

Integrated Resource Plan and Transmission Discussion PSAT Meeting January 23, 2020

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Agenda



MLGW Opening Remarks / Safety brief	10:00 am
Introduction – IRP Process	10:10 am
Load Forecast	10:20 am
Fuel Forecast	10:30 am
Resource Update	10:40 am
Other Model Considerations	11:10 am
Transmission Analysis Update	11:25 am
LTCE Results	12:00 pm
Next Steps	01:00 pm
Q&A	01:15 pm
 Meeting adjourn 	02:00 pm

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Introduction

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IRP Process Recap

- The IRP process is designed to identify the preferred plan for MLGW to supply of its current and forecasted load while meeting key objectives including:
 - Affordability / Least Cost / Rate Impact,
 - Reliability / Resource Adequacy
 - Sustainable / Environmental Stewardess
 - Stability / Risk Price Mitigation
- To identify the plan, resource options, Strategies and Scenarios were developed and analyzed resulting in a set of Portfolios (expansion decisions) subject to the Risk Analysis.
- Today we will present the final set of assumptions and analysis leading to these Portfolios and preliminary results.



IRP Process Recap

Where we are

- Finalized all input assumptions
- LTCE on Strategy 3: MISO + Self Supply in process to be finalized
- Modeling Strategy 1: All TVA underway
- Strategy 2: Full MISO is not viable nor preferred, further details today.
- Transmission analyses underway

What we plan to present in the next PSAT meetings

Today

- Update for load and fuel forecasts, resources, modeling considerations, transmission studies,
- Draft LTCE Results (Not Final)
- Next steps

February 27 2020

- Complete Strategy 3 and 1
- Risk Analysis & Transmission Analysis results

March 26 2020

• Recommendations, select best portfolio, Gap Analysis



IRP Assumptions Update

IRP Assumptions Update



- Load Forecast Update
- Gas / Fuel Price
- New Resources Update
- Limitations on Local Solar
- Modeling Considerations

Net Average Load Forecast

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- Updated energy efficiency (EE) forecast incorporates cumulative EE impacts and energy savings retirements after 10 year average EE measure life (0.5% reduction per year).
- Revised distributed solar (DS) forecast aligns with TVA's distributed solar forecast and reflects the expected economics of these resources.

	2020	2025	2030	2035	2039
System Average-MW	1,620.00	1,574.84	1,574.84	1582.73	1589.07
EV-MW	0.70	2.72	7.07	13.46	18.82
EE-MW	-0.00	-30.20	-69.59	-78.90	-79.14
DS-MW	-1.12	-3.88	-11.75	-16.68	-22.00
Development Loads-MW	23.05	23.05	23.05	23.05	23.05
Net System Average-MW	1,642.63	1566.53	1523.62	1521.66	1529.80
EV+EE+DS+Dev. Loads as %	1.4%	-0.5%	-3.4%	-4.0%	-3.9%

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Net Peak Load Forecast



- After EE and DS the load is expected to decline until 2032, followed by a slight increase.
- The Load Forecast Memo Memphis Final provides details on the forecast, including the known large commercial developments considered.

	2020	2025	2030	2035	2039
System Peak-MW	3,211.38	3,227.72	3,244.15	3,260.66	3,277.25
EV-MW	0.50	1.97	5.12	9.75	13.63
EE-MW	-0.00	-61.23	-142.17	-162.13	-162.95
DS-MW	-1.12	-3.89	-11.77	-18.72	-22.05
Development Loads-MW	34.10	34.10	34.10	34.10	34.10
Net System Peak-MW	3,244.87	3198.67	3,129.42	3,123.49	3,165.65
EV+EE+DS+Dev. Loads as %	1.0%	-0.9%	-3.7%	-4.4%	-4.4%

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New Resources update and land availability for solar PV

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Technology Options – Capital Costs

