and grounding	$4,203	$4,728	$5,253	$6,304	$7,880	$10,506	$13,133
Steel stand material cost	$3,444	$4,018	$4,592	$5,740	$8,036	$9,184	$11,480
Steel stand installation cost	$3,961	$4,621	$5,281	$6,601	$9,241	$10,599	$13,202
Foundation cost	$4,680	$5,782	$7,159	$8,948	$10,737	$11,013	$24,778

Bus support, bus, and fittings (3-phase) unit costs							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Foundation size (Cu. Yd)	3.1	3.9	4.8	6.0	7.2	9.6	14.4
Steel stand weight (pounds)	1000	1250	1500	1750	2000	3000	4500
Material cost	$6,041	$7,565	$8,721	$9,167	$9,613	$11,373	$13,107
Installation cost	$7,250	$9,077	$10,464	$11,000	$11,536	$13,648	$15,728
Steel stand material cost	$2,296	$2,870	$3,444	$4,018	$4,592	$6,888	$10,332
Steel stand installation cost	$2,640	$3,301	$3,961	$4,621	$5,281	$7,921	$11,882
Foundation cost	$4,267	$5,369	$6,607	$8,259	$9,912	$13,215	$19,822

Voltage Transformer (set of 3) unit costs							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Foundation size (Cu. Yd)	1.8	2.3	2.7	3.4	4.0	8.0	12.1
Steel stand weight (pounds)	1250	1350	1425	1500	1750	2000	2500
Material cost	$21,013	$23,640	$26,266	$28,893	$36,772	$44,126	$84,050
Installation cost	$2,101	$2,364	$2,627	$2,889	$3,152	$4,203	$5,253
Jumpers, conduit, wiring, grounding	$6,304	$7,092	$7,880	$9,456	$11,819	$15,759	$19,696
Steel stand material cost	$2,870	$3,100	$3,272	$3,444	$4,018	$4,592	$5,740
Steel stand installation cost	$3,301	$3,565	$3,763	$3,961	$4,621	$5,281	$6,601
Foundation cost	$2,477	$3,166	$3,717	$4,680	$5,506	$11,013	$16,656

Current Transformer (set of 3) unit costs							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Foundation size (Cu. Yd)	1.8	2.3	2.7	3.4	4.0	8.0	12.1
Steel stand weight (pounds)	1250	1350	1425	1500	1750	2000	2500
Material cost	$64,850	$81,056	$110,421	$121,452	$132,537	$220,868	$386,525
Installation cost	$2,101	$2,364	$2,627	$2,889	$3,152	$4,203	$5,253
Jumpers, conduit, wiring, grounding	$6,304	$7,092	$7,880	$9,456	$11,819	$15,759	$19,696
Steel stand material cost	$2,870	$3,100	$3,272	$3,444	$4,018	$4,592	$5,740
Steel stand installation cost	$3,301	$3,565	$3,763	$3,961	$4,621	$5,281	$6,601
Foundation cost	$2,477	$3,166	$3,717	$4,680	$5,506	$11,013	$16,656

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.

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. 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.

Power transformer ($/MVA)							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
69kV	$4,961	$4,039	$4,469	$4,705	$5,217	$6,406	$8,262
115kV	$4,039	$5,494	$4,469	$4,705	$5,217	$6,089	$7,472
138kV	$4,469	$4,469	$6,089	$4,961	$5,217	$6,089	$7,472
161kV	$4,705	$4,705	$4,961	$6,745	$5,494	$6,406	$7,862
230kV	$5,217	$5,217	$5,217	$5,494	$7,472	$6,406	$7,862
345kV	$6,406	$6,089	$6,089	$6,406	$6,406	$9,102	$8,0262
500kV	$8,262	$7,472	$7,472	$7,862	$7,862	$8,262	$12,198

Grid supporting devices unit costs are the costs associated to procure and install devices to support the grid. 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 the table below and should be included separate in a cost estimate if needed. Certain grid supporting devices are nominally rated less than transmission voltage (i.e., less than 69kV). In order to connect those devices to the transmission system, they must be stepped up to a transmission voltage. For a scoping cost estimate, MISO will discuss grid supporting device pricing with vendors.

