Filed with the Iowa Utilities Board on February 17, 2023, RPU-2022-0001

Zero Emissions Study

March 1, 2019

Although Prepared at Request of Counsel for Review by Counsel, in light of the IUB ruling, redacted for public release

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Key Determinations

- In all retirement scenarios studied, solar photovoltaic (solar PV) replacements provide the lowest cost zero emissions solution
  - Existing wind resources through Wind XII provide significant amounts of around-the-clock energy, although on peak periods, particularly in the summer months have shortfalls
  - New solar PV meets summer peak hours and other on-peak needs throughout the year
  - Costs are somewhat higher than the simple cycle and combined cycle natural gas plant resource options studied as a benchmark
  - High penetration solar builds adversely impact the generation profile compared to load shape, requiring significant off system sales or solar curtailments around noon, and significant hourly ramping in the late afternoon
    - Requires significant reliance on market solutions for balancing, but can be monitored and addressed as new solar is built
    - Self-supply by battery storage in lieu of market purchases can meet peaking needs, and address ramping impacts, but is the most costly option given current installation cost forecasts
    - Self-supply by CTs in lieu of storage is an alternative to meet peaking needs, but CT options were not considered for a zero emissions solution

Scenarios

Scenario	Scenario Description	Cases
2040 Retirement	- Existing coal and gas units retire in 2040 - Quad Cities Nuclear Power Station (QCNPS) retires in 2032	i) New build fossil (benchmark) ii) New builds with zero emissions sources
Book Life Retirement	- Existing coal and gas units retire sooner, at the end of their current book life, except Walter Scott 4 (2040) and Greater Des Moines Energy Center(2040) - QCNPS retires in 2032	i) New build fossil (benchmark) ii) New builds with zero emissions sources
Advanced Depreciation Retirement	- Existing coal units retire sooner, at the end of their advanced depreciation date, except WS 4 (2040); - Existing gas units retire at the end of book life' - QCNPS retires in 2032	i) New build fossil (benchmark) ii) New builds with zero emissions sources
Early Retirement	- Existing coal and gas units retire in 2021 - QCNPS retires in 2032	i) New build fossil (benchmark) ii) New builds with zero emissions sources

Net Present Value of Revenue Requirement

(Going Forward Costs, NPVRR, in real $2018)

Scenarios	NPVRR ($ millions)			Difference From 2040 Retirement, Fossil Build Case ($ millions)	
	Fossil Builds	Zero Emissions Builds	Difference	Fossil Builds	Zero Emissions Builds
2040 Retirement	11,337	13,711	2,375	0	2,375
Book Life Retirement	11,510	14,246	2,736	173	2,909
Advanced Depreciation Retirement (before book)	12,802	16,937	4,134	1,466	5,600
Early Retirement (2021) [1]	14,580	20,525	5,945	3,244	9,189

[1] Early retirement scenario assumes a $1 billion write-down of existing plant net of deferred taxes assumed to not be recoverable through future Iowa Utilities Board rulings

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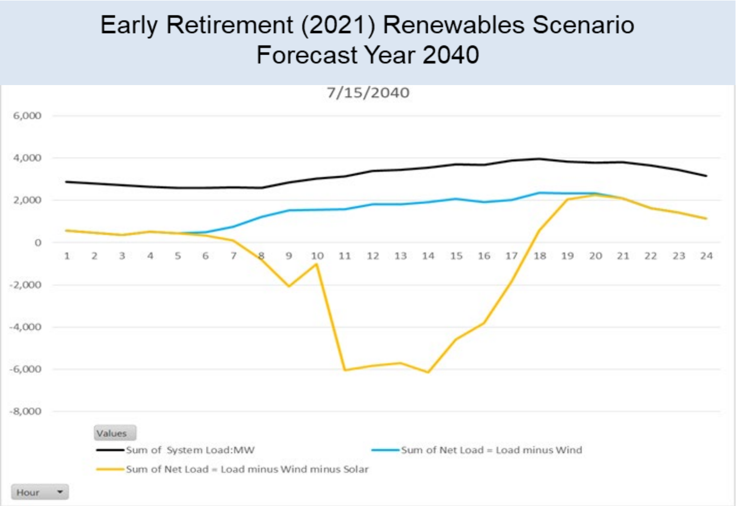
High Penetration Solar Considerations

- Net hourly load must be followed using owned dispatchable generation, storage, purchases from the market, or by wind/solar curtailments
  - Net hourly load = hourly load minus hourly wind production minus hourly solar production
  - Significant hour to hour change in net load MW across the afternoon period
  - Significant on-peak energy across the noon hour that must be sold or curtailed

Net Ramp Requirements; Net Load = Load minus Wind						
	Off Peak – Max Hour			On Peak – Max Hour		
Year	Load Only	Load Net of Wind	Load Net of Wind & Solar	Load Only	Load Net of Wind	Load Net of Wind & Solar
2019	337	662	662	414	637	637
2020	342	774	774	416	885	885
2025	342	907	3,832	455	944	3,728
2030	387	765	4,128	401	1,058	4,077
2035	351	858	4,762	446	942	5,053
2040	407	749	5,077	617	944	5,072



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Study Scope

- Achieve zero emissions for MidAmerican's Iowa/South Dakota resource mix from both a resource adequacy and cost-effectiveness standpoint
  - Purchases allowed, but capped by reviewing the monthly on peak/off peak net self-supply position
  - Resources for MidAmerican's Illinois load are provided through Illinois Power Agency procedures with plans approved by the Illinois Commerce Commission and resources selected via a competitive bidding process
- Perform the study utilizing spreadsheet models to provide high level conclusions to identify long term resource strategies and key areas for future review and study