Technology	Advanced 2x1 CCGT	Conventiona I 1x1 CCGT	Simple Cycle Advanced Frame CT	Simple Cycle Conventional Frame 7FA CT	Simple Cycle Aero CT	Coal With 30% CCS	Utility Solar PV - Tracking	Onshore Wind	Lithium Ion Batteries (4 hrs.)	Nuclear SMR
Fuel	Nat. Gas.	Nat. Gas.	Nat. Gas.	Nat. Gas.	Nat. Gas.	Coal	Sun	Wind	Elec. Grid	Uranium
Construction Time (Yrs)	3	3	2	2	2	5	1	2	<1	7
Size (MW)	950	350	343	237	50	600	50	100	5 MW / 20 MWh	50-1,200
Average Heat Rate (Btu/kWh), HHV	6,536	7,011	8,704	9,928	9,013	9,750	N/A	N/A	N/A	N/A
VOM (2018\$/MWh)	1.81	5.01	3.87	7.00	5.45	7.14	0.00	0.92	1.39	14.79
FOM (2018\$/kW-yr)	15.90	17.41	9.53	4.39	15.70	73.45	20.70	36.56	32.21	165.42
Range of Capital Cost (2018\$/kW)	947-874	1039-958	711-652	626-578	1136-1041	6135-5027	1245-702	1636-1399	1534-693	9539-5365
Range of LCOE (2018\$/MWh)	35-51	42-58	95-112	88-110	140-155	98-101	38-29	37-28	151-84	124-86

Key Changes / updates:

- MISO Solar to the MISO wind was added to the Portfolio Options and updated considering transmission cost as a blend of fixed and interruptible rates resulting in Arkansas \$7.34 / MWh and Mississippi \$9.19 / MWh.
- We have updated the cost of the 7FA CT's.
- The CCGTs have 6 hours minimum run time and 4 hours minimum down time, and CTs have 2 hours minimum run time and 1 hour minimum down time.
- Ramp rates are considered in the detailed PROMOD dispatches and for the CT and CCGT's are in the 50 MW/min range Unrestricted © Siemens AG 2019

- Local solar has important advantages as it is closer to the load, behind the transmission constraints, and has lower transmission costs.
- Without any constraints, as will be shown later, almost 3300 MW are economically built by the model.
- Considering that approximately 6 acres of land are required for every MW of PV, 3,300 MW of solar would require about 20,000 Acres or 30.9 sq. miles
- Consider that Shelby County has 763 sq. miles of land, 3,300 MW of PV equal to 4% of Shelby County
- Although we are not limited to Shelby County, to secure this amount of land can be a challenge, if the connections to the existing system are to be managed; the so called "Gen-Ties" that are typically in the tens of miles.
- Working with MLGW we identified areas that can be prospected for PV projects by future developers interested in responding to future request for proposals (RFP) issued by MLGW.

Local Solar Capacity Limitation



- Blue polygons are areas identified by MLGW close to substations and yellow polygons are areas identified by Siemens within range of existing lines.
- The sum of these two groups is about 24,000 acres to be prospected for PV in Shelby County (4,000 MW)
- 3,500 MW of PV would require 88% success rate in securing these properties
 - Mission impossible / if not very unlikely
- Assuming 25% of success rate of land procurement, about 1000 MW could be hosted.
- This is a challenge, but doable, particularly considering that outside of Shelby County, e.g. South of Tipton County, or southwest in Mississippi (Pink polygon) there is land that could host from 500 to 1000 MW of added PV.

Resource Summary

- We will present the results with no constraints for local PV as a reference and the LTCE's with a limit of 1000 MW local solar in the LTCE (constraint case)
- This analysis will inform the decisions that must be made to confront the likely reality of limits on PV development directly connected to MLGW; i.e. added thermal resources.
 - Also, we will discuss the impact of these decisions when facing lower limits (500 MW) or higher limits (2000 MW)
 - We will see that there is direct impact on the portfolio costs
- Details on generation options can be found on the Generation Technologies memo.



