PowerSimm for Applications of Resource Valuation

Presented by:

Sean Burrows, PhD
Alankar Sharma/Kristina Wagner
sburrows@ascendanalytics.com
303.415.1400

August 16, 2017

NorthWestern Energy

Ascend Analytics

Better models. Better decisions.

Outline

I. Renewables are proliferating throughout the WECC (partly due to QF contracts)

II. Renewables' impact on (1) flexible requirements and (2) market prices

III. Analysis of ancillary services with NorthWestern's current thermal fleet vs. additional ICEs and batteries

IV. Simulating how future prices increase value of flexible generating units:

   I. Lower market prices (lower implied heat rates)

   II. Volatile prices

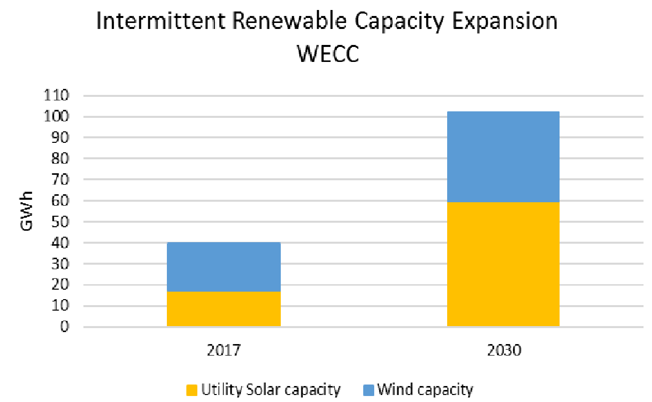
V. What resources are needed for the future of increased regulation requirements and volatile prices?

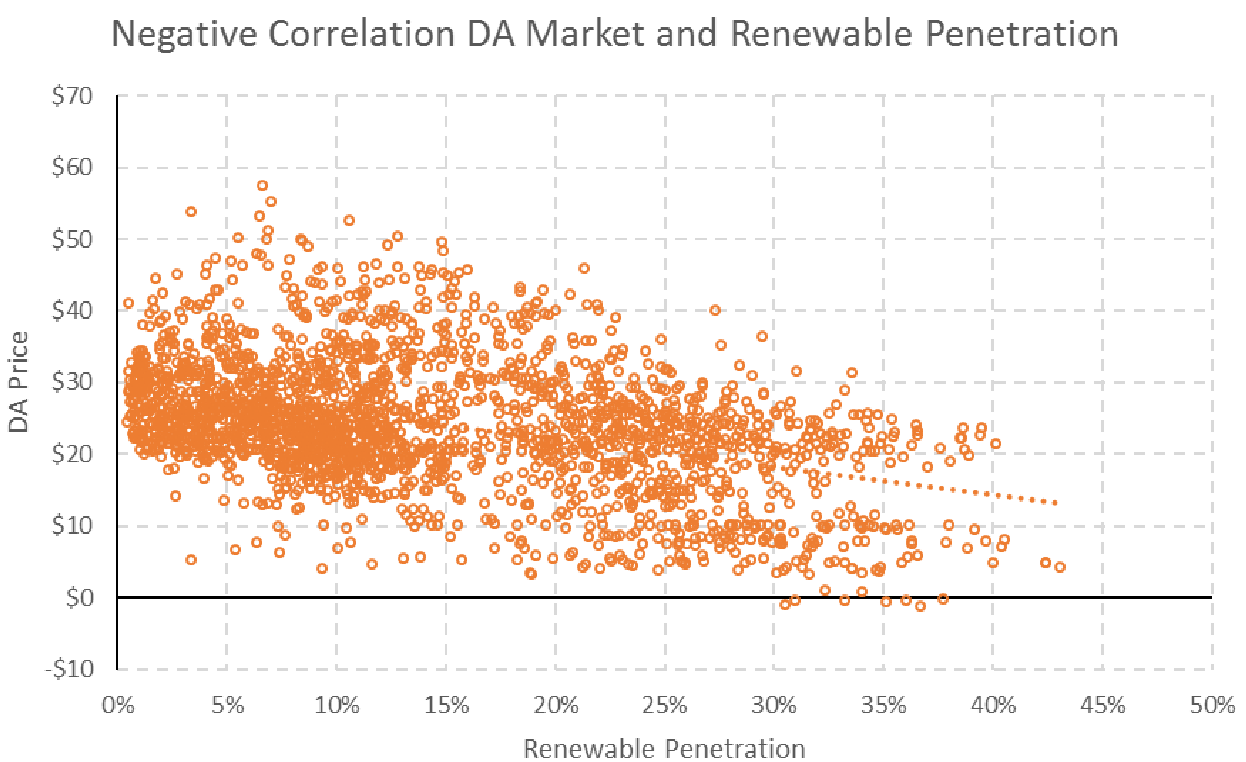
As renewables add zero variable cost energy, average market price declines

Renewable energy is being deployed aggressively in the WECC

RPS Standards in WECC

California – 100% RPS by 2045
Oregon – 50% by 2040
Washington – 15% by 2020
Nevada – 25% by 2025
Arizona – 15% by 2025
New Mexico – 20% by 2020
Colorado 30% by 2020





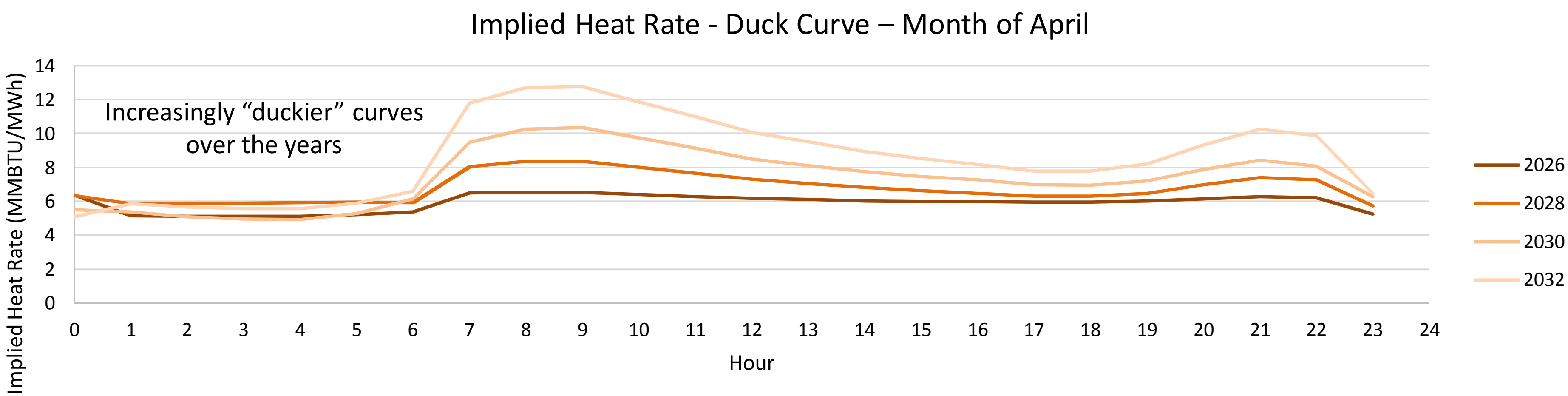
CAISO 2014-2016

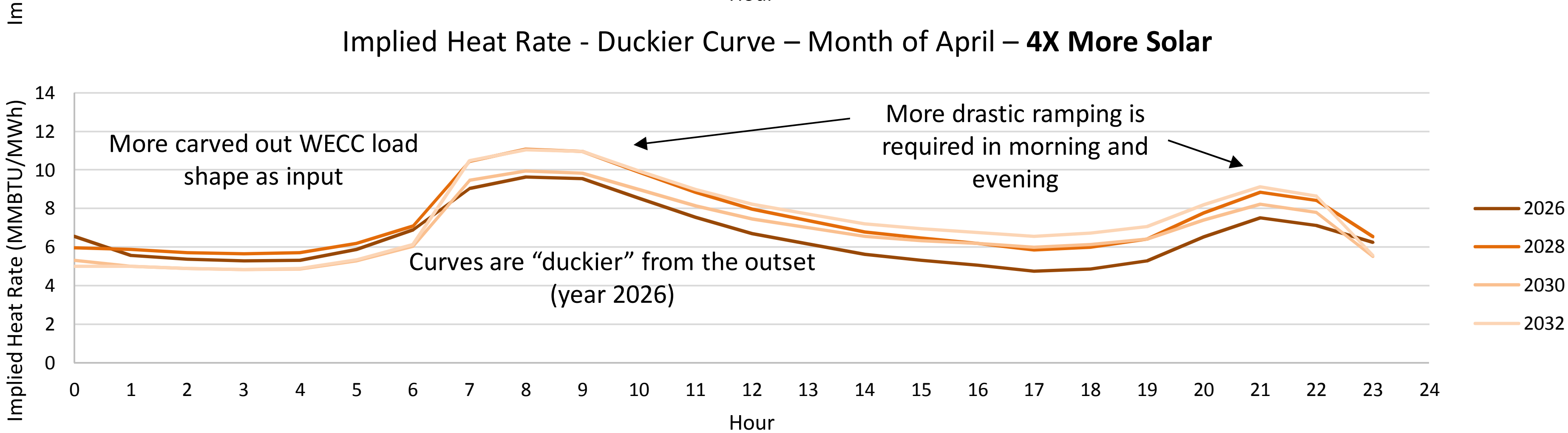
As markets connected to NorthWestern mature and saturate with high renewable penetration, NorthWestern's power prices will experience a greater decline.