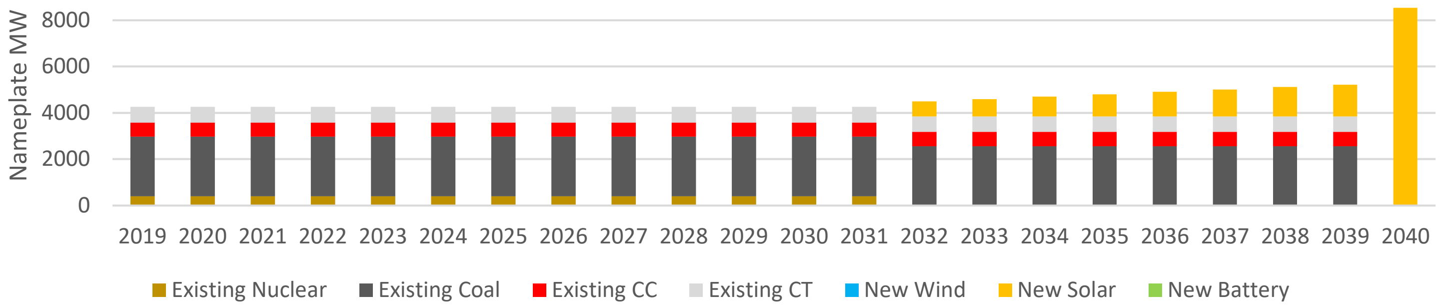
Study Scope

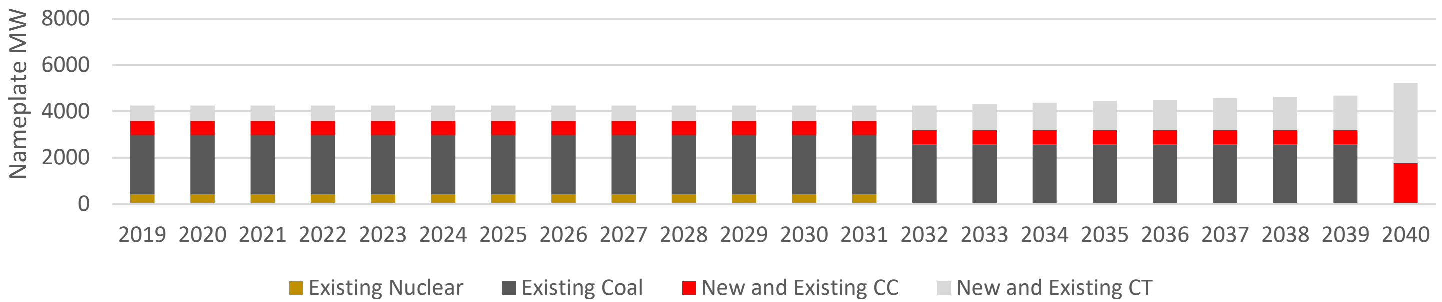
- Study the impact of retiring all MidAmerican coal-fired and gas-fired generation, with replacement from wind, solar PV, and storage resources
- Analyze the net present value or revenue requirement (NPVRR) and annual revenue requirement (ARR) based upon retirement timing and new resource selection
- Save for later studies, the following aspects of a changing resource mix:
  - Assessments using the nine factor criteria of reasonableness, which are used to make resource recommendations in Iowa
  - Capacity and energy market price impacts resulting from MidAmerican’s or other market participant’s changing resource mix
  - Voltage, transmission, primary frequency response, quick start, ramp, and other reliability/resiliency factors
    - MISO has begun Renewable Integration Impact Assessment Studies

Scenarios

- For each scenario, a fossil build case is constructed as a benchmark for comparison, but the zero emissions build case is the focus of the study
- Fossil benchmark case
  - Includes gas-fired simple cycle and combined cycle plant new build options
  - Is used to compare to the zero emissions case
- Zero emissions case
  - Includes wind, solar and battery storage new build options
  - Provides zero emissions resources by 2040 or earlier

Retirement and New Build Timing
(Existing Wind Through Wind XII Assumed to Remain)





Generator	2040 Scenario Retirement Date
Louisa	2040
Neal 3	2040
Neal4	2040
OGS	2040
Walter Scott 3	2040
Walter Scott 4	2040
Riverside	2040
GDMEC	2040
Moline CT	2040
Coralville CT	2040
Pleasant Hills CT	2040
Sycamore CT	2040
River Hills CT	2040
Merle Parr CT	2040
Electrifarm CT	2040
Quad Cities Nuclear	2032

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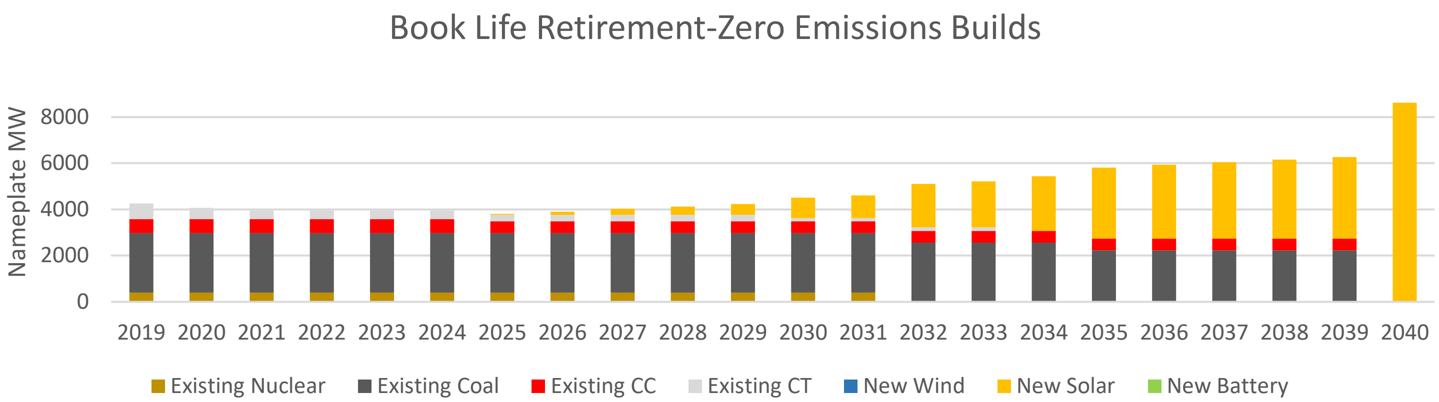
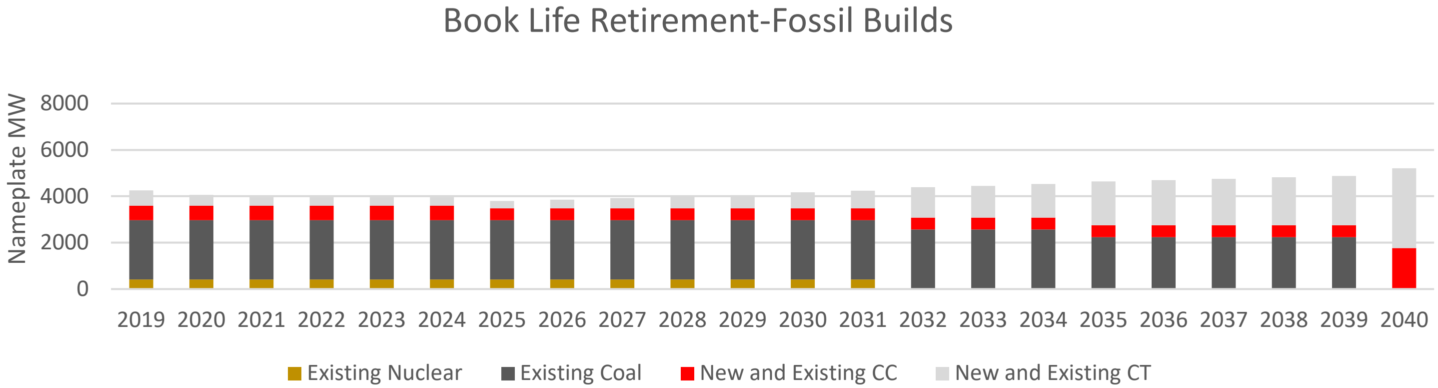
Retirement and New Build Timing
(Existing Wind Through Wind XII Assumed to Remain)