Natural Gas Market Considerations

Gas Pipeline Cost, Tariff, and Capacity Availability Assessment



- To develop self-supply options including CCGT and CT, MLGW assessed three gas pipeline supply options.
- Trunkline was found to have the lowest cost enhanced firm transport tariff rate (\$0.3811/Dth), followed by Texas Gas and then ANR.
- Trunkline is estimated to have sufficient capacity availability to support one or more CCGT/CT options on or about 2025, based on modeling and analysis of shipper contract roll-offs.
- Modeling also demonstrated that delivered gas indexed to Trunkline would be lower cost than either Texas Gas or ANR.
- In conclusion, a CCGT and/or CT option can be supported at lowest cost and with greatest likelihood of available capacity first via Trunkline, then Texas Gas, then ANR. More detail is available in the Siemens Gas Outlook Memo.



Natural Gas Price Outlook Cost Components: Henry Hub + Market Gas Hub Index + Transport Tariff

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Annual Henry Hub Natural Gas Forecast (2018\$/MMBtu)

Monthly Forecast Gas Basis to Henry Hub (2018\$/MMBtu)



Pipeline (Zone to Zone)	Tariff	Demand Rate (\$/Dth)	Commodity Rate (\$/Dth)	ACA Rate (\$/Dth)	Equivalent Fuel Rate (\$/Dth)	Unit Rate (\$/Dth)
ANR (SE to ML-2)	FTS-3 w/ 2hr+balancing	\$0.7257	\$0.0347	\$0.0013	\$0.0438	\$0.8055
Texas Gas (1-1)	FT+WNS+SNS	\$0.4028	\$0.0553	\$0.0020	\$0.0364	\$0.4965
Trunkline (Field Zone to 1A)	QNT+FSS	\$0.3364	\$0.0080	\$0.0013	\$0.0354	\$0.3811

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Modeling Considerations for MLGW

- Aurora is the program used to determine the Long Term Capacity Expansion (LTCE) plan that results in the least cost of supply, subject to a number of constraints, some of which will be discussed next.
- The system is modeled zonal with transmission limitations; MLGW is one zone, TVA is one zone; MISO Arkansas is one zone and so on.
- The external systems; MISO and TVA also have their projected LTCE and interact with MLGW based on the transmission limitations. Below shows MISO LTCE.

	MISO Installed Capacity (GW)									
Year	Coal	СС	СТ	Nuclear	Wind	Solar	DGSolar	Hydro	Storage	Other
2025	46.4	42.4	46.1	10.9	24.8	11.0	1.8	2.3	4.0	2.1
2026	44.1	47.0	46.2	9.5	26.0	12.1	1.8	2.3	4.0	2.1
2027	42.5	48.8	47.6	9.5	27.6	13.0	1.9	2.3	4.0	2.1
2028	38.7	50.6	48.9	9.5	30.0	14.2	2.0	2.3	4.0	2.1
2029	36.6	51.5	49.9	9.5	32.5	15.7	2.1	2.3	4.1	2.1
2030	35.5	52.5	50.5	9.2	34.6	19.2	2.2	2.3	4.1	2.1
2031	33.0	53.4	50.8	8.4	37.4	22.8	2.3	2.3	4.1	2.1
2032	31.7	53.4	49.6	8.4	40.2	26.4	2.4	2.3	4.1	2.1
2033	31.3	54.3	49.6	7.8	43.5	30.0	2.5	2.3	4.2	2.1
2034	30.3	55.8	49.6	6.7	46.9	33.8	2.6	2.3	4.2	2.1
2035	29.0	56.7	49.3	5.9	50.2	37.2	2.7	2.3	4.2	2.1
2036	28.4	56.8	48.9	5.9	53.6	40.3	2.8	2.3	4.2	2.1
2037	28.4	56.7	48.9	5.9	56.9	43.4	2.9	2.3	4.2	2.1
2038	26.6	56.7	48.9	5.4	60.0	46.2	2.9	2.3	4.3	2.1
2039	26.6	56.7	48.9	4.9	63.0	48.6	3.0	2.3	4.3	2.1