Grid supporting devices unit costs							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Reactor ($/MVAr)	$14,262	$14,262,	$14,262	$14,262	$14,262	$14,262	$14,262
Capacitor bank ($/MVAr)	$10,506	$10,506	$10,506	$10,506	$10,506	$10,506	$10,506
Static VAr Compensator ($/MVAr)	$101,043	$101,043	$101,043	$101,043	$101,043	$101,043	$101,043
STATCOM ($/MVAr)	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
Synchronous condenser ($/MVAr)	$150,000/MVAr + $150/kw (step-up to 69kV)						
Energy storage (lithium ion)	Battery system: $300/kwh + Inverter: $80/kw + $150/kw (step-up to 69kV)						

Control Enclosure and communication system

Cost estimated for one control enclosure of approximately 500 square feet. Material and installation cost are the cost to procure and deliver one control enclosure to site (laydown yard), offload and placement of the control enclosure on the foundation and wiring of the AC/DC systems to field equipment. Control enclosure includes AC panels, DC panels, cable tray, and all other typical components. Relay panels are considered separately. Battery and battery charger costs is the material and installation cost for the batteries in the control enclosure and their associated battery charger. Communication equipment costs are the cost to 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.

Control enclosure unit costs

Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Foundation size (Cu. Yd)	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Material and installation cost	$315,188	$315,188	$315,188	$315,188	$315,188	$315,188	$315,188
Battery and battery charger	$105,063	$105,063	$105,063	$105,063	$105,063	$105,063	$105,063
Communication equipment	$105,063	$105,063	$105,063	$105,063	$105,063	$157,594	$157,594
Station service power	$115,569	$115,569	$115,569	$115,569	$115,569	$136,581	$136,581
Foundation cost	$24,778	$24,778	$24,778	$24,778	$24,778	$24,778	$24,778

Relay Panels

Costs estimated for one relay panel per voltage class. Material cost is the cost to procure and deliver one relay panel to 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 control enclosure; wiring from field equipment; inter-panel wiring to other relay panels inside control enclosure.

Relay panel unit costs

Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Material cost	$19,699	$24,558	$30,731	$34,671	$38,348	$51,218	$64,088
Installation cost	$39,399	$49,117	$61,462	$69,341	$76,696	$102,436	$128,176

Control Cable, Conduit, and Cable Trench

Control cable unit cost is the cost associated with 1000 feet of control cable. Material cost is the cost to procure and deliver 1000 feet of control cable to site (laydown yard). Installation cost includes placing and pulling control cable in conduit and/or cable trench and bringing the control cable to its end point where it will be landed. Final wiring of landing on terminal blocks is included in other unit costs.

Control cable unit costs

Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Material cost per 1000 feet	$3,152	$3,152	$3,152	$3,152	$3,152	$4,203	$4,203
Installation cost per 1000 feet	$5,253	$5,253	$5,253	$5,253	$5,253	$5,253	$5,253

Conduit unit cost is the cost associated with 1000 feet of conduit. Material cost is the cost to procure and deliver 1000 feet of conduit to 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.

Conduit unit costs

Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Material cost per 1000 feet	$3,152	$3,152	$3,152	$3,152	$3,152	$3,152	$3,152
Installation cost per 1000 feet	$42,025	$42,025	$42,025	$42,025	$42,025	$42,025	$42,025

Cable trench unit cost is the cost associated with 1 foot of cable trench inclusive of lid/cover. Material cost is the cost to procure and deliver 1 foot of cable trench to 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.

Cable trench unit costs

Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Material cost per 1 foot	$52	$52	$52	$52	$52	$52	$52
Installation cost per 1 foot	$210	$210	$210	$210	$210	$210	$210

2.4 HVDC Converter Stations

Converter stations are required at each endpoint of an HVDC transmission line in order to interconnection with the A/C transmission system. MISO includes in its guide two converter station design types - line-commutated thyristor valve technology (LCC) and Voltage-Source transistor technology (VSC).

In addition to only a converter station, there would also be A/C substation equipment needed to interconnect. Typical interconnection voltages would be 230kV A/C for a ±250kV HVDC transmission line, 345kV A/C for a ±400kV HVDC transmission line, and 500kV A/C for a ±500kV and ±600kV HVDC transmission line. For the purposes of creating a cost estimate, in the tables below, MISO assumes its exploratory costs for a new 4-position, breaker-and-a-half substation for the A/C substation costs connected with a new converter station.

At each converter station, MISO assumes a ground electrode is installed. 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 option of return path 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 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.

Line Commutated Converter (LCC) Stations are composed of thyristor valves and are located indoors to provide safe, clean and controlled operating environment. The cost of bipolar converter station valve hall includes land and land acquisition, building, DC switching station equipment including DC filters, converter transformer, insulation, control devices and services. LCC stations require A/C 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.