Generator	Book Life Scenario Retirement Date
Louisa	2040
Neal 3	2035
Neal4	2040
OGS	2040
Walter Scott 3	2040
Walter Scott 4	2040
Riverside	2025
GDMEC	2040
Moline CT	2020
Coralville CT	2025
Pleasant Hills CT	2034
Sycamore CT	2020
River Hills CT	2021
Merle Parr CT	2025
Electrifarm CT	2030
Quad Cities Nuclear	2032

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Retirement and New Build Timing
(Existing Wind Through Wind XII Assumed to Remain)

Advanced Depreciation Retirement-Zero Emissions Builds

Nameplate MW

[redacted]

2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040

Existing Nuclear · Existing Coal · Existing CC · Existing CT · New Wind · New Solar · New Battery

Advanced Depreciation Retirement-Fossil Builds

Nameplate MW

[redacted]

2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040

Existing Nuclear · Existing Coal · New and Existing CC · New and Existing CT

Generator	Advanced Depreciation Scenario Retirement Date
[redacted]	

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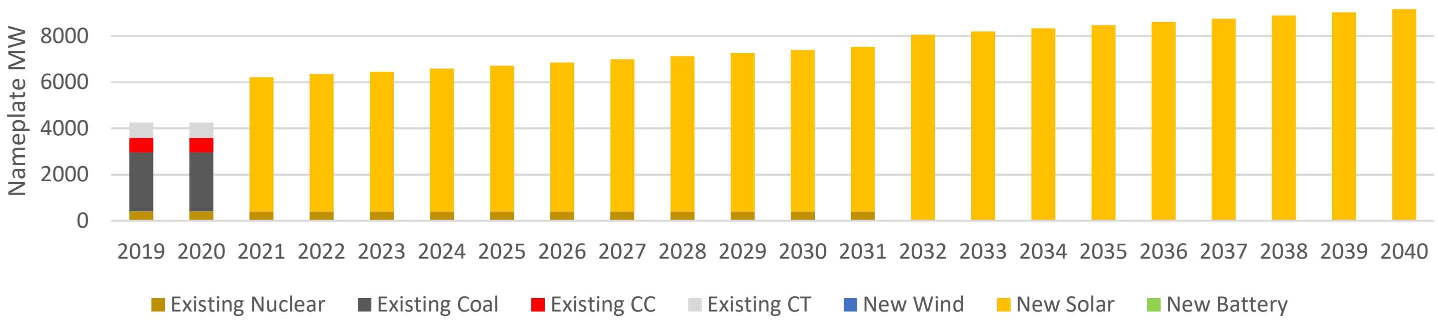
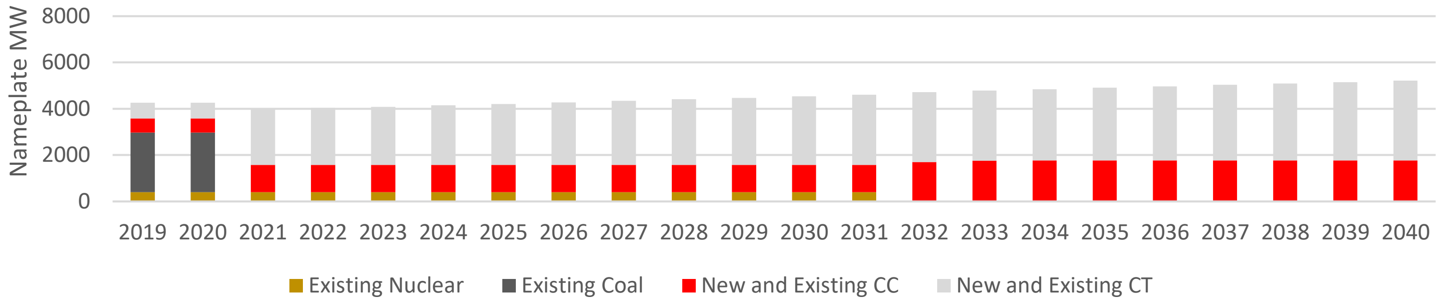
Retirement and New Build Timing

(Existing Wind Through Wind XII Assumed to Remain)

Early (2021) Retirement-Zero Emissions Builds



Early (2021) Retirement-Fossil Builds



Generator	Early Retirement Scenario Retirement Date
Louisa	2021
Neal 3	2021
Neal4	2021
OGS	2021
Walter Scott 3	2021
Walter Scott 4	2021
Riverside	2021
GDMEC	2021
Moline CT	2021
Coralville CT	2021
Pleasant Hills CT	2021
Sycamore CT	2021
River Hills CT	2021
Merle Parr CT	2021
Electrifarm CT	2021
Quad Cities Nuclear	2032

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Conclusions

- Using going forward costs
  - Excludes capacity value, replacement cost if units would be retired, potential carbon taxes, and retail revenue effects
  - Coal resources are profitable except Louisa and Ottumwa
    - Louisa and Ottumwa are profitable when carbon prices become effective and elevate market prices (subject to ultimate carbon policy rules)
  - Natural gas-fired Greater Des Moines Energy Center combined cycle (CC) is profitable when carbon prices become effective
  - Quad Cities Nuclear Power Station is not profitable
- When considering replacement costs needed for summer peaking capacity needs:
  - Retiring all thermal resources by 2040 replacing with fossil resources is the lowest cost option of the cases studied
  - Retiring all thermal resources by 2040 and replacing them with solar PV is the lowest cost zero emissions option of the cases studied

Conclusions (continued)

- In all retirement scenarios studied, new solar builds are projected to be the least costly zero emissions case new build option
  - Existing wind resources through Wind XII provide significant amounts of around-the-clock energy, although on peak periods, particularly in the summer months have shortfalls
  - Solar builds fill in the summer peaking and other on-peak period needs
  - Effect on net load of increasing solar penetrations is significant and may be infeasible
- Addition of a carbon tax, not assessed in this study, changes the economics
  - Carbon prices are a reduce coal plant production in the models, but are not assessed as a operational cost (tax) against remaining energy production
- Differing book life assumptions for various resources and accompanying end-effects impacts economic study results for new resource builds