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MLGW LTCE was formulated subject to the following Constraints:

- 1) MLGW to be an annual net importer.
- 2) Imports have transmission limits of 2200 MW for the system to be secure under contingencies.
- 3) Exports have transmission limits of 1500 MW (updated), again for system to be secure under contingencies.
- MLGW has to meet an Unforced Capacity Reserve Margin target as a MISO member (UCAP); currently 8.4%.
- 5) 300 MW annual limit for local solar builds to account for integration concerns with a total limit of 1000 MW as discussed earlier.
- 6) 400 MW MISO total wind limit to be consistent with the limited resource availability in Arkansas and Mississippi.
- 7) The combination of MISO wind and MISO solar cannot exceed 2200 MW due to import constraints.
- 8) Solar and wind contribute to the capacity requirements as discussed in later in this presentation.
- RPS targets increasing from 5% to 15% of total energy from renewable zero carbon resources from 2025-2039 with a linear increase.

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• Renewable resources have an Effective Load Carrying Capability (ELCC) or capacity credit that measure of the

Solar and Wind Effective Load Carrying Capability

- additional load that the system can supply with the resource in place and with no net change in reliability. The ELCC of PV and Wind is not static, but the credit used to define value changes year by year depending on the forecasted system conditions.
- As penetration levels increase, the ELCC decreases:
 - ELCC for wind decreases slightly
 - ELCC for solar sees a steeper

drop



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Self Build + MISO LTCE Constraints

Other Consideration / Constraints:

- The large 2x1 Combined Cycle (950 MW) was removed as option due to reliability considerations;
 - it represents about 30% of the peak demand and its outage would represent the single largest contingency.
 - The extended trip of the steam turbine would force the extender shutdown of the CCGT.
 - Under the "No Deal" Scenario, having such large CCGT would require installing additional thermal reserves to be able to reliably supply the load under the condition for loss of a transmission facility and a generation unit (N-G-1) under night peak.



Transmission Analyses Updates

Transmission Updates Overview

- The analysis mainly focus on Strategy 3 (MISO + Self Supply) assuming complete separation from TVA; i.e. No-Deal
- Overall transmission plan has to be optimized for reliability and economics
- Several interconnection portfolios have been tested, considering:
 - Connecting to MISO in the North, West, and South
 - Rights of Way for lines (ROW) and substation constraints; land availability
 - Capacity under N-1 contingencies
 - Future generation interconnections
- Various transmission analyses are being conducted:
 - Transfer analysis to determine import/export capability
 - Steady state contingency analysis for N-1 and & N-1-1 to identify reliability upgrades
 - Stability analysis for system dynamics
 - Hourly nodal production cost analysis to identify potential congestion, renewable curtailment and overall production cost

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Transmission Expansion Plan

- Reviewed area transmission system in detail and proposed three (3) new connections with MISO South Entergy Arkansas and Mississippi (see map on next slide):
 - New ~25 miles San Souci-MISO to New Shelby-MLGW 500 kV line
 - New ~8 miles West Memphis-MISO to New Allen-MLGW 500 kV line
 - New ~8 miles Twinkletown-MISO to New Allen-MLGW 230 kV line
- Detailed expansion plan including network one-line diagrams of before and after system configurations were presented to MLGW transmission team and are currently under review.
- This plan also ensures TVA plant especially Allen CC not to be stranded; that is new transmission facilitates to allow full transfer of the power back to TVA after separation (500 kV connection).
- Total capital expenditure for the proposed transmission expansion is estimated to be about \$320 million (2019), of which about \$25 million is the estimated cost of TVA new facilities for severance.
- The final expansion plan is still under review and the detailed cost estimates are subject to refinement

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Transmission Expansion Plan



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Transfer Analysis

- Siemens performed a power deliverability study called the "First Contingency Incremental Transfer Capability (FCITC) analyses" based on the proposed expansion plan.
- This analysis allows finding the maximum transfers before an element would overload under contingencies and found that:
 - a. Import capability from MISO South to MLGW is about 2200 MW
 - constraint is around Batesville area in northern Mississippi
 - b. Export capability from MLGW to MISO South is about 1500 MW
 - constraint is around Indianola area in central west Mississippi

Due to local PV limitation by MLGW, higher export capability is not necessary

• The 2200 MW and 1500 MW transfer limits are used in the LTCE zonal analysis.