NorthWestern Energy

Effect of increasing renewable penetration on WECC load

- The **duck curves** demonstrate how power prices are sensitive to renewables
- Solar saturation:
  - carves out load → **carved-out heat rates**, **higher price volatility**, **increased flexible generation requirements**
  - Shifts curves downwards → overall **lower heat rates** and **lower net-returns** for inflexible thermal units





Ancillary Services Modeled

Ancillary services modeled are specific to Northwestern Energy region; not tied to NERC standards

Contingency Reserves: Resources that address outages of major units	
Spinning requirements	Online resources that can quickly address major outages; must respond within 10 minutes
Non-spinning requirements	Offline resources that can quickly address outages; must respond within 10 minutes
Flexible Reserves: Resources that address system variability outside of contingency events.	
Regulation up requirements	Online resources that can quickly ramp up to meet rapid changes in system requirements; must respond within 1 minute
Regulation down requirements	Online resources that can quickly ramp down to meet rapid changes in system requirements; must respond within 1 minute
INC requirements	System balancing reserves that provide additional capability; must respond within 10 minutes
DEC requirements	System balancing reserves that backoff generation; non-binding

Renewables increase NorthWestern's flexible requirements

Flexible generation = 15 minute ramp (INC) + 1 minute ramp (Regulation)

SCENARIO	INC CAPACITY	REGULATION CAPACITY	TOTAL FLEXIBLE REQUIREMENTS
Base	252	44	296
+100 MW Solar	262 (4%)	50 (1%)	312 (5%)
+200 MW Wind	375 (49%)	60 (63%)	435 (45%)
+100MW Solar AND +200MW Wind	375 (49%)	75 (68%)	450 (52%)

Increasing renewable penetration causes growth in system flexibility requirements to provide regulation and fast-ramping services

NorthWestern Energy

June 8, 2017 Resource Adequacy Commission presentation study

How are ancillary contributions fixed?

Value				
	DGGS 1-2			
Row Labels	GENERATION - Thermal Generation MWh	RegulationDOWN - RegulationDOWN	RegulationUP - RegulationUP	Spin - Spin
3 6:00	3.5		20	
3 7:00	25	20		
3 8:00	25	20		
3 9:00	25	20		
3 10:00	25	20		
3 11:00	25	20		
3 12:00	25	20		
3 13:00	25	20		
3 14:00	25	20		
3 15:00	25	20		
3 16:00	25	20		
3 17:00	25	20		
3 18:00	25			
3 19:00	25			
3 20:00	14.773172			10.226828
3 21:00	25	20		
3 22:00	3.5		21.5	
3 23:00	3.5		21.5	
4 0:00	3.5		21.5	
4 1:00	3.5		21.5	
4 2:00	3.5		21.5	
4 3:00	3.5		21.5	
4 4:00	3.5		20	
4 5:00	3.5		21.5	
4 6:00	3.5		21.5	
4 7:00	3.5		21.5	

Regulation is the most expensive ancillary service

Fast ramping units provide regulation

When economics of energy dispatch are “in the money” and unit is online, it can commit to **Regulation** and **Spin**

- Hourly unit commitment performed on co-optimization between ancillary requirements and energy dispatch.
- Full fuel cost is considered for co-optimization. (Fuel cost + Startup Cost + VOM Cost)
- Units can be committed to only one of Spin or Regulation requirement in any hour

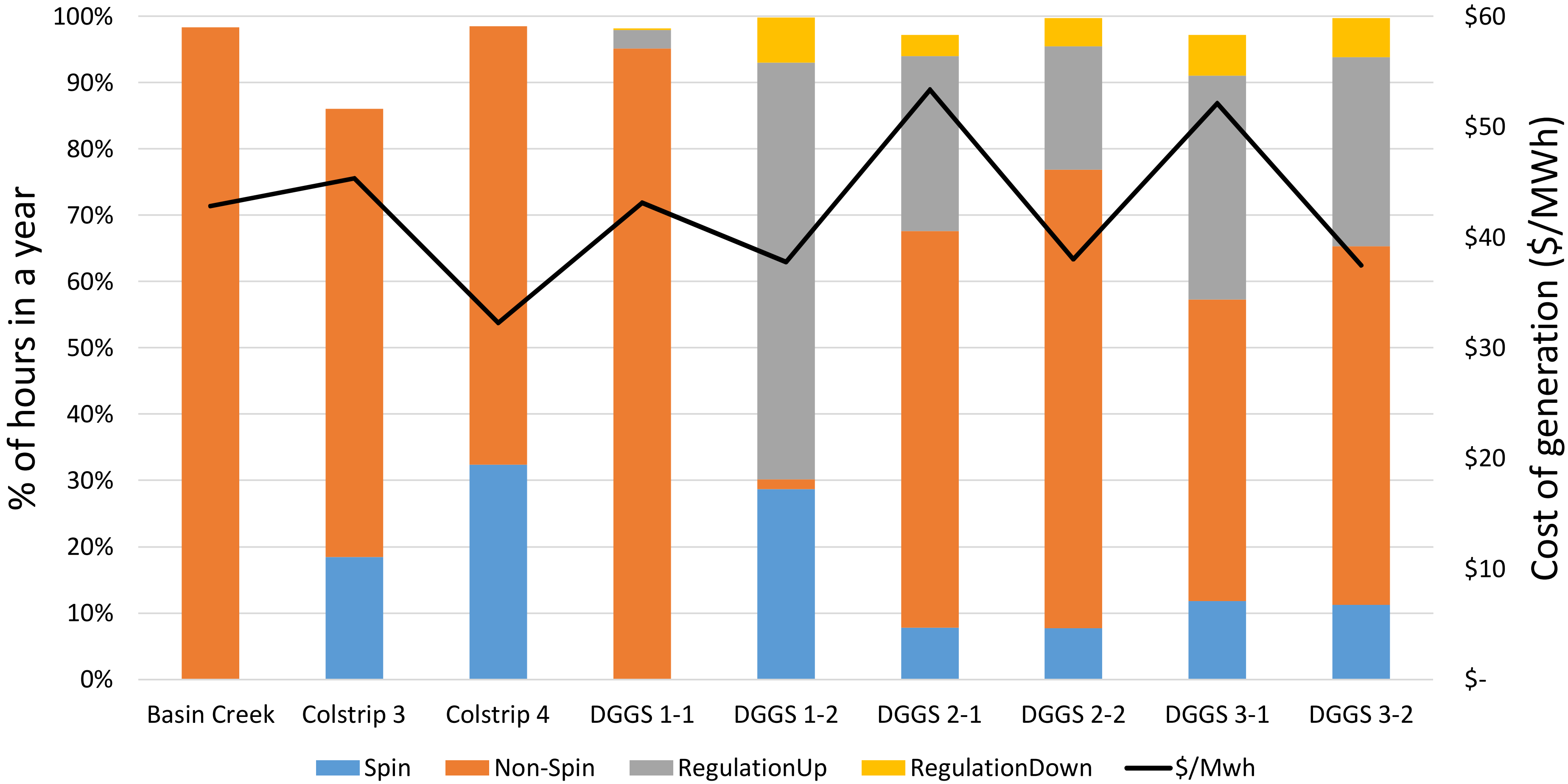
How are ancillary contributions fixed?

Value		
	Generation Asset	
	Simple HR 2017 Basin Creek 1-9 2015 single	
Row Labels	GENERATION - Thermal Generation MWh	NonSpin - NonSpin
2020-01		
3 10:00		51
3 11:00		51
3 12:00		51
3 13:00		51
3 14:00		51
3 15:00		51
3 16:00		51
3 17:00		51
3 18:00	51.75	
3 19:00	51.75	
3 20:00		51
3 21:00		51
3 22:00		51
3 23:00		51
4 0:00		51
4 1:00		51
4 2:00		51
4 3:00		51
4 4:00		51
4 5:00		51
4 6:00		51
4 7:00		51
4 8:00		51
4 9:00		51
4 10:00		51
4 11:00		51

When economics of energy dispatch are not "in the money", the unit can provide **NonSpin** if it has the appropriate ramp rate (able to come online in 10 minutes)