Key Areas for Future Study

- Use of more dynamic modeling - MidAmerican's new AURORA software:
  - Develops a fundamentals model of the Eastern Interconnection with the ability to model wind and solar as generation, rather than load reducers
  - Perform new build resource optimizations dynamically instead of using a spreadsheet model with static prices
  - Perform hourly studies of MidAmerican's resource adequacy within AURORA
- Case sensitivities impacting capacity and energy prices, e.g.
  - Changing resource mix by MidAmerican and regionally
  - High gas/low gas fuel price scenarios
  - Higher load growth, both MidAmerican (e.g. datacenters) and regionally (economic growth)
  - Lower load growth (e.g. electric vehicle charging load and/or distributed generation)
  - Carbon policy timing and state implementation plan requirement and inclusion of carbon expense, if any

Key Areas for Future Study (continued)

- Voltage, transmission, primary frequency response, and other reliability/resiliency considerations
- Assessments using MidAmerican’s nine factor criteria of reasonableness, which are used in lieu of least cost planning in developing new resource recommendations in Iowa

Carbon Emissions

Historical, Fall 18 Plan Forecast, and Book Life Retirement

- From 2005 through 2017, MEC has reduced its carbon intensity by 46% and CO2 metric tons by 26% while increasing net generation (MWh) by 38%

	PAST ACTUAL DATA													YE Projection	Near Term Projections		
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2 (Million Tons)	20.260	20.099	21.923	24.735	23.074	25.832	23.324	21.226	19.972	19.825	16.747	14.405	15.087	17.757	17.328	17.328	17.328
Generation (Net Millions of MWh)	22.567	23.198	26.319	29.461	28.519	31.398	29.504	30.337	29.468	30.193	29.455	29.749	31.178	34.472	36.976	40.601	43.585
CO_2 (lbs/Net MWh)	1,796	1,733	1,666	1,679	1,618	1,645	1,581	1,399	1,356	1,313	1,137	968	968	1,030	937	854	795

	Fall 2018 Plan																			
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
CO_2 (Tons) F18 Plan	12.025	12.941	13.418	14.306	13.435	12.976	13.899	13.815	11.847	12.291	12.279	12.666	13.138	14.088	14.628	14.523	14.716	14,716	14,716	14,716
Generation (Net MWh) F18 Plan	40.479	41.589	42.037	42.826	41.994	41.548	42.424	42.761	40.966	41.304	41.341	37.823	38.302	39.288	39.805	39.706	39.904	39,904	39,904	39,904
CO_2 Rate (lbs/Net MWh) F18 Plan	594	622	638	668	640	625	655	646	578	595	594	670	686	717	735	732	738	738	738	738

	Book Life Retirement with New Solar Builds																			
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
CO_2 (Tons) F18 Plan	12,007	12,920	13,398	14,287	13,402	12,945	13,864	13,781	11,809	12,236	12,221	12,605	13,077	14,004	12,698	12,556	12,974	12,743	12,743	60
Generation (Net MWh) F18 Plan	40,455	41,560	42,011	42,840	42,089	41,761	42,733	43,173	41,791	42,203	43,129	39,706	40,550	42,196	41,050	41,008	41,517	41,387	46,470	34,065
CO_2 Rate (lbs/Net MWh) F18 Plan	594	622	638	667	637	620	649	638	565	580	567	635	645	664	619	612	625	616	548	4

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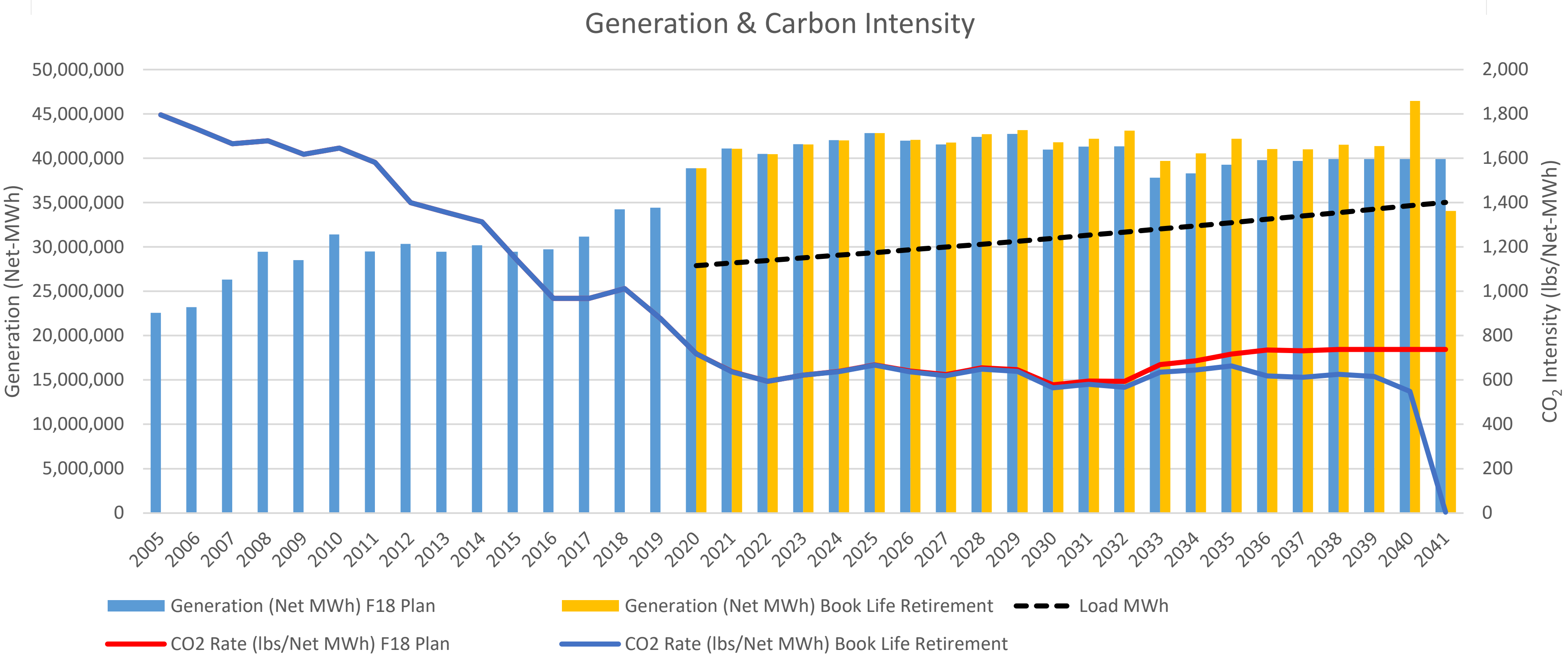
Carbon Emissions

Historical, Fall 18 Plan Forecast, and Book Life Retirement



Load growth rate 1.1% per year

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Appendix 1:
Additional Scenario Details and Resource Adequacy Analyses