Converter Station Line Commutated Converter (LCC) – one end				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Power Transfer	500MW	1500MW	2000MW	2400MW
Assumed Reactive Power Need	167MVAR	500MVAR	667MVAR	800MVAR
Ground electrode line length	20 miles	20 miles	20 miles	20 miles
Valve hall	$30.8M	$112.8M	$153.8M	$189.6M
A/C filters	$3.1M	$11.3M	$15.4M	$19.0M
Reactive power	$16.9M	$50.5M	$67.4M	$80.9M
A/C Substation	$11.0M	$16.1M	$23.4M	$23.4M
Ground electrode	$2.8M	$3.7M	$3.8M	$4.0M
Ground electrode line	$4.1M	$10.3M	$12.3M	$15.4M

Voltage Source Converter (VSC) Stations are composed of IGBT valves and are located indoors to provide safe, clean and controlled operating environment. The cost of bipolar converter station valve hall includes land and land acquisition, building, 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.

Converter Station Voltage Source Converter (VSC) – one end				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Power Transfer	500MW	1500MW	2000MW	2400MW
Ground electrode line length	20 miles	20 miles	20 miles	20 miles
Valve hall	$73.8.M	$235.8M	$317.8M	$389.5M
A/C Substation	$11.0M	$16.1M	$23.4M	$23.4M
Ground electrode	$2.8M	$3.7M	$3.8M	$4.0M
Ground electrode line	$4.1M	$10.3M	$12.3M	$15.4M

3. Initial assumptions

To create a cost estimate, MISO must make initial assumptions about the scopes of work for potential projects. This section lists out all the initial assumptions MISO makes. 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 A/C and HVDC Transmission Lines

Line length

The line length for a transmission line 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 is intended to account 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/re-conductor projects, MISO assumes that the existing right-of-way is adequate. MISO does not share its assumed proxy route information with stakeholders, as the route could be perceived as a MISO endorsed/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 considers are intended to be indicative of right-of-way widths for transmission lines in each voltage class. Different project conditions in different locations may have a wider or narrower right-of-way width than the indicative value MISO assumes. MISO's assumptions for right-of-way width are in the tables below:

Right-of-Way width

A/C Transmission (single and double circuit)							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Feet	80	90	95	100	125	175	200

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

Structures per mile

In order to create a cost estimate for transmission lines, MISO makes indicative assumptions about the quantity of structures per mile required. The indicative assumptions are not connected to any specific project. For A/C Transmission, MISO assumes steel pole structure type for 69kV – 345kV, and steel tower structure type for 500kV. For HVDC, MISO assumes steel pole structure type for 250kV, and steel tower structure for 400kV – 600kV. The quantity of structures per mile that MISO assumes for its cost estimates are shown in the tables below:

Structures per mile – A/C transmission
Steel tower & steel pole (single circuit / double circuit)

Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Tangent structures	9 / 9.5	8.5 / 9	8 / 8.5	7 / 7.5	5 / 7	4.5 / 6	3.0 / 5
Running angle structures	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1
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 / 0.25
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 / 0.25

Structures per mile – A/C transmission
Wood pole (single circuit / double circuit)

Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
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 / N/A
Running angle structures	1 / 1	1 / 1	1 / N/A	1 / N/A	1 / N/A	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 / N/A

Structures per mile – HVDC transmission
Steel tower & steel pole (single circuit)

Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Tangent structures	4.5	4.0	3.5	3.0
Running angle structures	0.5	0.5	0.5	0.5
Non-angled structures	0.25	0.25	0.25	0.25
Angled structures	0.25	0.25	0.25	0.25

Conductor selection

Conductor selection for MISO's exploratory cost estimates are shown in the table below. The conductor selected is intended to be typical for a circuit in the voltage class. Specific solution ideas may necessitate different conductors than as shown below.

Conductor selection per circuit – A/C Transmission							
Voltage class	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Conductor size	477kcmil	795kcmil	795kcmil	795kcmil	795kcmil	795kcmil	954kcmil
Conductor type	ACSS	ACSS	ACSS	ACSS	ACSS	ACSS	ACSR
Conductor quantity	1	1	1	1	1	2	3
Amp rating	1175	1650	1650	1650	1650	3300	3000
Power rating (MVA)	140	329	394	460	657	1972	2598

Conductor selection per circuit – HVDC Transmission				
Voltage class	± 250kV line	± 400kV line	± 500kV line	± 600kV line
Conductor size	1590kcmil	1590kcmil	1590kcmil	1590kcmil
Conductor type	ACSR	ACSR	ACSR	ACSR
Conductor quantity per pole	1	2	2	2
Power transfer	500MW	1500MW	2000MW	2400MW

Land and Terrain type

A significant cost driver for transmission line projects is the land and terrain types encountered. MISO recognizes that different States present different environments to be accounted for in its cost estimates. In order to provide exploratory cost estimates on a State-by-State basis, MISO makes different assumptions on the land and terrain encountered unique to each State in the MISO footprint. The indicative assumptions in the tables below are not tied to any specific project and are intended for the sole purpose of providing MISO's exploratory cost estimate.