Generation Interconnection and Siting

- For CCGT and CT plants:
 - The latest LTCE plan calls for building 2x350 MW CCGT and 3x237 MW CT units (to be discussed in the LTCE update section)
 - The preferred location for CCGT and CT are generally in the east adjacent to the gas lines
 - Currently one CCGT is modelled in Collierville area and one CCGT is modelled in Chambers Chapel area
 - CT are co-located one-to-one with the CCGT
- For PV generation:
 - There is ongoing effort on the local PV land availability review, as discussed earlier
 - Currently the limit is set to be 1000 MW of local PV
 - About half is modeled in the north of Shelby county
 - Another half is modelled in the southeast area
- There are costs associated with generation interconnection, and could vary depending on the specific project
- Final siting and costs are to be determined

Reliability Analysis

- Steady state (power flow) analysis was conducted for the identified interconnection options and different dispatch / system conditions:
 - 2025 Summer Day-Peak with normal dispatch (CC and PV online)
 - 2025 Summer Night-Peak with normal dispatch (CC online)
 - 2025 Summer Day-Peak max import of 2200 MW (reduced local generation)
 - 2035 Summer Day-Peak with normal dispatch (CC and PV online)
 - 2035 Summer Night-Peak with normal dispatch (CC online)
 - 2035 Summer Day-Peak with max generation where all of MLGW generations are at max
- Steady state contingency analysis assumptions:
 - Scale MLGW system load according to load forecast by year
 - Monitor all 100 kV above facilities in Entergy Arkansas, Mississippi, MLGW and TVA for thermal and voltage violations
 - N-1 & N-1-1 contingencies under NERC TPL-001-4 Category P1 through P7

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Reliability Analysis

- Steady state contingency analyses results:
 - Identified potential thermal or voltage violations under the proposed expansion plan
 - Identified facilities to be upgraded, e.g.161 kV rebuild, which costs about \$1-1.2 million / mile
 - Preliminary list of facilities were presented and discussed with MLGW transmission team, mainly around north and west where MISO interconnections are bringing power into MLGW
 - Total cost estimate is about \$100 million mainly for upgrading MLGW's existing transmission for transfer capability support and reliability concerns.
- Dynamic analyses (underway):
 - Identify system reactive and voltage performance under various scenarios
 - Check whether local thermal units are stable under disturbances
 - Identify if additional reactive support is required
- Final costs are under review and subject to refinement

Nodal Production Cost Analysis

- Nodal production cost analyses (underway):
 - Full 8760 hourly simulations for near term and long term
 - Stage various generations from LTCE over the years in the model
 - Identify transmission system congestion if any
 - Identify system economic performance under different future conditions
 - Resolve congestion if any by building new or upgrading existing transmission, and test reliability
- Full simulations are to be started soon once the final LTCE preferred plan is determined

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Long Term Capacity Expansion

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Lessons Learned from Prior LTCE Results

A large number of LTCE have been run to date and we derive some lessons and observations expected to hold for the rest of the analysis:

- Renewable generation is economic and with <u>no limits</u> it could reach values close to MLGW total energy load (day time send to MISO, night time supply from MISO).
 - Limits are imposed by transmission, maximum local build; MLGW is to be a net importer.
 - Lower renewable technology prices for PV and Wind would not make a difference in the buildout.
- The timing of the PV installation is a function of balancing on one hand the expectation of declining prices (delay) and having to purchase from MISO market on the other (advance).
- Capacity is sourced from MISO, subject to transmission limitations, which results in CT's installed in the first year.
- MISO Capacity purchases drops as more resources (PV and Wind) are added to the mix.
- Transmission limitations prevent purchasing all the requirements from MISO and it is not the least cost solution as evidenced by the maximization of self-build/contracted PV and Wind