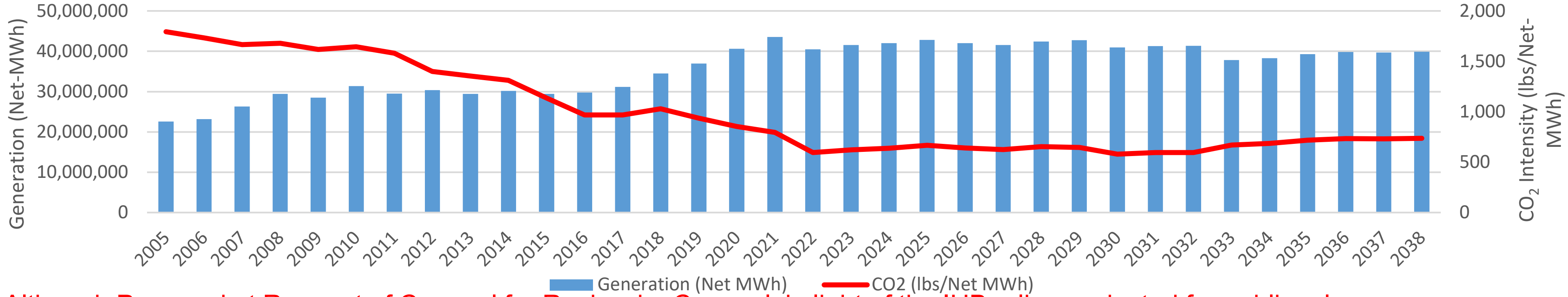
Carbon Emissions

Historical and Fall 18 Plan Forecast

- From 2005 through 2017, MEC has reduced its carbon intensity by 46% and CO2 metric tons by 26% while increasing net generation (MWh) by 38%

	PAST ACTUAL DATA													YE Projection	Near Term Projections		
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	2019	2020	2021
CO_2 (Million Tons)	20.260	20.099	21.923	24.735	23.074	25.832	23.324	21.226	19.972	19.825	16.747	14.405	15.087	17.757	17.328	17.328	17.328
Generation (Net Millions of MWh)	22.567	23.198	26.319	29.461	28.519	31.398	29.504	30.337	29.468	30.193	29.455	29.749	31.178	34.472	36.976	40.601	43.585
CO_2 (lbs/Net MWh)	1,796	1,733	1,666	1,679	1,618	1,645	1,581	1,399	1,356	1,313	1,137	968	968	1,030	937	854	795

	PROMOD 12-4-18																
	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**
CO_2 (Million Tons)	12.025	12.941	13.418	14.306	13.435	12.976	13.899	13.815	11.847	12.291	12.279	12.666	13.138	14.088	14.628	14.523	14.716
Generation (Net Millions of MWh)	40.479	41.589	42.037	42.826	41.994	41.548	42.424	42.761	40.966	41.304	41.341	37.823	38.302	39.288	39.805	39.706	39.904
CO_2 (lbs/Net MWh)	594	622	638	668	640	625	655	646	578	595	594	670	686	717	735	732	738



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Going Forward Cost Assessments

- The Net Present Value of Revenue Requirement (NPVRR) results indicate that new build fossil scenarios have somewhat lower costs
  - Including incremental going forward costs
  - Excluding previously booked costs assumed to be sunk costs
  - Excluding the cost of servicing debt and offsetting return on existing plant, assuming we will recover that cost under all scenarios
  - Excluding existing wind assets, assumed to be retained under all scenarios
  - Offsetting costs with energy market revenues that align with the Fall 2018 plan forecast

2040 Retirement Scenario

Going Forward Costs, Benchmark vs. Zero Emission Case

NPVRR$_{2080}$ ($2018): (- benefit/ + cost)			
Resource	Benchmark	Zero Emissions	Difference
[redacted]			

- NPVRRs for existing resources are the same in the benchmark and renewables scenarios for the 2040 retirement scenario
- The last 5 rows compare the new build solar and benchmark fossil NPVRRs

Annual Revenue Requirement

(ARR, Nominal $)

Annual Revenue Requirement of Incremental Going Forward Costs (Nominal $millions) (+Cost/-Benefit)																						
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041

[redacted]

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Annual Going Forward Costs

Existing Resources

- Coal resources
  - Louisa and Ottumwa are profitable when carbon pricing becomes effective and elevates electric market prices
- Nuclear resources
  - Quad Cities is not profitable
- Natural gas resources
  - Greater Des Moines Energy Center is profitable when carbon pricing becomes effective and elevates electric market prices
  - Riverside and simple cycle combustion turbines are not profitable
- From a capacity perspective, MidAmerican is long capacity, and annual costs of all resources are less than MidAmerican's avoided capacity cost (cost of new entry, "CONE")
- Annual values do not consider capacity, voltage, transmission, primary frequency response, quick start, ramp, and other reliability/resiliency factors

Annual Going Forward Costs ($)

Fall 18 Plan Assumptions

Generating Plant	Annual Revenue Requirement (Nominal $x1,000) (+Cost/-Benefit)																		
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038

[redacted]

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Annual Going Forward Costs ($/KW-Year)

Fall 18 Plan Assumptions

Generating Plant	Annual Revenue Requirement (Nominal $ per KW-Year) (+Cost/-Benefit)																		
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
[redacted]																			

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Hourly Self-Supply Load Serving Capability

- The average hourly on-peak and off-peak monthly net load position was studied to evaluate self-supply capability for MidAmerican's Iowa/South Dakota load
  - Hourly Net load = Hourly Load minus Hourly Wind Production
- The analysis assumes all existing resources through Wind XII remain through the planning horizon, and only Quad Cities Nuclear retirement (2032), and indicates:
  - Existing wind resources provide significant energy to serve the load throughout the planning horizon, even under higher load growth scenarios
  - Solar and storage are good candidates to provide the required energy as summer on peak energy is the primary need

Hourly Self-Supply Load Serving Capability
(no new resource builds)

- In 2020, the average hourly shortfall of generation capability to meet hourly load is minimal
  - Load can be met with or without peaker CT generation
  - Shows hedge capability from existing resources - market purchases opportunities may be more economical

[redacted]

Hourly Load Serving
(no new resource builds)

- Following Quad Cities Nuclear Power Station retirement in 2032, the replacement need is primarily summer peaking, even under higher load growth scenarios

[redacted]

Hourly Load Serving
(No New Resource Builds)

- In 2040, the replacement need remains summer-based
  - Existing wind resources through Wind XII provide significant amounts of around-the-clock energy, although on peak periods, particularly in the summer months and under high load growth cases have shortfalls
  - Solar and storage are good candidates to provide the required energy

[redacted]

Load & Capability

Base Case and Higher Load Forecast Scenarios

- While not assessed for new renewables builds strategies in this study, the High Load ("HL") and Higher Load ("HHL") Scenarios indicate a shortfall by the early 2020s; much sooner than the base case
  - HL and HHL are higher than "conservative" case studied, but ultimately not utilized for Fall 2018 Plan