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	Crop land	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 A/C Substations

In order to provide exploratory cost estimates for substations, MISO makes indicative assumptions for the quantity of equipment required for substation upgrades and for new substations. The indicative assumptions for substation equipment tables below are not tied to any specific project and are intended for the sole purpose of providing MISO's exploratory cost estimate.

Initial assumptions – bus ratings							
Voltage class	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Amp rating	1200	2000	2000	2000	2000	3000	3000
Power rating (MVA)	143	398	478	558	797	1793	2598

Substation upgrade – add 1 position (ring / breaker-and-a-half / double-breaker bus)

Scope of work	69kV	115kV	138kV	161kV	230kV	345kV	500kV
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
Access road (mile)	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
Disconnect switches (each)	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
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
Deadend structure	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
Relay panel(s)	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

Substation upgrade – add 2 positions (ring / breaker-and-a-half / double-breaker bus)

Scope of work	69kV	115kV	138kV	161kV	230kV	345kV	500kV
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
Access road (mile)	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
Disconnect switches (each)	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
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
Deadend structure	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
Relay panel(s)	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

New substation – 4 positions (ring / breaker-and-a-half / double-breaker bus)

Scope of work	69kV	115kV	138kV	161kV	230kV	345kV	500kV
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
Access road (mile)	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
Disconnect switches (each)	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
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
Deadend structure	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
Relay panel(s)	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

New substation – 6 positions (ring / breaker-and-a-half / double-breaker bus)

Scope of work	69kV	115kV	138kV	161kV	230kV	345kV	500kV
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
Access road (mile)	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
Disconnect switches	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
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
Deadend structure	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
Relay panel(s)	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

4. Exploratory Costs

In the planning process it can be helpful to explore many different project ideas quickly to assess broadly if they would be viable. MISO provides exploratory cost estimates which are intended for projects with low levels of scope definition. Exploratory cost estimates are high-level cost estimates which MISO does not recommend using 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 below are based on the assumptions and cost data as 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, all the details of which are shared with stakeholders for their review and comment. In the tables below, MISO is providing its exploratory cost estimate in a $/mile cost as defined by its voltage class and by the State where the potential project would be developed.

4.1 A/C and HVDC Transmission Lines

Exploratory cost estimate – A/C Transmission
New single circuit transmission line $/mile

Location – State	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Arkansas	$1.5M	$1.7M	$1.8M	$1.8M	$1.9M	$3.1M	$3.3M
Illinois	$1.6M	$1.7M	$1.8M	$1.9M	$2.0M	$3.2M	$3.3M
Indiana	$1.5M	$1.7M	$1.7M	$1.8M	$1.9M	$3.0M	$3.2M
Iowa	$1.5M	$1.7M	$1.8M	$1.8M	$1.9M	$3.1M	$3.3M
Kentucky	$1.6M	$1.8M	$1.9M	$1.9M	$2.1M	$3.3M	$3.5M
Louisiana	$1.8M	$2.0M	$2.1M	$2.1M	$2.3M	$3.6M	$3.9M
Michigan	$1.6M	$1.8M	$1.9M	$1.9M	$2.1M	$3.3M	$3.5M
Minnesota	$1.6M	$1.7M	$1.8M	$1.9M	$2.0M	$3.2M	$3.4M
Mississippi	$1.8M	$1.9M	$2.0M	$2.1M	$2.3M	$3.6M	$3.8M
Missouri	$1.5M	$1.7M	$1.8M	$1.8M	$1.9M	$3.1M	$3.2M
Montana	$1.4M	$1.6M	$1.6M	$1.7M	$1.7M	$2.8M	$3.0M
North Dakota	$1.4M	$1.6M	$1.7M	$1.7M	$1.8M	$2.9M	$3.0M
South Dakota	$1.4M	$1.6M	$1.7M	$1.7M	$1.8M	$2.9M	$3.0M
Texas	$1.7M	$1.9M	$2.0M	$2.0M	$2.2M	$3.5M	$3.7M
Wisconsin	$1.6M	$1.8M	$1.8M	$1.9M	$2.0M	$3.2M	$3.4M