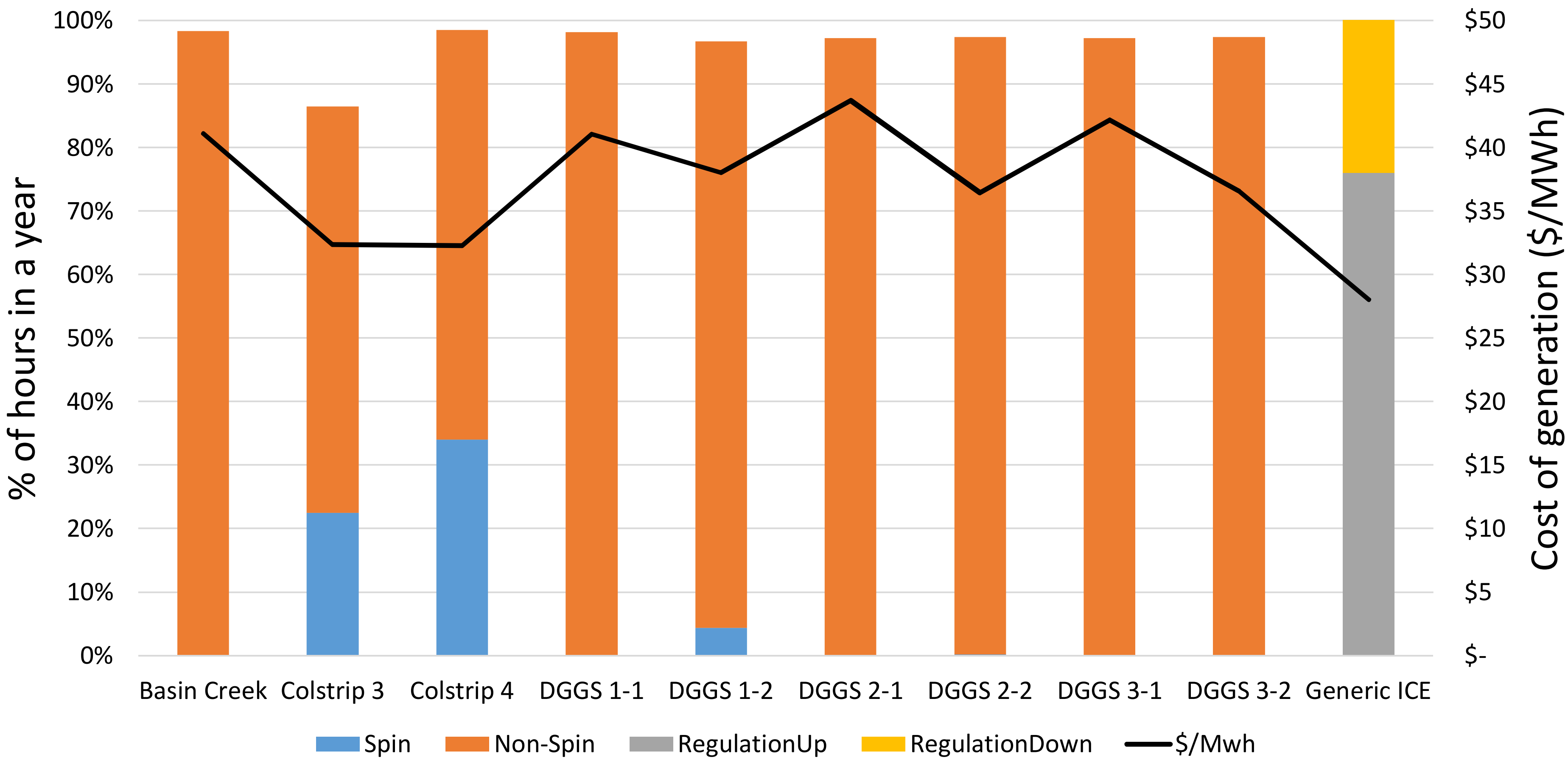
- Maximum amount of unit contribution can be fixed via UI

How is current fleet doing in providing ancillary services? Base portfolio



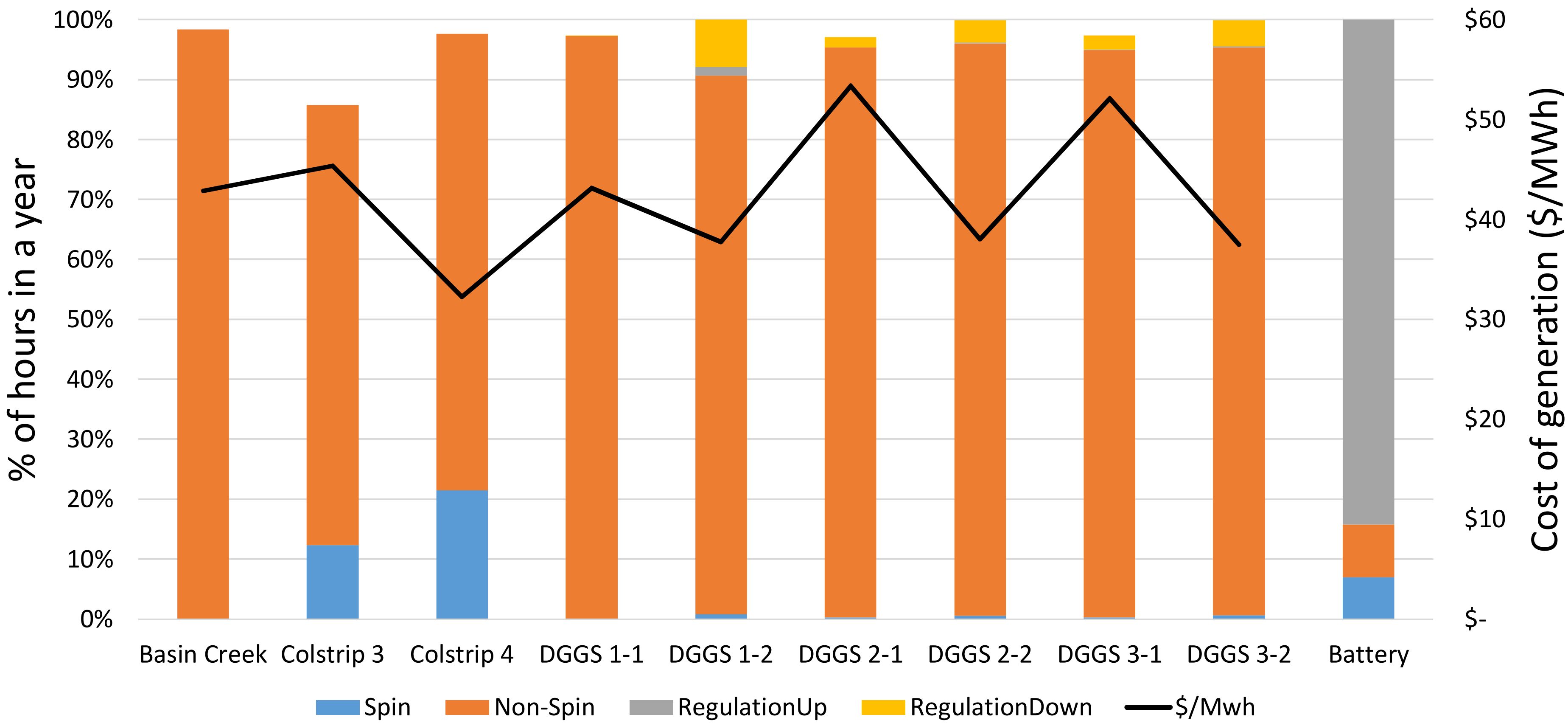
- Units with flexible characteristics better serve Regulation and Spin (DGGS cheaper to operate than Basin Creek based on VOM cost comparison)
- Combined ownership of Colstrip limits it to only Spin and Non-Spin, not contributing Regulation

Ancillary contributions with competing ICE unit



- Due to its flexibility and low VOM cost, the ICE can efficiently provide expensive ancillary services (i.e. regulation) and remove this burden from more expensive units
- Other units can more reliably provide energy and Spin and Non Spin products

Ancillary contributions with competing battery



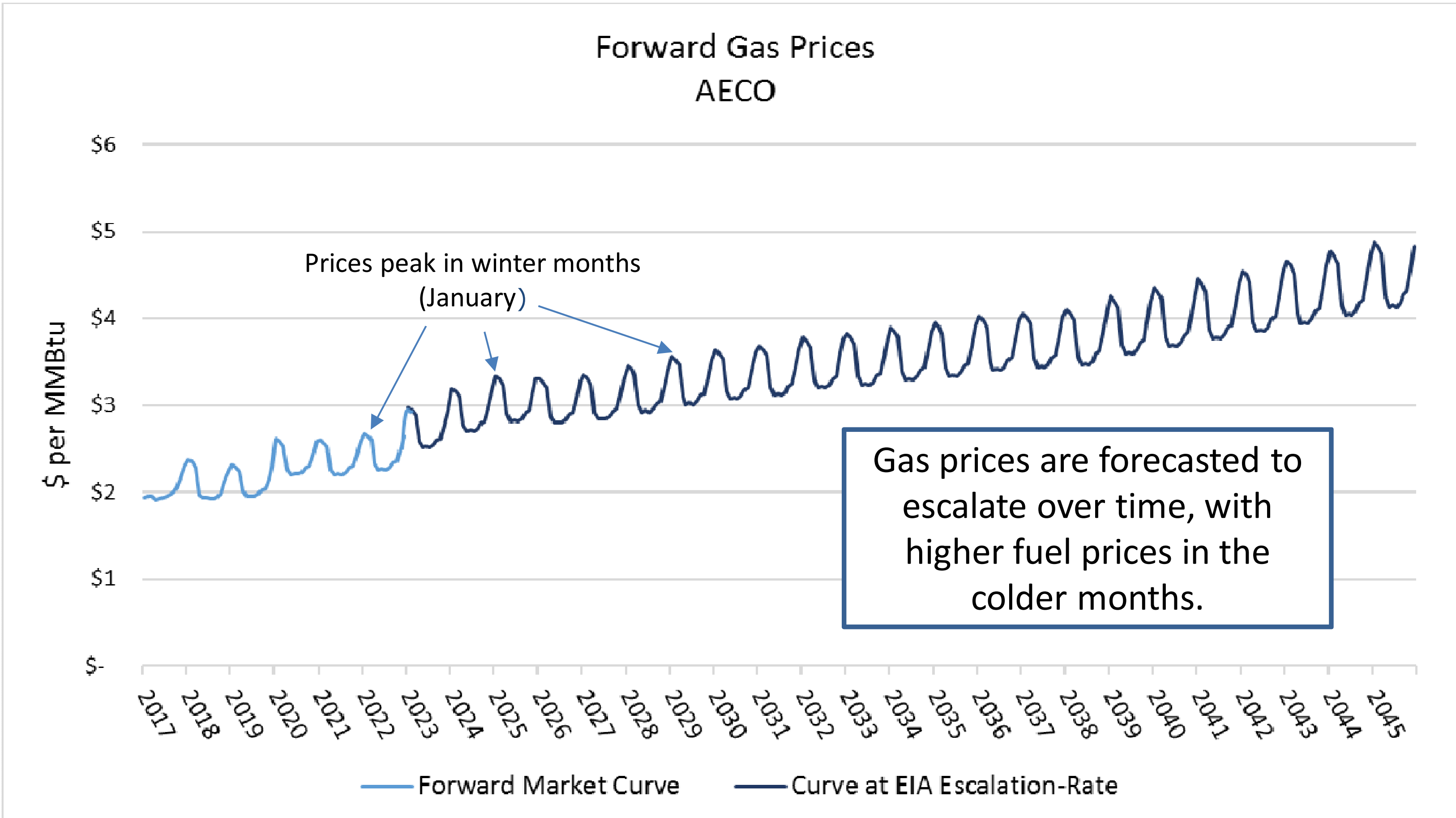
- Batteries are the cheapest flexible resource to operate
- Batteries serve all of Up side ancillary products (Regulation Up, Spin)
- Batteries are unique in their ability to provide Spin and Non Spin as there is no fixed “off” state for a battery