Load and Capability Forecast: Fall 18 Plan

Planning Year -->	2019 - 20	2020 - 21	2021 - 22	2022 - 23	2023 - 24	2024 - 25	2025 - 26	2026 - 27	2027 - 28	2028 - 29	2029 - 30	2030 - 31	2031 - 32	2032 - 33	2033 - 34	2034 - 35	2035 - 36	2036 - 37	2037 - 38	2038 - 39
Reserve Margin Surplus/(Shortfall) - Fall18 Plan	527	627	651	597	570	514	463	413	355	303	251	198	146	-310	-360	-412	-464	-514	-563	-614

Load and Capability Forecast: Fall 18 Plan - HIGH LOAD (HL) Scenario

Planning Year -->	2019 - 20	2020 - 21	2021 - 22	2022 - 23	2023 - 24	2024 - 25	2025 - 26	2026 - 27	2027 - 28	2028 - 29	2029 - 30	2030 - 31	2031 - 32	2032 - 33	2033 - 34	2034 - 35	2035 - 36	2036 - 37	2037 - 38	2038 - 39
Reserve Margin Surplus/(Shortfall) - HL	447	441	367	192	35	-93	-202	-311	-426	-530	-618	-699	-752	-1,207	-1,258	-1,309	-1,361	-1,411	-1,461	-1,511

Load and Capability Forecast: Fall 18 Plan - HIGHER LOAD (HHL) Scenario

Planning Year -->	2019 - 20	2020 - 21	2021 - 22	2022 - 23	2023 - 24	2024 - 25	2025 - 26	2026 - 27	2027 - 28	2028 - 29	2029 - 30	2030 - 31	2031 - 32	2032 - 33	2033 - 34	2034 - 35	2035 - 36	2036 - 37	2037 - 38	2038 - 39
Reserve Margin Surplus/(Shortfall) - HHL	438	415	337	158	-6	-159	-299	-439	-580	-682	-735	-787	-839	-1,295	-1,346	-1,397	-1,449	-1,499	-1,549	-1,599

Retirement Scenarios

- For each case studied, hourly generation production in excess of the hourly load was calculated to determine the short(-)/long(+) self-supply position
- The *net* hourly self-supply position is used to determine the next resource need
  - For example, if the Short(-)/Long(+) analysis shows a net short position only in the on peak period in July and August for a given year, then likely new build candidates are summer peaking resources which include:
    - Fossil benchmark case: simple cycle and combined cycle natural gas plants
    - Renewables case: solar and battery storage
  - Assumes fossil resources dispatch as per the Fall 2018 Plan forecast

Retirement Scenarios

- The slides to follow provide additional details for each case:
  - The timing and nameplate capacity (MW) for retirements and new builds
  - The net hourly self-supply position after the retirements and new builds
  - Shortfall energy will be higher in the Benchmark Fossil cases
    - The new build combined cycle (CC) resources in these cases have a low capacity factor (~11% annual), consistent with Fall 2018 plan price forecasts, but significantly lower than what would be expected to be economic for CC installations
    - The CCs were assumed to replace retiring coal resources on approximately 0.6 MW of combined cycle capacity to 1 MW of coal capacity basis; CC resources have the capability to be dispatched at higher capacity factors to provide a hedge against higher prices
    - More dynamic modeling of future price scenarios would help resolve CCs as candidate new resource build options

2040 Retirement Scenario

- Retirements:
  - Quad Cities retires in 2032
  - All coal and gas generation retires in 2040
- Wind provides significant year-round energy, resulting in primarily summer on-peak energy needs
- New builds fossil case (benchmark):
  - New natural gas fired simple cycle combustion turbines (CTs) prior to 2040 to meet summer peaking requirement related to load growth Quad Cities Nuclear Power Station retirement
  - New gas-fired combined cycle plants (CCs) in 2040 for year-around energy as coal retires
- New builds renewables case:
  - Solar is the replacement resource for all needs

Generator	2040 Scenario Retirement Date
Louisa	2040
Neal 3	2040
Neal4	2040
OGS	2040
Walter Scott 3	2040
Walter Scott 4	2040
Riverside	2040
GDMEC	2040
Moline CT	2040
Coralville CT	2040
Pleasant Hills CT	2040
Sycamore CT	2040
River Hills CT	2040
Merle Parr CT	2040
Electrifarm CT	2040
Quad Cities Nuclear	2032

2040 Retirement Scenario

- Annual MW additions are incremental and expressed as nameplate capacity
- The total column reflects total new build capacity for each scenario

Base Case																					
Planning Year	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41	Total
Retirements (Name Plate, MW)																						
Nuclear MW	0	0	0	0	0	0	0	0	0	0	0	0	406	0	0	0	0	0	0	0	0	406
Coal MW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2564	2,564
CC MW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	617	617
CT MW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	666	666
Oil MW																						0
Total	0	0	0	0	0	0	0	0	0	0	0	0	406	0	0	0	0	0	0	0	3,848	4,254
Benchmark Case Builds (Name Plate, MW)																						
CT	0	0	0	0	0	0	0	0	0	0	0	0	403	62	63	64	61	61	61	60	2,611	3,446
CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,764	1,764
Total	0	0	0	0	0	0	0	0	0	0	0	0	403	62	63	64	61	61	61	60	4,375	5,210
Zero Emissions Case Builds (Name Plate, MW)																						
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar	0	0	0	0	0	0	0	0	0	0	0	0	645	102	104	106	104	103	103	102	7,164	8,533
Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	645	102	104	106	104	103	103	102	7,164	8,533

Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – 2040 Retirement Fossil Benchmark Case

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – 2040 Retirement Zero Emissions Case

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Book Life Retirement Scenario

- Retirements:
  - Quad Cities retires in 2032
  - Neal 3 retires in 2035
  - All other coal-fired, plus gas-fired Greater Des Moines Energy Center retires in 2040
  - All gas retires at the end of book life
- Wind provides significant year-round energy, resulting in primarily summer on-peak energy needs
- New builds fossil case (benchmark):
  - New CTs beginning in 2025
  - New CCCTs in 2040
- New builds zero emissions case:
  - Solar is the replacement resource

Generator	Book Life Scenario Retirement Date
Louisa	2040
Neal 3	2035
Neal4	2040
OGS	2040
Walter Scott 3	2040
Walter Scott 4	2040
Riverside	2025
GDMEC	2031
Moline CT	2020
Coralville CT	2025
Pleasant Hills CT	2034
Sycamore CT	2020
River Hills CT	2021
Merle Parr CT	2025
Electrifarm CT	2030
Quad Cities Nuclear	2032

Book Life Retirement Scenario

- Annual MW additions are incremental
- The total column reflects total new build capacity for each scenario