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

Exploratory cost estimate – A/C Transmission New double circuit transmission line $/mile							
Location – State	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Arkansas	$2.2M	$2.5M	$2.6M	$2.7M	$3.2M	$5.2M	$5.4M
Illinois	$2.2M	$2.5M	$2.6M	$2.7M	$3.2M	$5.2M	$5.4M
Indiana	$2.2M	$2.4M	$2.6M	$2.6M	$3.1M	$5.1M	$5.3M
Iowa	$2.2M	$2.5M	$2.6M	$2.7M	$3.1M	$5.1M	$5.4M
Kentucky	$2.3M	$2.5M	$2.7M	$2.8M	$3.3M	$5.3M	$5.6M
Louisiana	$2.4M	$2.7M	$2.9M	$3.0M	$3.5M	$5.7M	$6.0M
Michigan	$2.3M	$2.5M	$2.7M	$2.8M	$3.3M	$5.3M	$5.6M
Minnesota	$2.2M	$2.5M	$2.6M	$2.7M	$3.2M	$5.2M	$5.5M
Mississippi	$2.4M	$2.7M	$2.9M	$2.9M	$3.5M	$5.6M	$5.9M
Missouri	$2.2M	$2.4M	$2.6M	$2.6M	$3.1M	$5.1M	$5.3M
Montana	$2.1M	$2.3M	$2.5M	$2.5M	$3.0M	$4.9M	$5.1M
North Dakota	$2.1M	$2.3M	$2.5M	$2.5M	$3.0M	$4.9M	$5.1M
South Dakota	$2.1M	$2.3M	$2.5M	$2.5M	$3.0M	$4.9M	$5.2M
Texas	$2.4M	$2.7M	$2.8M	$2.9M	$3.4M	$5.5M	$5.8M
Wisconsin	$2.2M	$2.5M	$2.7M	$2.7M	$3.2M	$5.3M	$5.5M

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

Exploratory cost estimate – A/C Transmission Rebuild and reconductor transmission line $/mile							
Location – All States	69kV line	115kV line	138kV line	161kV line	230kV line	345kV line	500kV line
Rebuild – single circuit	$1.4M	$1.5M	$1.6M	$1.6M	$1.7M	N/A	N/A
Rebuild – double circuit	$2.0M	$2.3M	N/A	N/A	N/A	N/A	N/A
Reconductor – per circuit	$0.30M	$0.34M	$0.34M	$0.35M	$0.33M	$0.54M	$0.65M

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

Exploratory cost estimate – HVDC Transmission New bipole transmission line $/mile				
Location – State	250kV line	400kV line	500kV line	600kV line
Arkansas	$2.0M	$2.4M	$2.5M	$2.7M
Illinois	$2.1M	$2.4M	$2.5M	$2.7M
Indiana	$2.0M	$2.3M	$2.4M	$2.5M
Iowa	$2.1M	$2.3M	$2.5M	$2.6M
Kentucky	$2.2M	$2.5M	$2.7M	$2.9M
Louisiana	$2.4M	$2.9M	$3.1M	$3.3M
Michigan	$2.2M	$2.5M	$2.7M	$2.8M
Minnesota	$2.1M	$2.4M	$2.6M	$2.7M
Mississippi	$2.4M	$2.8M	$3.0M	$3.2M
Missouri	$2.0M	$2.3M	$2.4M	$2.6M
Montana	$1.8M	$2.1M	$2.2M	$2.3M
North Dakota	$1.9M	$2.1M	$2.2M	$2.4M
South Dakota	$1.9M	$2.1M	$2.2M	$2.4M
Texas	$2.3M	$2.7M	$2.9M	$3.1M
Wisconsin	$2.1M	$2.5M	$2.6M	$2.8M

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

4.2 A/C Substations

In the planning process it can be helpful to explore many different project ideas quickly to assess broadly if they would be viable. MISO provides exploratory cost estimates which are intended for projects with low levels of scope definition. Exploratory cost estimates are high-level cost estimates which MISO does not recommend using 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 below are based on the assumptions and cost data as 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, all the details of which are shared with stakeholders for their review and comment.

Substations have a variety of layouts and arrangements. MISO's exploratory cost estimates for substations are intended to capture the most common substation arrangements that are estimated in MISO's planning process. The arrangements selected for the exploratory indicative cost estimates in this section 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 line ratings assumed by MISO for its transmission line project cost estimates.