Need for flexible resources

Value	Column Labels						
	Ancillary Reserve						
Row Labels	INCLUSIVEANCVIOLATION - Inclusive Ancillary Violations	INCLUSIVEANCVIOLCOST - Inclusive Ancillary Violation Costs	NONSPINVIOLATION - NonSpin violations	NONSPINVIOLCOST - NonSpin violation cost	SPINVIOLATION - Spin violations	SPINVIOLCOST - Spin violation cost	TOTALANCVIOLATIONCOST - Total Ancillary Violations
2017-01	48	1,680	0	0	3,923	58,849	60,529
2017-02	54	1,873	0	0	4,295	64,432	66,304
2017-03	70	2,450	6	45	3,280	49,206	51,701
2017-04	908	31,763	9	70	10,984	164,755	196,587
2017-05	246	8,593	7	56	2,414	36,216	44,865
2017-06	205	7,176	25	202	2,792	41,878	49,257
2017-07	375	13,108	0	0	922	13,835	26,943
2017-08	128	4,463	0	0	1,306	19,592	24,054
2017-09	83	2,888	13	101	2,968	44,517	47,506
2017-10	7,373	258,055	27	216	188	2,817	261,088
2017-11	10,489	367,115					367,115
2017-12	5,704	188,100	2,137	17,094			205,194
2018-01	7,339	256,856	2	18	3,288	50,306	307,180
2018-02	6,813	243,206	21	173	3,068	46,938	290,317
2018-03	1,943	69,365			1,959	29,973	99,339
2018-04	1,368	48,838	3,652	29,802	3,332	50,972	129,612
2018-05	1,647	58,798	10,728	87,538	5,517	84,410	230,746
2018-06	126	4,480	14,497	118,299	2,206	33,755	156,534
2018-07	521	18,582	0	0	967	14,802	33,385
2018-08	18	643	90	737	1,238	18,940	20,321
2018-09	2,865	102,263	465	3,795	335	5,128	111,186
2018-10	1,031	36,809	0	4	36	552	37,365
2018-11	3,289	117,400	0	0			117,400
2018-12	16,558	579,308	3,954	32,267			611,575

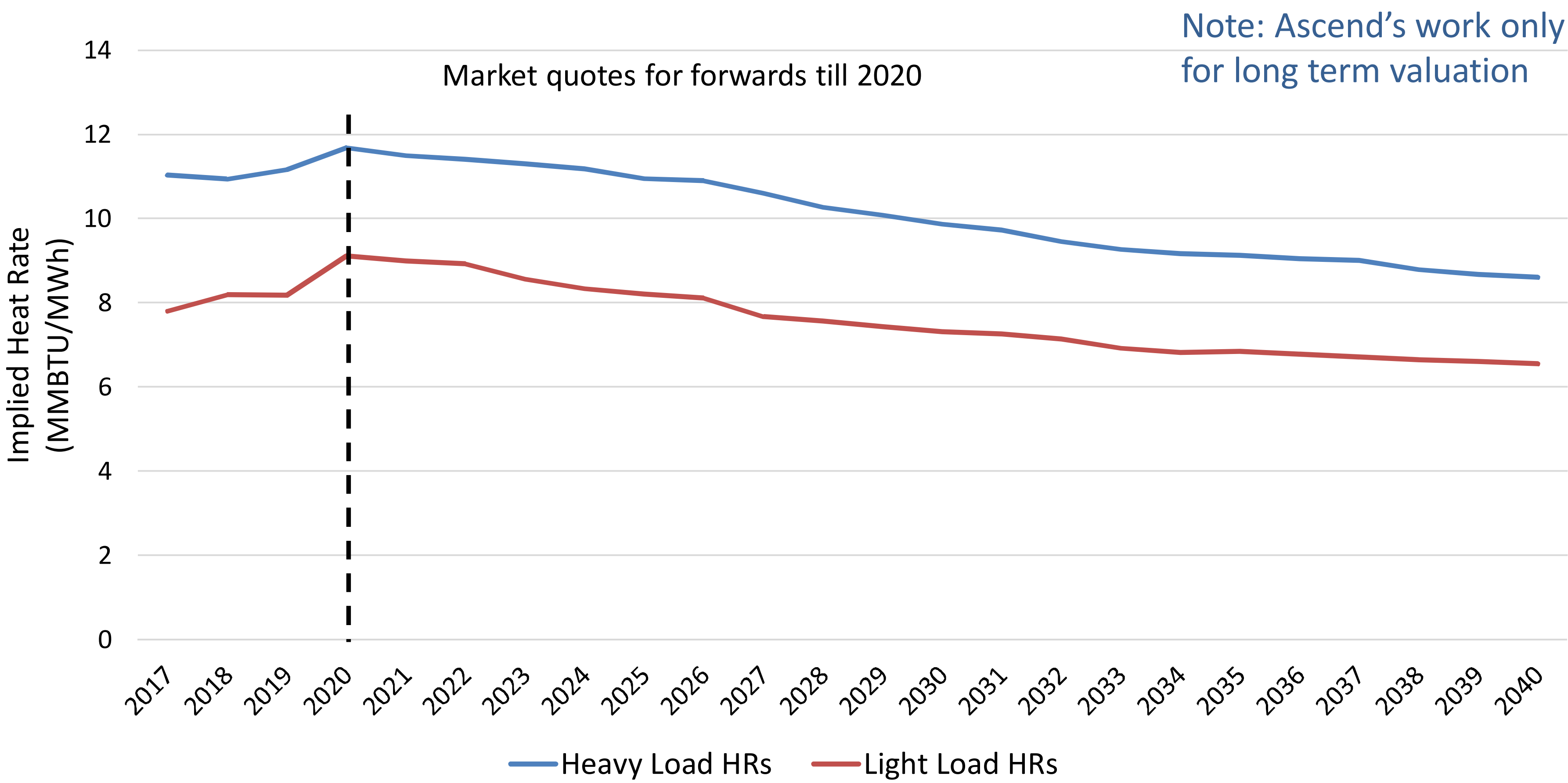
- NorthWestern’s current fleet is unable to adequately fulfill ancillary requirements due to capacity characteristics
- Violations are reported across all ancillary types
- Being a BA, for reliability reasons, NorthWestern Energy should look to expand existing fleet with flexible resources
- ICEs and Batteries are some of the cheapest, most flexible resources

Forward fuel prices



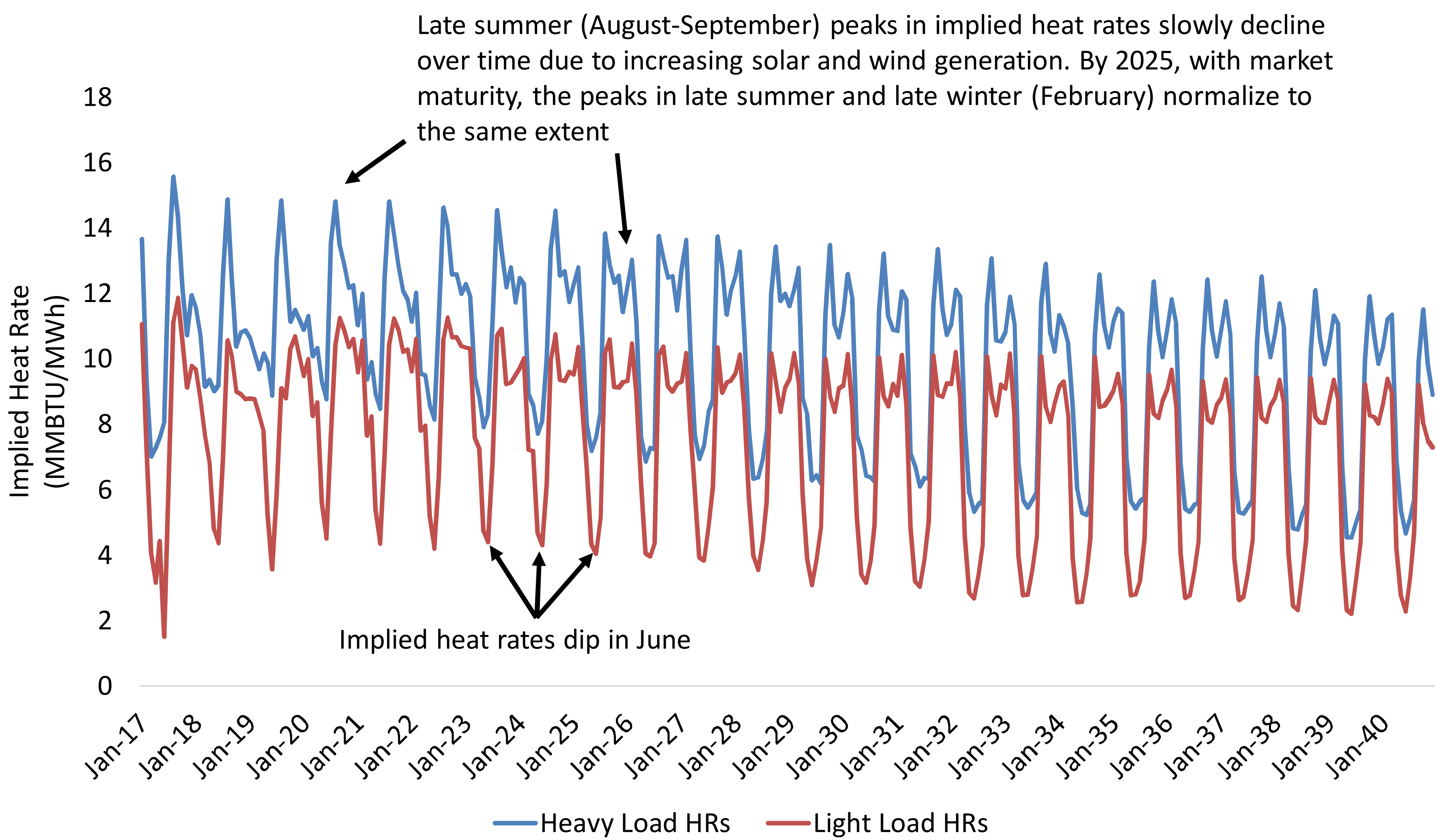
Source: Canadian Gas Price Reporter

Long-term implied heat rates (annual)