Retirement Case																						
Planning Year	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41	Total
Retirements (Name Plate, MW)																						
Nuclear MW	0	0	0	0	0	0	0	0	0	0	0	0	406	0	0	0	0	0	0	0	0	406
Coal MW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	331	0	0	0	0	2234	2564
CC MW	0	0	0	0	0	108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	510	617
CT MW	188	104	0	0	0	87	0	0	0	0	143	0	0	0	143	0	0	0	0	0	0	666
Oil MW																						0
Total	188	104	0	0	0	195	0	0	0	0	143	0	406	0	143	331	0	0	0	0	2,743	4254
Benchmark Case Builds (Name Plate, MW)																						
CT	0	0	0	0	0	25	62	71	64	64	261	64	559	61	228	433	61	61	61	60	1,311	3446
CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,764	1764
Total	0	0	0	0	0	25	62	71	64	64	261	64	559	61	228	433	61	61	61	60	3,075	5210
Renewable Case Builds (Name Plate, MW)																						
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar	0	0	0	0	0	40	100	114	103	104	420	107	898	108	374	704	114	112	114	114	5,094	8620
Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	40	100	114	103	104	420	107	898	108	374	704	114	112	114	114	5,094	8620

Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – Book Life Retirement Fossil Benchmark Case

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – Book Life Retirement Zero Emissions Case

[redacted]

Although Prepared at Request of Counsel for Review by Counsel, in light of the IUB ruling, redacted for public release

Advanced Depreciation Scenario

- Retirement Case retirements:
  - Quad Cities retires in 2032
  - Neal 3 retires in 2029
  - Walter Scott 3 retires in 2035
  - Louisa retires in 2027
  - Greater Des Moines retires in 2021
  - Neal 4 retires in 2028
  - Walter Scott 4 retires in 2040
  - Ottumwa retires in 2025
- Wind provides significant year-round energy, resulting in primarily summer on-peak energy needs
- New builds fossil case (benchmark):
  - New CTs beginning in 2025
  - New CCCTs beginning in 2031
- New builds zero emissions case:
  - Solar is the replacement resource

Generator	Advanced Depreciation Scenario Retirement Date
Louisa	2027
Neal 3	2029
Neal4	2028
OGS	2025
Walter Scott 3	2035
Walter Scott 4	2040
Riverside	2021
GDMEC	2031
Moline CT	2020
Coralville CT	2025
Pleasant Hills CT	2034
Sycamore CT	2020
River Hills CT	2021
Merle Parr CT	2025
Electrifarm CT	2030
Quad Cities	2032

Advanced Depreciation Scenario

- Annual MW additions are incremental
- The total column reflects total new build capacity for each scenario

Advanced Retirement Case																						
Planning Year	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41	Total
Retirements (Name Plate, MW)																						
Nuclear MW	0	0	0	0	0	0	0	0	0	0	0	0	406	0	0	0	0	0	0	0	0	406
Coal MW	0	0	0	0	0	330	0	585	233	331	0	0	0	0	0	499	0	0	0	0	586	2564
CC MW	0	617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	617
CT MW	188	104	0	0	0	87	0	0	0	0	143	0	0	0	143	0	0	0	0	0	0	666
Oil MW																						0
Total	188	721	0	0	0	417	0	585	233	331	143	0	406	0	143	499	0	0	0	0	586	4254
Benchmark Case Builds (Name Plate, MW)																						
CT	0	286	66	44	69	547	62	768	335	0	73	64	0	0	227	0	34	61	61	60	689	3446
CC	0	0	0	0	0	0	0	0	0	410	178	0	529	59	0	562	26	0	0	0	0	1764
Total	0	286	66	44	69	547	62	768	335	410	251	64	529	59	227	562	60	61	61	60	689	5210
Renewable Case Builds (Name Plate, MW)																						
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar	0	457	107	75	113	880	106	1,236	550	711	439	126	917	127	392	980	134	132	134	132	1,140	8888
Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	457	107	75	113	880	106	1,236	550	711	439	126	917	127	392	980	134	132	134	132	1,140	8888

Hourly Load Serving Assessment

- ~~The net hourly self-supply position (GWh) Short(-)/Long(+) – Advanced Depreciation Fossil Benchmark Case~~

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
1	[redacted]																						
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9	[redacted]																						
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11	[redacted]																						
12	[redacted]																						

Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – Advanced Depreciation Zero Emissions Case

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Early Retirement Scenario

- Retirements:
  - Quad Cities retires in 2032
  - All other coal and gas generation retires in 2021
- Wind provides significant year-round energy, resulting in primarily summer on-peak energy needs
- New builds fossil case (benchmark):
  - New CTs beginning in 2021
  - New CCCTs beginning in 2021
- New builds zero emissions case:
  - Solar is the primary replacement resource

Generator	Early Retirement Scenario Retirement Date
Louisa	2021
Neal 3	2021
Neal4	2021
OGS	2021
Walter Scott 3	2021
Walter Scott 4	2021
Riverside	2021
GDMEC	2021
Moline CT	2021
Coralville CT	2021
Pleasant Hills CT	2021
Sycamore CT	2021
River Hills CT	2021
Merle Parr CT	2021
Electrifarm CT	2021
Quad Cities Nuclear	2032

Early Retirement Scenario

- ~~Annual MW additions are incremental~~
- The total column reflects total new build capacity for each scenario

Intermediate Case																						
Planning Year	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37	2037-38	2038-39	2039-40	2040-41	Total
Retirements (Name Plate, MW)																						
Nuclear MW	0	0	0	0	0	0	0	0	0	0	0	0	406	0	0	0	0	0	0	0	0	406
Coal MW	0	2564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,564
CC MW	0	617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	617
CT MW	0	666	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	666
Oil MW																						0
Total	0	3,848	0	0	0	0	0	0	0	0	0	0	406	0	0	0	0	0	0	0	0	4,254
Benchmark Case Builds (Name Plate, MW)																						
CT	[redacted]																					
CC																						
Total																						
Zero Emissions Case Builds (Name Plate, MW)																						
Wind	[redacted]																					
Solar																						
Battery																						
Total																						

Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – Early Retirement Fossil Benchmark Case

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Hourly Load Serving Assessment

- The net hourly self-supply position (GWh) Short(-)/Long(+) – Early Retirement Zero Emissions Case

On Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Off Peak	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
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Ramp Requirement Assessment

Existing Load and Wind Resources Only

- The ramp requirement was first assessed assuming the existing hourly load forecast and existing resources through Wind XII
- The analysis computed the hour to hour change in load, net of existing wind generation
  - Net hourly load = hourly load minus hourly wind production from Wind I through Wind XII
- Ramp Observations
  - Because existing resources and market purchases have reasonably met historical net load ramp, and
  - Because there is no significant change to the forecasted net hourly load ramp requirement throughout the planning horizon, then
  - Existing resources and market purchases are anticipated to be capable of meeting future ramp requirements