Exploratory cost estimate – substation upgrade							
Scope of work	69kV	115kV	138kV	161kV	230kV	345kV	500kV
Add 1 position (ring bus)	$1.1M	$1.3M	$1.5M	$1.6M	$1.9M	$3.0M	$4.7M
Add 1 position (breaker-and-a-half bus)	$1.5M	$1.8M	$2.0M	$2.3M	$2.7M	$4.4M	$6.5M
Add 1 position (double-breaker bus)	$1.7M	$2.0M	$2.3M	$2.5M	$3.0M	$4.7M	$7.0M
Add 2 positions (ring bus)	$2.3M	$2.6M	$2.9M	$3.3M	$3.8M	$6.0M	$9.3M
Add 2 positions (breaker-and-a-half bus)	$2.8M	$3.2M	$3.7M	$4.1M	$4.8M	$7.6M	$11.5M
Add 2 positions (double-breaker bus)	$3.5M	$4.1M	$4.6M	$5.1M	$6.0M	$9.5M	$14.1M

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

Exploratory cost estimate – new substation							
Scope of work	69kV	115kV	138kV	161kV	230kV	345kV	500kV
4 positions (ring bus)	$6.6M	$7.3M	$8.0M	$8.7M	$9.8M	$14.0M	$20.2M
4 positions (breaker-and-a-half bus)	$7.9M	$8.8M	$9.7M	$10.6M	$12.1M	$17.5M	$25.4M
4 positions (double-breaker bus)	$9.1M	$10.2M	$11.3M	$12.3M	$14.1M	$21.0M	$30.6M
6 positions (ring bus)	$8.4M	$9.3M	$10.3M	$11.2M	$12.8M	$18.7M	$27.3M
6 positions (breaker-and-a-half bus)	$10.1M	$11.4M	$12.6M	$13.7M	$15.9M	$23.8M	$34.8M
6 positions (double-breaker bus)	$11.8M	$13.4M	$14.9M	$16.3M	$18.9M	$28.6M	$41.9M

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

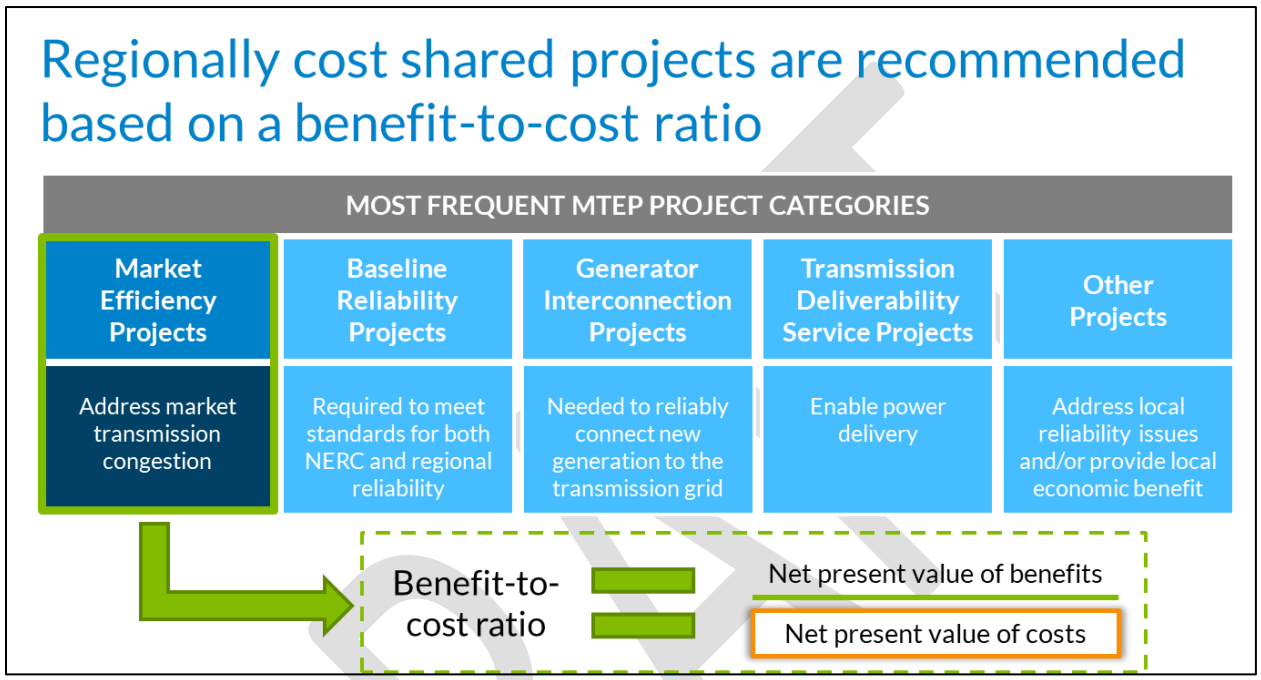
4.3 HVDC Converter Stations

Exploratory cost estimate – HVDC Transmission Converter Station (one end)				
Location – All States	250kV line	400kV line	500kV line	600kV line
Line Commutated Converter	$106M	$315M	$424M	$510M
Voltage Source Converter	$140M	$409M	$549M	$664M