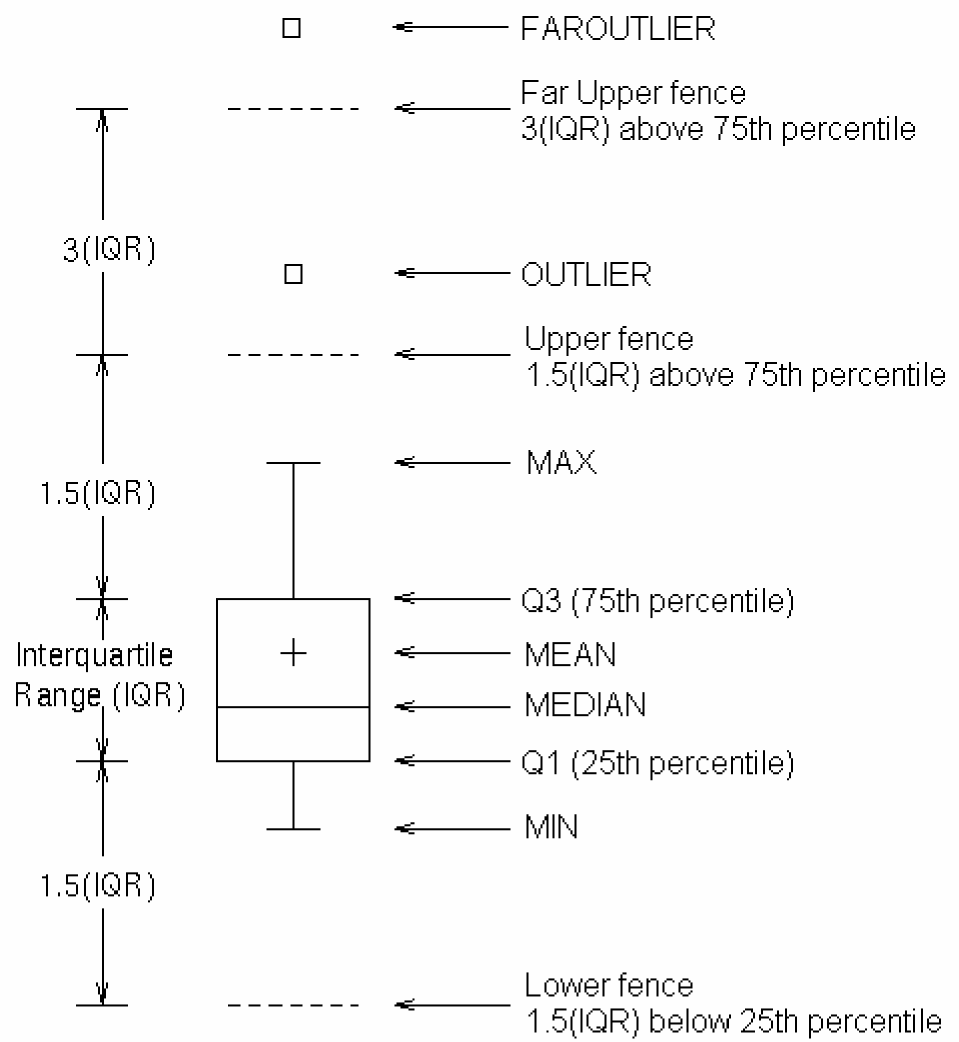


- Due to the increasing penetration of zero variable cost renewable generation in WECC, the implied heat-rate is expected to **decrease steadily over time**.
- Decreasing heat rates make **thermal units less efficient** and **less profitable**

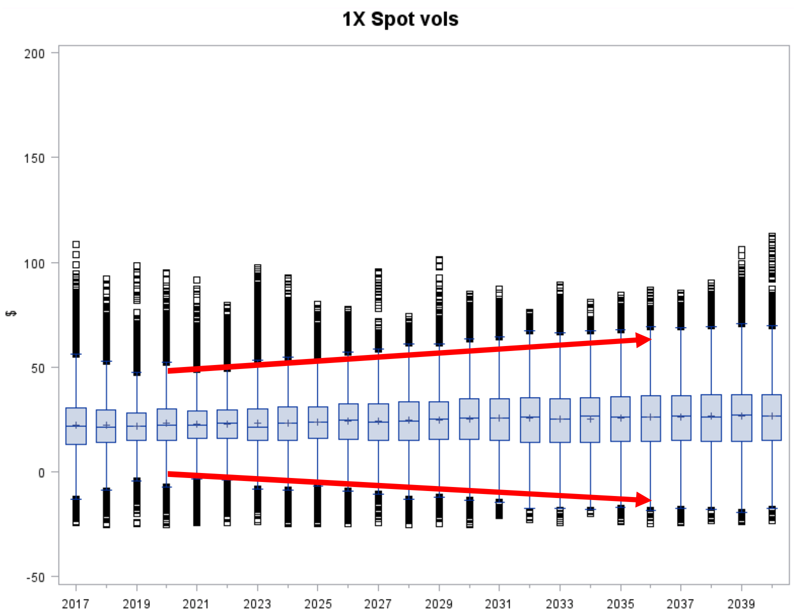
Long-term implied heat rates (monthly)



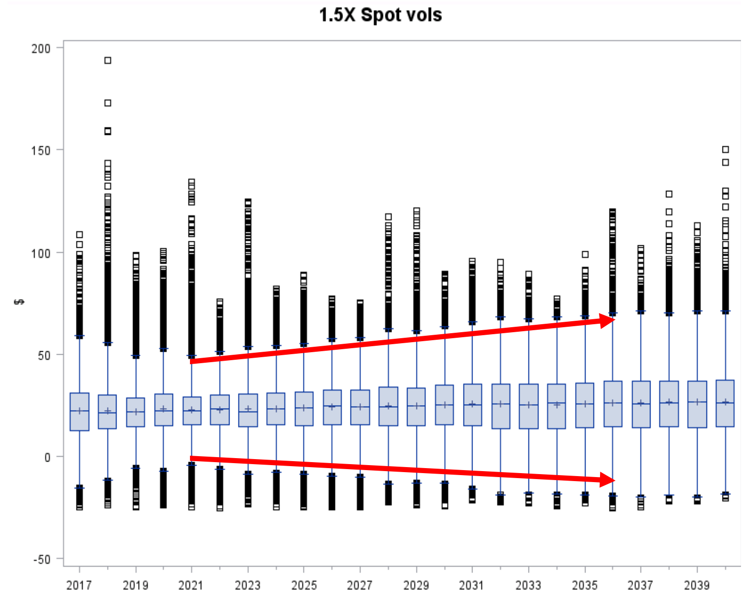
Understanding box plots for spot simulations