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Final Strategies and Scenarios

Based on the lessons learned, we propose the following changes:

Changes on Strategies

- Strategy 1 : TVA (Full requirement contract)
- Strategy 2 : Full market purchase from MISO, not practical due to transmission limits and cost of renewable
- Strategy 3 : MISO + Self Supply

Changes in Scenarios

- Scenario 1 : Reference Scenario
- Scenario 2 : High Load, Low Gas
- Scenario 3 : High Load
- Scenario 4 : Low Load
- Scenario 5: High Technology dropped as renewables already at upper limit an a high tech case would not add more renewables

The scenarios proposed are designed to identify changes in the thermal composition of the Portfolios due to externalities; higher / lower load and lower gas prices.

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Total Plani	ned LTCE Ca	ses	
	Strategy 1*	Strategy 2*	Strategy 3
Scenario 1	S1S1		S3S1
Scenario 2	S1S1		S3S2
Scenario 3	S1S1		S3S3
Scenario 4	S1S1		S3S4

LTCE Case Nomenclature

S3S′

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Scenario #

Long Term Capacity Expansion

- Two capacity expansion plans will be presented next.
- The first one is the 1000 MW solar limit case:
 - It is considered one of most realistic Portfolios run to date
 - This plan also considers the reference assumptions with respect of load and fuel prices presented earlier.
 - This case provides information on the changes in the supply options to deal with the practicalities of siting the PV
- The second plan is the 3,500 MW solar limit case:
 - An unconstrained case with respect of solar build and provides for comparison of the cost implications associated with the limitation on the availability of local solar.

LTCE Buildout Comparison

- Without limits 3,250 MW of PV are installed locally and together with the MISO imports that are also maxed out at 1,900 + 300 = 2,200 MW limit, supplying most of the energy needs.
- 5 CTs (1,291 MW) are added for reserves and peaking service at night (when there is no PV).

Buildout with 3500 MW Solar Limit

Year	Conventional Simple Cycle Frame CT 4x237 MW	Advanced Simple Cycle Frame CT 1x343 MW	Local Solar	MISO Solar	MISO Wind	MISO Capacity	Total w/o MISO CAP
2025	948	343	600	0	0	2140	1891
2026	0	0	600	0	0	1952	600
2027	0	0	50	0	0	1932	50
2028	0	0	500	0	300	1738	800
2029	0	0	50	0	0	1722	50
2030	0	0	600	1900	0	965	2500
2031	0	0	600	0	0	816	600
2032	0	0	50	0	0	826	50
2033	0	0	50	0	0	831	50
2034	0	0	50	0	0	843	50
2035	0	0	50	0	0	857	50
2036	0	0	50	0	0	871	50
2037	0	0	0	0	0	977	0
2038	0	0	0	0	0	922	0
2039	0	0	0	0	0	948	0
Total	948	343	3250	1900	300		6741

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LTCE Buildout Comparison

- Local solar and MISO imports are both at their maximums 1,000 MW and 2,200 MW, respectively.
- Energy needs are complemented by 2x350 MW CCGTs
- 3 CT's (711 MW) are added for reserves and peaking service at night complementing the CCTG