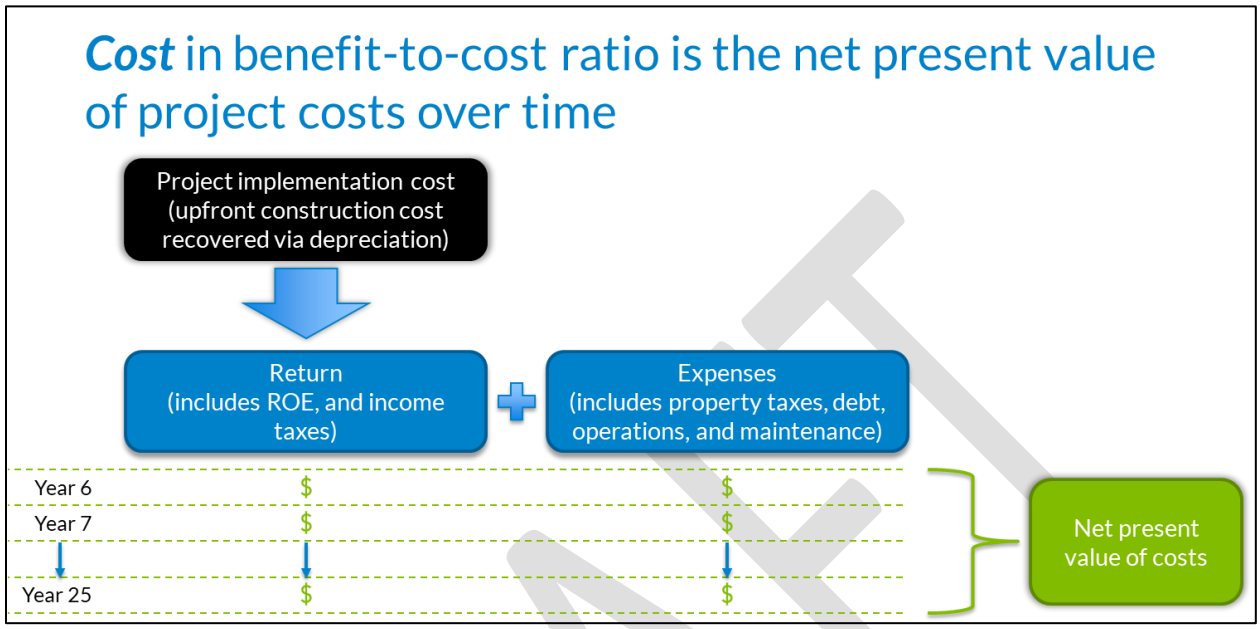
Includes contingency (30%) and AFUDC (7.5%)

5. Costs Over Time

In MISO's yearly MTEP, certain types of projects may be identified to be recommended to our 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).



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



In its estimate of costs over time, MISO makes assumptions about the following cost inputs:

Year #	Present Value Discount Rate	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	Net Present Value Cost

Year(s)

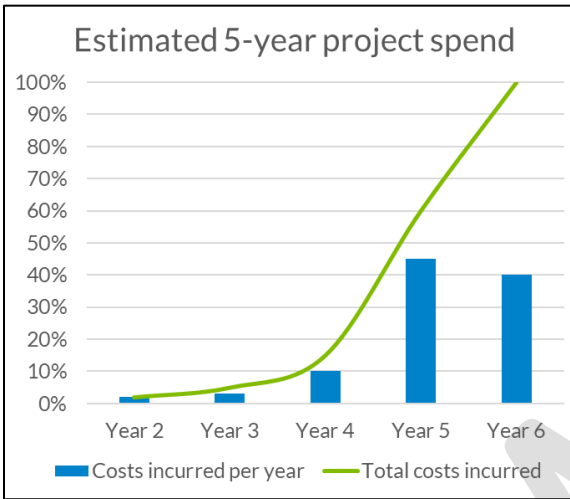
MISO defines the Project Costs to be used in the benefit-to-cost ratio as the present value of the annual revenue requirements projected for the first 20 years of the project's life (Attachment FF Section II.C.7). An example of the years used in the calculation for a project that will take 5 years to construct is that years 6 through 25 will be the first 20 annual revenue requirement years. The present value cost calculation is over the same period for which the project benefits are determined.

Present Value Discount Rate

Calculated by MISO 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.

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 a construction spend per year and an annual inflation rate of 2.5%. The graph and table below show how an example $100M project is expressed as a nominal cost estimate at an assumed 5-year project development time span.