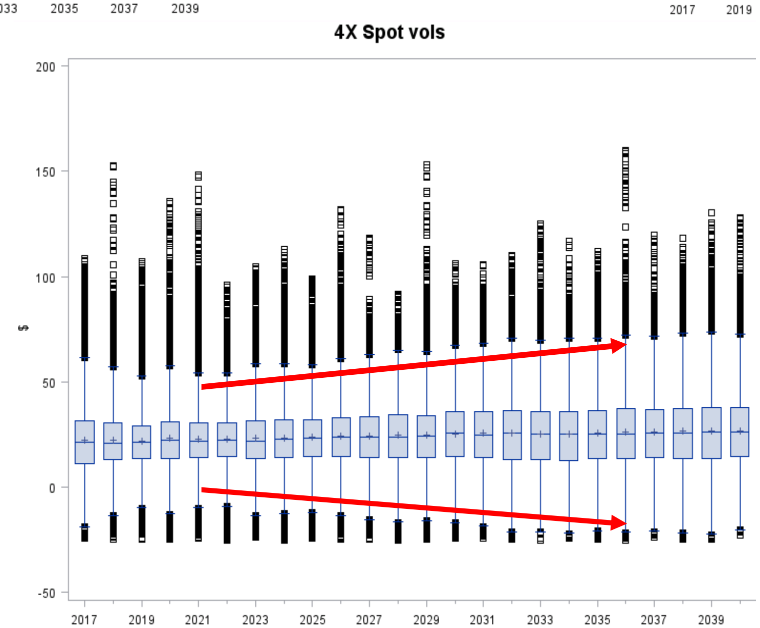


Effects of increasing spot volatilities on prices



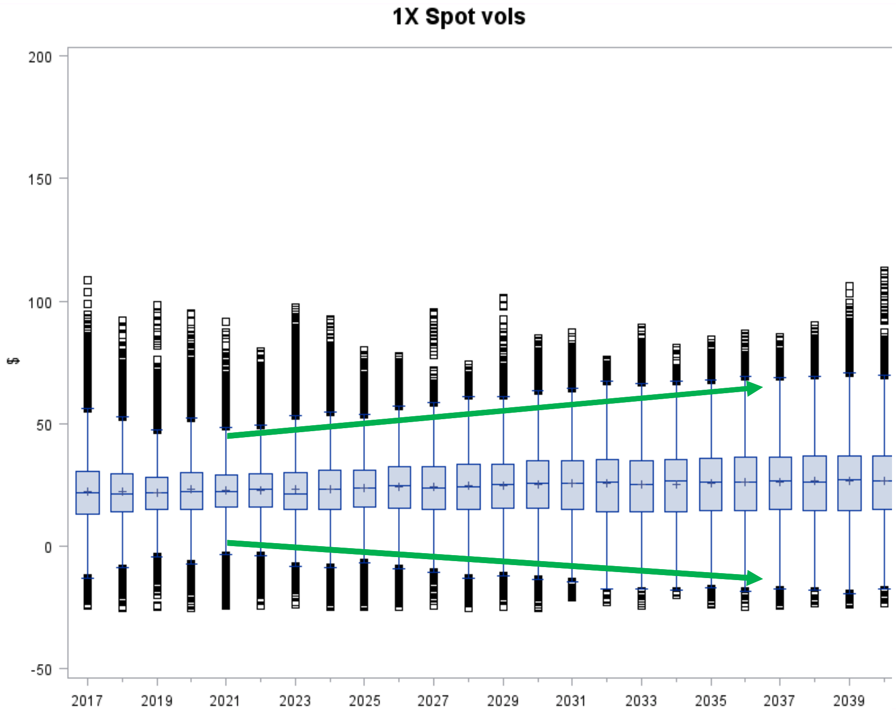
Increasing spot volatility leads to a larger range of simulated prices