Buildout with 1000 MW Solar Limit

Year	Combined Cycle 1x1 2x350 MW	Conventional Simple Cycle Frame CT 3x237 MW	Local Solar	MISO Solar	MISO Wind	MISO Capacity	Total w/o MISO CAP
2025	700	711	300	0	400	2056	2111
2026	0	0	0	0	0	2042	0
2027	0	0	0	0	0	2029	0
2028	0	0	0	0	0	2015	0
2029	0	0	0	0	0	2002	0
2030	0	0	0	1800	0	1512	1800
2031	0	0	200	0	0	1464	200
2032	0	0	150	0	0	1437	150
2033	0	0	0	0	0	1457	0
2034	0	0	300	0	0	1406	300
2035	0	0	50	0	0	1416	50
2036	0	0	0	0	0	1438	0
2037	0	0	0	0	0	1461	0
2038	0	0	0	0	0	1484	0
2039	0	0	0	0	0	1506	0
Total	700	711	1000	1800	400		4611

Cost Comparison \$/MWh

- The graphs provide the all in cost in \$/MWh for each of the technologies providing energy; CCGT, Solar and wind.
- The CCGT has higher costs than the renewable and it goes up as the capacity factor decreases.
- This impacts the cost of supply and NPV.

1000MW Solar Limit

3500MW Solar Limit

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NPV Comparison with 3.5% Discount Rate (\$ Million)

The NPV of the 1000 MW case is 9.3% higher (\$ 657 Million) than the unconstrained case driven by higher fuel costs, partially compensated by reduction in fixed costs.

Cost Type	1000MW S	olar
Fuel Cost	1,471	19%
VOM Cost	472	6%
Emission Cost	208	3%
Fixed Cost	3,835	50%
Total Before Market	5,986	77%
Unrestricted © SMarket Cost	1,756	23%
Page 40 Total After Market	7,742	100%

Cost Type	3500M	W Solar	
Fuel Cost	399	6%	
VOM Cost	112	2%	
Emission Cost	64	1%	
Fixed Cost	4,615	65%	
Total Before Market	5,190	73%	
Market Cost	1,895	27%	
Total After Market	7,085	100%	Enerav Business

Buildout with 3500MW Solar Limit

LTCE Results - Portfolio Costs (3500MW Solar)

- The unconstrained case net average total supply cost (after market revenue) is \$617 million per year
- The portfolio costs fluctuate around 45 \$/MWh.

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LTCE Results - Portfolio Costs (1000MW Solar)

- The 1000 MW case net average yearly cost (after market revenue) is \$674 million per year, 9.2% higher than the unconstrained case (\$617 million)
- The portfolio costs fluctuate around \$50/MWh (11%) higher than the unconstrained case (\$45/MWh)

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LTCE Results

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Installed Capacity grows slowly with MISO Capacity Purchases to meet reserve margin

- Under both LTCEs, MISO Capacity purchases keep MLGW at 8.4% reserve margin throughout the study period.
- There is no energy not served or loss of load hours (LOLH).

Delays in building solar under both cases

- PV and Wind are built overtime with a bias towards 2030's
- The graphs shows the actual cost of MISO imports in \$/MWh (blue) versus the cost of PV and Wind that would be realized at the time they are built.
- We note that building wind and solar is cheaper than importing power, but as we wait lower prices are possible (particularly PV).
- Hence timing is balanced between minimizing imports (build sooner) versus waiting for lower prices (build later)

LTCE Results - Renewable Target

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3500MW Solar Limit

- The renewable is installed due to economics and portfolios always widely exceed the RPS Targets
- Reach values over 50% penetration by 2031

1000MW Solar Limit

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Market Transaction Comparison (1000MW solar vs 3500MW solar)

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- With the selected portfolio (1,000 MW limit) both the payments to the market and the energy purchases are greater than the revenues and energy sales. With the unconstrained build out more energy is sold than purchased at the end.