Ramp Capability Assessment

Existing Load and Wind Resources Only

- Ramp Observations (continued)
  - Existing resource retirements will reduce ramp self-provision capabilities while increasing solar penetration will amplify on-peak period ramping needs

Net Ramp Requirements; Net Load = Load minus Wind						
	Off Peak – Max Hour			On Peak – Max Hour		
Year	Load Only	Load Net of Wind	Load Net of Wind & Solar	Load Only	Load Net of Wind	Load Net of Wind & Solar
2020	774	-15	191	885	24	198
2025	907	-13	202	944	25	213
2030	765	-14	199	1,058	27	215
2035	858	-14	209	942	26	217
2040	749	-15	216	944	29	224

Existing Resource Ramp Capability		
WS 4	Ramp Up / Down	MW
Coal	Up	[redacted]
CC Gas	Up	
Peaker Gas	Up	
Peaker Oil	Up	
Coal	Down	
CC Gas	Down	
Peaker Gas	Down	
Peaker Oil	Down	

Although Prepared at Request of Counsel for Review by Counsel, in light of the IUB ruling, redacted for public release

Ramp Requirement Assessment

Early Retirement (2021) Scenario

- The ramp requirement was next assessed assuming the existing hourly load forecast and existing resources through Wind XII, and the solar build from the Early Retirement (2021) Scenario
  - Early Retirement Scenario was selected because it shows the earliest change to the hourly ramp requirement of the scenarios studied
- The analysis computed the hour to hour change in load, net of existing wind and solar generation
  - Net hourly load = hourly load minus hourly wind production from Wind I through Wind XII minus new solar builds
- Ramp Observations
  - Existing resource retirements will reduce ramp self-provision capabilities while increasing solar penetration will amplify hourly self-supply ramping requirement
  - Alternatives to MidAmerican self-supply of ramp: Market purchases or solar curtailments

Ramp Capability Assessment

Early Retirement (2021) Scenario

- Ramp Observations (continued)
  - Potential issues could be similar to the "duck curve" as described by CAISO
  - https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf)

Net Ramp Requirements; Net Load = Load minus Wind						
	Off Peak – Max Hour			On Peak – Max Hour		
Year	Load Only	Load Net of Wind	Load Net of Wind & Solar	Load Only	Load Net of Wind	Load Net of Wind & Solar
2019	337	662	662	414	637	637
2020	342	774	774	416	885	885
2025	342	907	3,832	455	944	3,728
2030	387	765	4,128	401	1,058	4,077
2035	351	858	4,762	446	942	5,053
2040	407	749	5,077	617	944	5,072

Ramp Capability Assessment

Selected Day From Early Retirement (2021) Scenario

- There are no solar builds in year 2020 for the Early Retirement Scenario, so the net load only includes wind production offsetting the hourly load

[redacted]

Ramp Capability Assessment

Selected Day From Early Retirement (2021) Scenario

- The “duck” appears in 2021 due to the high penetration of solar beginning in 2021 in the Early Retirement Scenario; requires significant off-system sales at noon on a summer day

[redacted]

Ramp Capability Assessment

2040 – 4 days Day From Early Retirement (2021) Scenario

[redacted]

Utility Scale Solar Land Requirement

- The land required for solar construction is significant
  - The analysis indicates new solar PV builds are from 8500 – 9200 MW (nameplate)
    - Higher load forecasts possible due to data center potential would result in even more new solar PV resource builds
  - At 5 acres per MW, the land required for utility scale solar is:
    - 42,500 – 46,000 acres
    - 66 - 72 square miles (640 acres/square mile)

Appendix 2: Key Assumptions

Existing Resources

Cost Forecasts

- Existing resources, capital and O&M (fixed and variable)
  - Forecast is from the Fall 2018 financial plan,
  - The spending pattern from the first 20 years is repeated for subsequent years, escalated at 2.25% per year
- Energy revenue
  - Utilizes production cost runs from the Fall 2018 financial plan
  - Escalates costs and revenues at 2.25% per year
  - Market prices from the Fall 2018 plan are utilized to forecast energy revenues
  - Impacts of the changing resource mix (MidAmerican or regionally) are not assessed, but are planned for future studies
  - Carbon pricing assumptions only implicitly modeled the effect of the Environmental Protection Agency's (EPA's) proposed Affordable Clean Energy (ACE) rule

[redacted]

New Resources

Cost Forecasts

- A 63 year NPVRR analysis (year 2018 through 2081) is utilized
  - Allows for a new wind resource built in 2041 to reach the end of its book life
  - Capacity factors impact market revenues, thereby impacting NVPRR
  - Does not include the cost of servicing the debt on existing assets
  - Does not include administrative and general (A&G) cost assignments to the generation account or changes to A&G resulting from a changing resource mix
- Alternative views of NPVRR on next slide:
  - Per MW of accredited summer-rated capacity
  - Per MW of nameplate capacity
  - Per MWh of energy production

New Resources

Cost Forecasts ($NPVRR)

[redacted]

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041

Wind Solar Battery New CT New CCCT

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041

Wind Solar Battery New CT New CCCT

[redacted]

Wind Solar Battery New CT New CCCT

New Resources
Cost Forecasts

	Overnight Cost (Resource /Transmission) ($/kW)	Fixed O&M ($/kW-year)	Variable O&M ($/kWh)	Unit Size (MW)	Book Life (years)	Capacity Factor (%)	Major Overhaul/Repower Timing
CT-gas	[redacted]						
CCCT-gas							
Wind							
Solar							
Battery							

Notes
- Solar is weighted cost; 90% utility scale and 10% community solar garden
- CT and CCCT MW are the nominal ratings for Iowa (International Standards Organization, "ISO")
- CT and CCCT capacity factors are based production cost model runs for a CT and CCCT dispatched against the same Fall 2018 Plan prices used for other resources
- Wind, solar, and battery MW are listed as 1 MW, but assumed to be scalable to any size

Confidential - Prepared at Request of Counsel for Review by Counsel Protected by the Attorney-Client Privilege

Wind Maturity Curve

Extrapolated Beyond 2040

Wind Maturity Curve
% change from 2018

[redacted]

Solar Maturity Curve

Extrapolated Beyond 2040

[redacted]

Although Prepared at Request of Counsel for Review by Counsel, in light of the IUB ruling, redacted for public release

Battery Maturity Curve

Extrapolated Beyond 2040

[redacted]

MidAmerican's GreenAdvantage™

- Fall 2018 Plan assumptions (includes Wind XII)

MidAmerican Energy Company
GreenAdvantage ™
Renewable Percentage

2019 Plan	75%
2020 Plan	95%
2021 Plan	101%
2022 Plan	102%
2023 Plan	102%
2024 Plan	101%
2025 Plan	100%
2026 Plan	99%
2027 Plan	97%
2028 Plan	96%

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