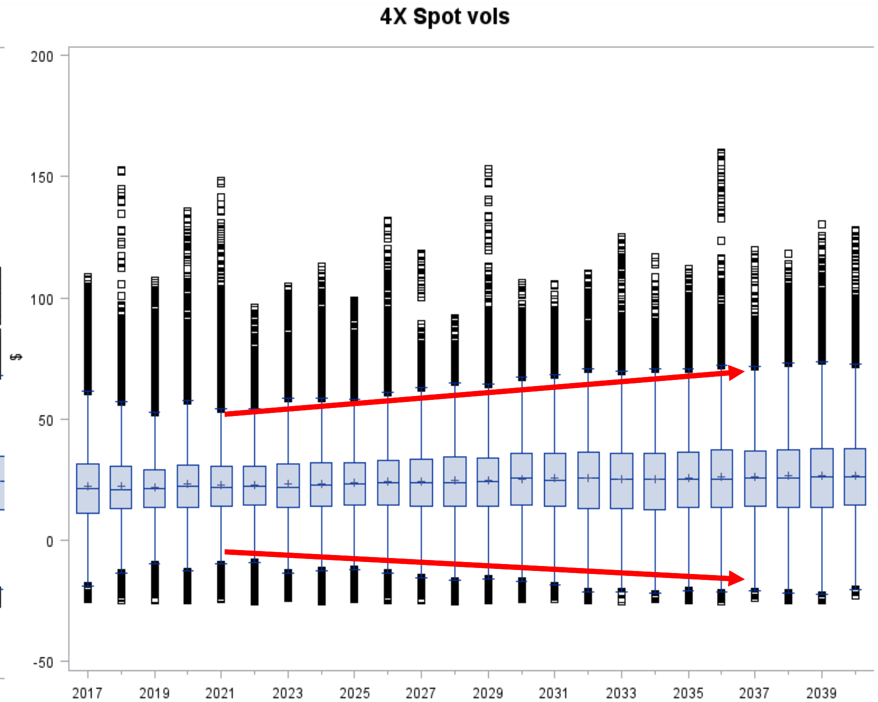




NorthWestern Energy

Effects of increasing spot volatilities on prices

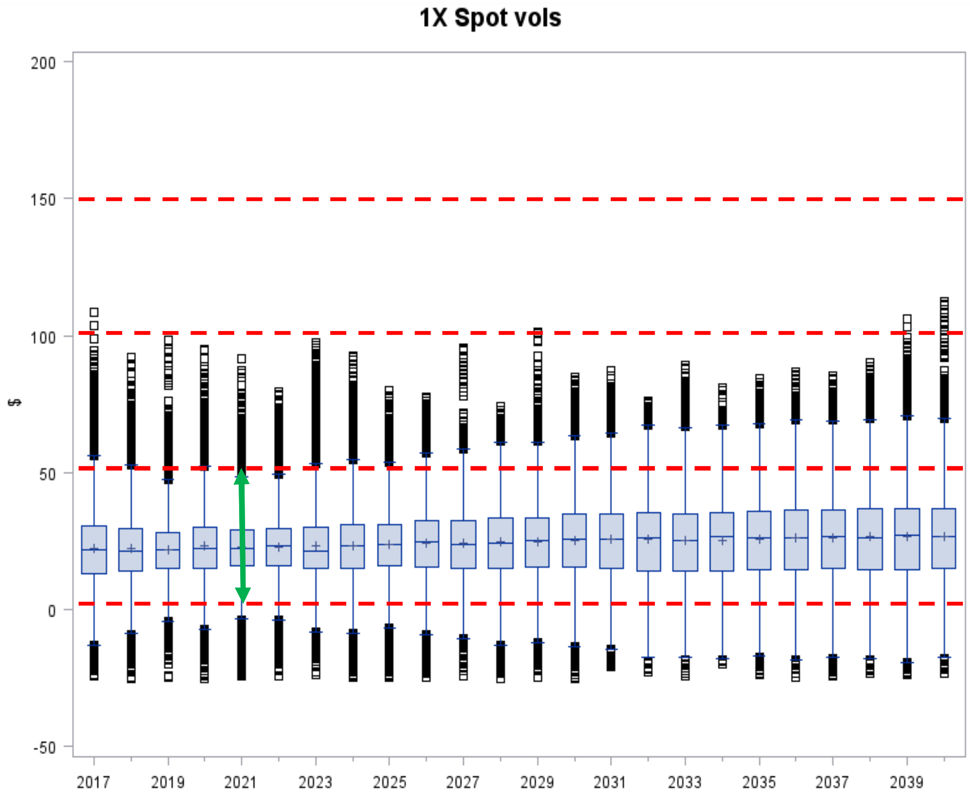


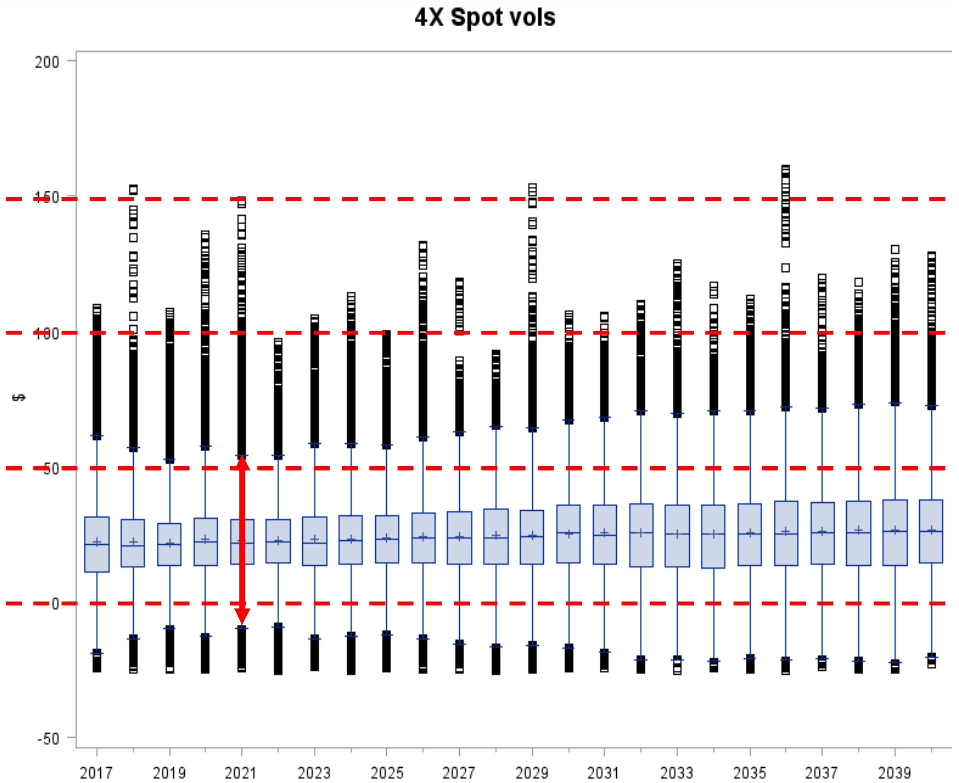


Increasing volatility = larger inter-quartile range

Higher volatilities imply higher upper limit of simulated prices

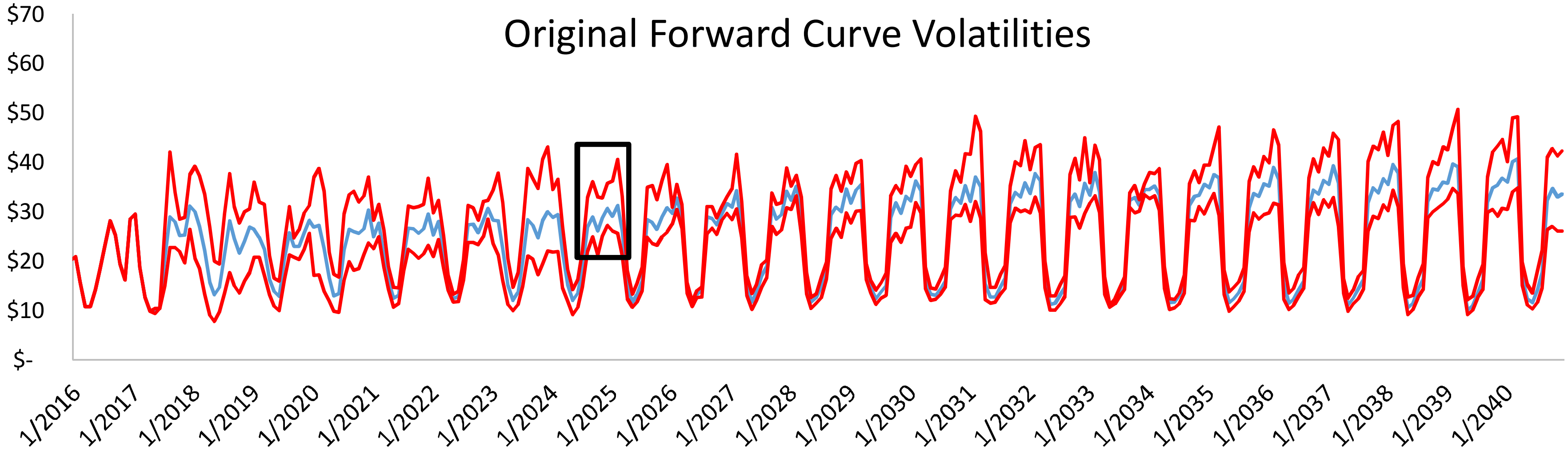
Effects of increasing spot volatilities on prices

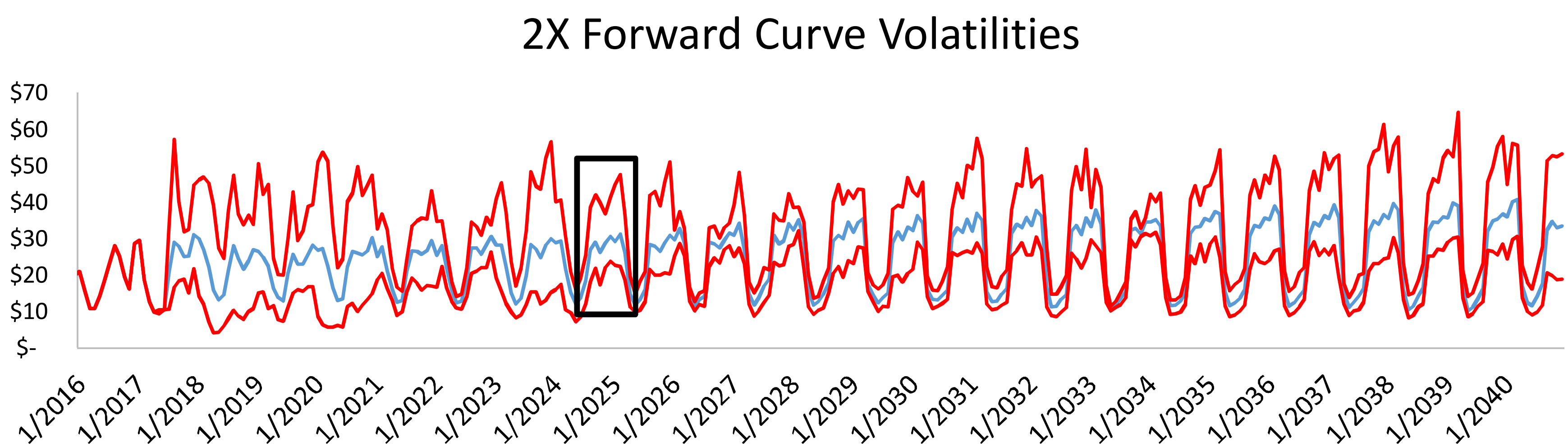




- Simulations are effectively unbounded but have a soft lower limit on negative prices according to economics of the marginal thermal unit (~ -$25)
- As **hourly volatility increases**:
  - **Greater density of prices** in upper bounds of simulations
  - **Greater inter-quartile range of intra-day price simulations** (e.g. Years 2021, 2024); i.e. larger spread

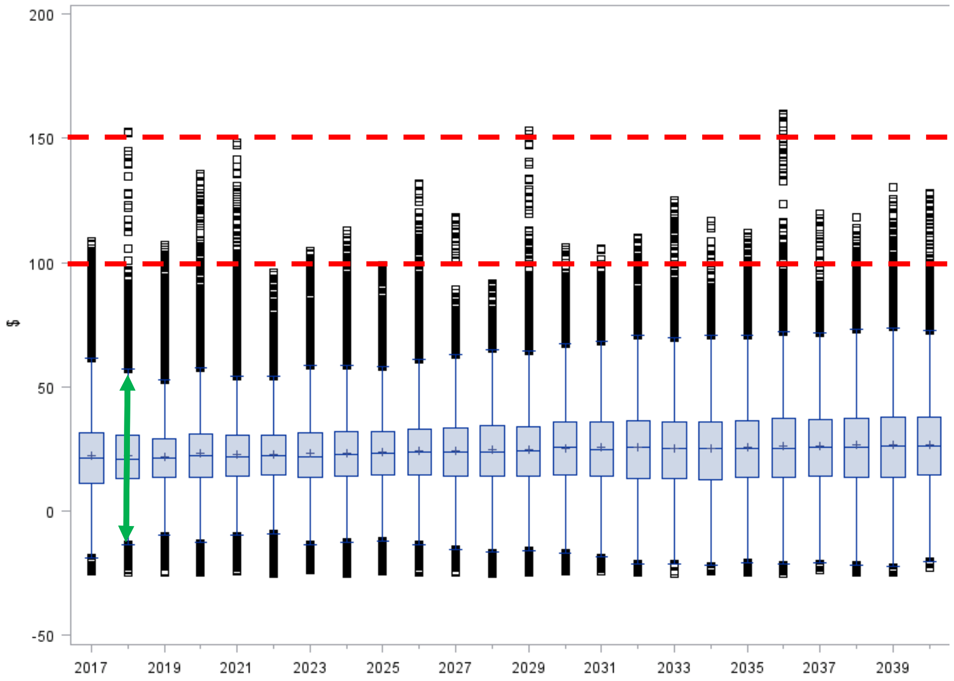
Simulated forward curves and 2X forward volatility