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Long Term Capacity Expansion Observations

- The local solar limit results in building two 350 MW CCGTs, which resulted an increase in the NPV of about 9.3% with respect of a case without limits.
- If the limits in local solar are reduced to 500 MW, the energy from the local PV would have to be provided by thermal and this would result in one more CCGT (total 3x350 MW).
- On the other hand, if there is more solar available (e.g. 2000 MW), then possibly only one CCGT would be necessary.
- The total costs of the 1000 MW case appear to indicate competitiveness with TVA, but this still needs to be assessed and other costs need to be added:
 - Transmission Costs
 - Cost of becoming a balancing area / MISO Member.
 - Cost of services provided by TVA.
 - Other costs to be defined

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Next Steps

Discussion and Next Steps

- Model the low gas price and high demand Scenario and determine the LTCE
- Model the low demand scenario and determine the LTCE
- Run the Risk Analysis and select a preferred Portfolio
- Transmission analysis including PROMOD analysis
- Gap Analysis to identify among others, the cost of becoming a Balancing Authority, new staffing and overhead, planning, compliance, etc., cost of MISO membership, cost of community services provided by TVA, and others to determine the total costs of the Portfolio
- Assess the TVA only Strategy for comparison.
- Final assessments and recommendations
- Draft IRP report

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Glossary

- All-in Capital Cost = The capital costs for building a facility within the plant boundary, which includes equipment, installation labor, owners costs, allowance for funds used during construction, and interest during construction.
- Appalachia Basin = Marcellus Shale Play and Utica Shale Play.
- Average Demand = Average of the monthly demand in megawatts.
- Average Heat Rate = The amount of energy used by an electrical generator to generate one kilowatt hour (kWh) of electricity.
- Baseload Heat Rate = The amount of energy used by an electrical generator to generate one kilowatt hour (kWh) of electricity at baseload production. Baseload production is the production of a plant at an agreed level of standard environmental conditions.
- Breakeven Cost = Average price of gas required to cover capital spending (ideally adjusted to regional prices).
- BAU = Business As Usual
- BTU = British Thermal Unit = unit of energy used typically for fuels.
- CF = Capacity Factor. The output of a power generating asset divided by the maximum capacity of that asset over a period of time.
- CC = Combined Cycle
- EE = Energy Efficiency
- ELCC = Effective Load Carrying Capability
- CCS = Carbon Capture and Sequestration
- CT = Combustion Turbine
- DER = Distributed Energy Resources, distributed generation, small scale decentralized power generation or storage technologies
- DS = Distributed Solar
- Dth = Dekatherm (equal to one million British Thermal Units or 1 MMBtu)
- EFT = Enhanced Firm Transportation (varies by pipeline but can include short- or no-notice changes to day-ahead nominations of fuel delivery
- FID = Final Investment Decision
- FOM = Fixed operations and maintenance costs
- FT = Firm Transportation. FT capacity on a natural gas pipeline is available 24/7 and is more expensive than interruptible transportation (IT) capacity but unused FT capacity can be sold on secondary market.
- Futures = Highly standardized contract. Natural gas futures here are traded on the New York Mercantile Exchange (NYMEX) or Chicago Mercantile Exchange (CME).
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Glossary

- PPA = Power Purchase Agreement; contract to purchase the power from a generating asset
- IPP = Independent Power Producer
- IRP = Integrated Resource Plan
- LNG = Liquified natural gas
- LCOE = Levelized cost of energy
- LOLE = Loss of load expectation
- LOLH = Loss of load hours
- LTCE = Long Term Capacity Expansion Plan; optimization process to select generation
- MMBTu = million British Thermal Units, unit of energy usually used for fuels
- MWh = unit of energy usually electric power = 1 million watts x hour
- MW = unit of power = 1 million watts
- Peak Demand = The maximum demand in megawatts (MW) in a year.
- PV = Photovoltaic
- Reserve Margin = The amount of electric generating capacity divided by the peak demand.
- RPS = Renewable Portfolio Standard: a regulation that requires the increased production of energy from renewable energy sources
- SMR = Small Modular Reactor
- "Sweet Spot" Core Acreage = Areas within a natural gas play that offer the highest production at least cost.
- Utility Scale = large grid-connected power generation, could be solar, gas, diesel, etc.
- VOM = Variable operations and maintenance costs
- Wheeling = a transaction by which a generator injects power onto a third party transmission system for delivery to a client (load).