Example: Project cost = $100M, Contingency = $20M, AFUDC = $9M
Present year project implementation cost = $129M
Nominal project implementation cost = $146.6M

Estimated 5-year project spend

Year	2*	3	4	5	6	Subtotal
Costs incurred per year	2%	3%	10%	45%	40%	100%
Present year project implementation cost	$2.6M	$3.9M	$12.9M	$58.0M	$51.6M	$129.0M
Convert to nominal dollars at 2.5% inflation rate. Nominal cost = present year cost * (1 + inflation rate) ^ (project year)						
Nominal project implementation cost	$2.7M	$4.2M	$14.2M	$65.7M	$59.8M	$146.6M

Net Plant and Annual Depreciation Factor

The Gross plant less depreciation based on a 40-Year asset life, which is 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 below, 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 O's and GG's provided by MISO Transmission Owners and vary by State as shown in the table below:

Expense Factor and Return Factor (by State)

State	Expense Factor	Return Factor (adjusted for the first year of depreciation)
Arkansas	2.73%	8.28%
Illinois	3.40%	8.47%
Indiana	2.91%	8.41%
Iowa	3.16%	8.63%
Kentucky	2.84%	8.25%
Louisiana	2.54%	8.37%
Michigan	3.34%	8.25%
Minnesota	3.03%	8.49%
Mississippi	2.73%	8.18%
Missouri	2.95%	8.26%
Montana	2.90%	8.29%
North Dakota	3.23%	8.20%
South Dakota	3.15%	7.86%
Texas	3.45%	7.86%
Wisconsin	3.45%	8.37%

Annual cost to be recovered

Calculation of the estimated annual revenue requirement which is the sum of the depreciation factor, the expense factor, and the return factor multiplied by the Gross Transmission Plant value.

Net Present Value Cost

Appling the discount rate to the first 20 years of the annual revenue requirement results in the NPV 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

For example, if we were estimating the costs over time for a project in Arkansas, that had a nominal cost estimate of $172.0M, and we use a discount rate of 7.00%, based on the approach we described above, the net present value of cost over the first 20 years of in-service life would be $174.1M as shown in the table below:

Year #	Present Value Discount Rate	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	Net Present Value Cost
MTEP Year	1.000							
1	0.935							
2	0.873							
3	0.816							
4	0.763							
5	0.713				8.28%			
6	0.666	$195,567,182	$190,678,003	2.50%	8.07%	2.73%	$26,016,045	$17,335,590
7	0.623	$195,567,182	$185,788,823	2.50%	7.86%	2.73%	$25,611,281	$15,949,419
8	0.582	$195,567,182	$180,899,643	2.50%	7.66%	2.73%	$25,206,516	$14,670,422
9	0.544	$195,567,182	$176,010,464	2.50%	7.45%	2.73%	$24,801,752	$13,490,510
10	0.508	$195,567,182	$171,121,284	2.50%	7.24%	2.73%	$24,396,987	$12,402,191
11	0.475	$195,567,182	$166,232,105	2.50%	7.04%	2.73%	$23,992,223	$11,398,532
12	0.444	$195,567,182	$161,342,925	2.50%	6.83%	2.73%	$23,587,458	$10,473,114
13	0.415	$195,567,182	$156,453,746	2.50%	6.62%	2.73%	$23,182,694	$9,619,994
14	0.388	$195,567,182	$151,564,566	2.50%	6.42%	2.73%	$22,777,929	$8,833,674
15	0.362	$195,567,182	$146,675,387	2.50%	6.21%	2.73%	$22,373,165	$8,109,065
16	0.339	$195,567,182	$141,786,207	2.50%	6.00%	2.73%	$21,968,400	$7,441,457
17	0.317	$195,567,182	$136,897,027	2.50%	5.80%	2.73%	$21,563,636	$6,826,495
18	0.296	$195,567,182	$132,007,848	2.50%	5.59%	2.73%	$21,158,871	$6,260,147
19	0.277	$195,567,182	$127,118,668	2.50%	5.38%	2.73%	$20,754,107	$5,738,683
20	0.258	$195,567,182	$122,229,489	2.50%	5.17%	2.73%	$20,349,342	$5,258,657
21	0.242	$195,567,182	$117,340,309	2.50%	4.97%	2.73%	$19,944,578	$4,816,877
22	0.226	$195,567,182	$112,451,130	2.50%	4.76%	2.73%	$19,539,813	$4,410,393
23	0.211	$195,567,182	$107,561,950	2.50%	4.55%	2.73%	$19,135,049	$4,036,479
24	0.197	$195,567,182	$102,672,771	2.50%	4.35%	2.73%	$18,730,284	$3,692,612
25	0.184	$195,567,182	$97,783,591	2.50%	4.14%	2.73%	$18,325,520	$3,376,462
								$174,140,771