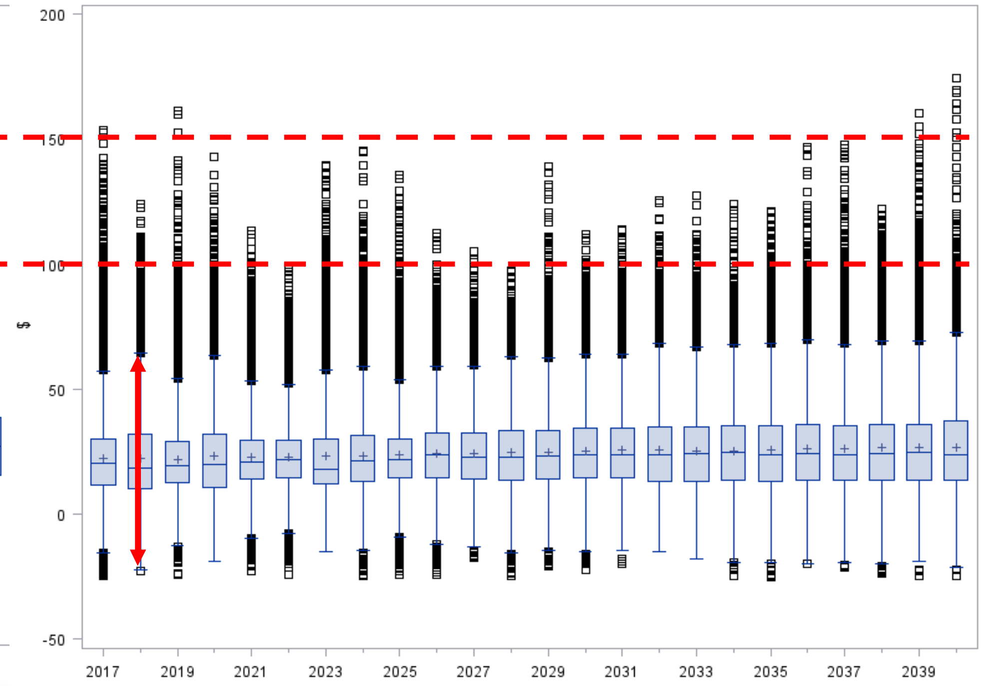


Same spot volatility, higher forward volatility

1X FC Vol 4X Spot Vol

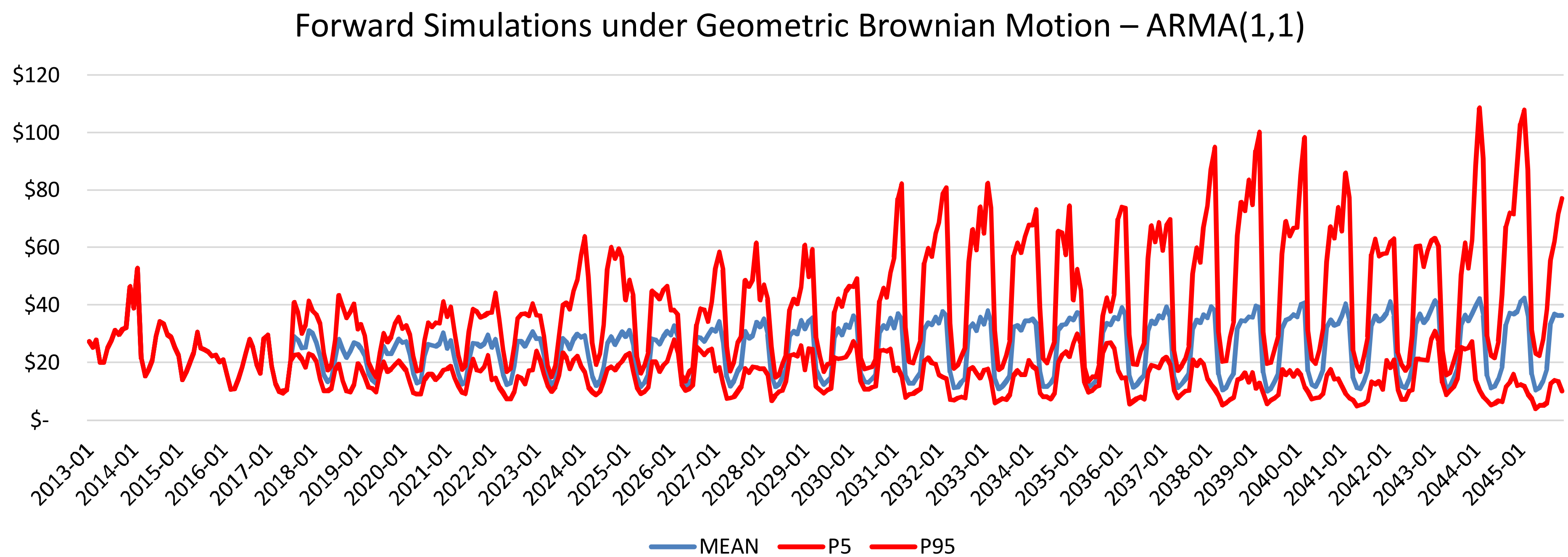


2X FC Vol 4X Spot Vol



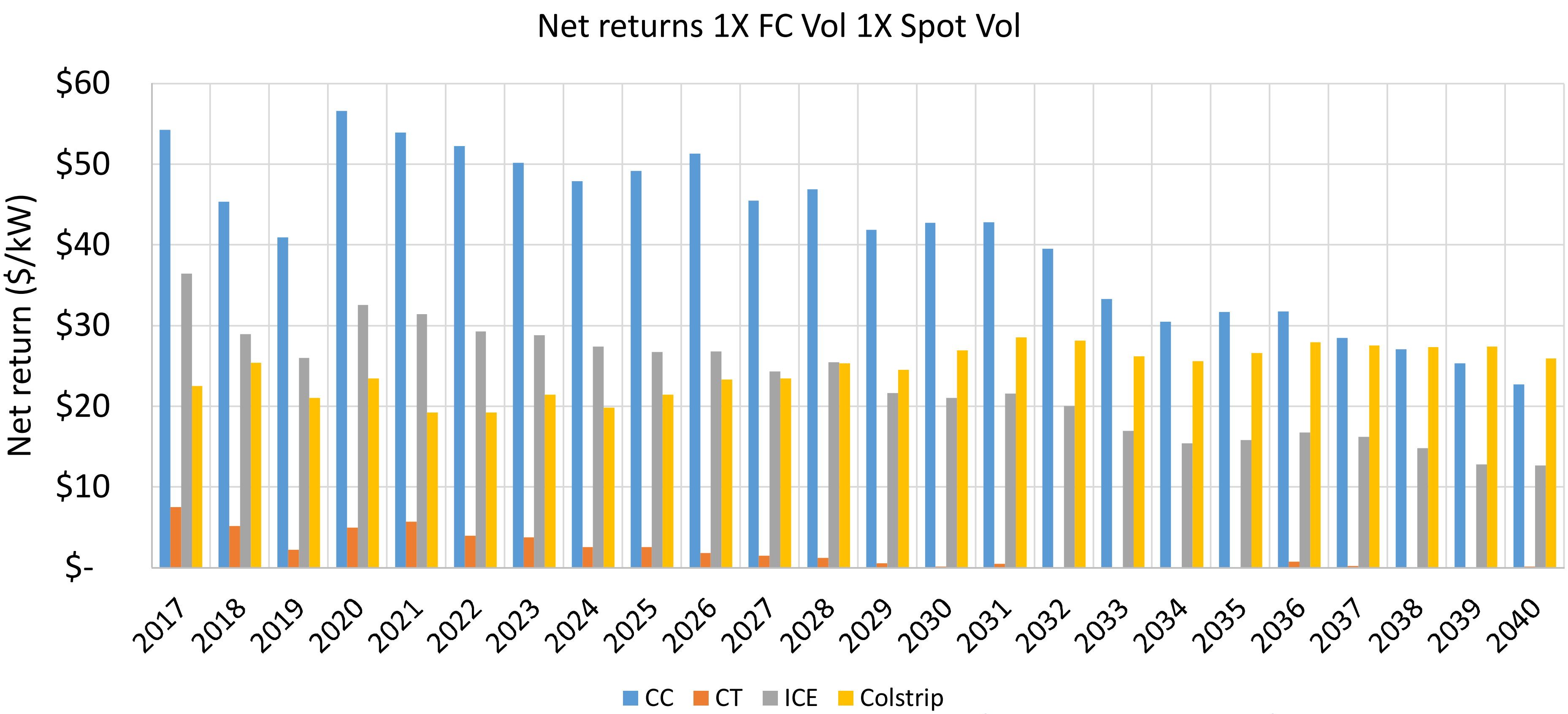
- Prices are more volatile when high spot volatility is combined with increasing forward volatility
- Greater inter quantile range for 2X forward volatility case

Geometric Brownian motion simulation of forwards



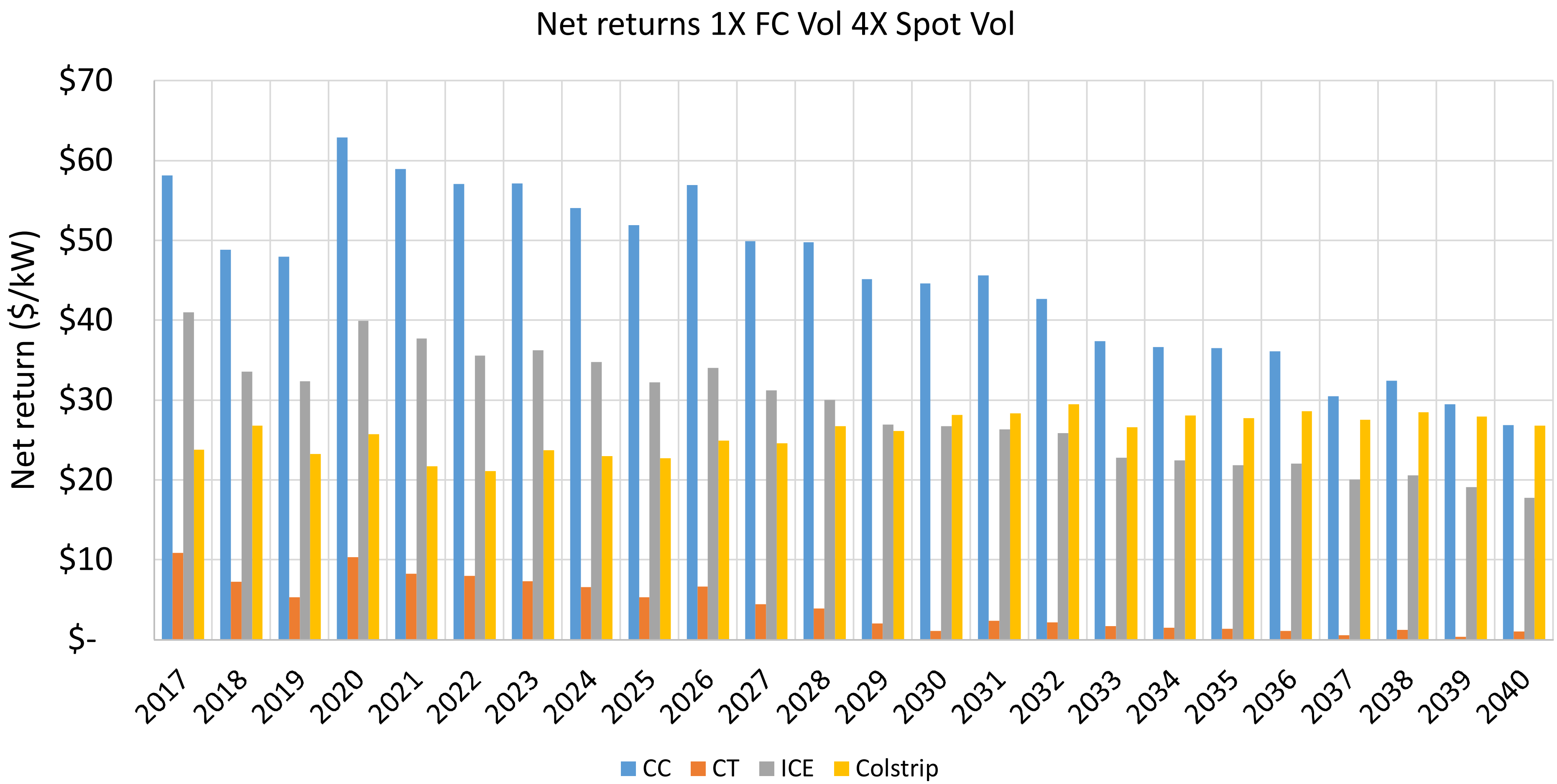
- Geometric Brownian motion is a stochastic simulation where price simulations become non-mean reverting and do not follow volatility structures
- Since prices are non-mean reverting, simulations around the mean can be absurdly high or absurdly low
- Mean monthly power prices of approximately $100 is highly unexpected
- P5 and P95 of price simulations do not obey correct volatility term structures

Thermal returns under base case price scenario



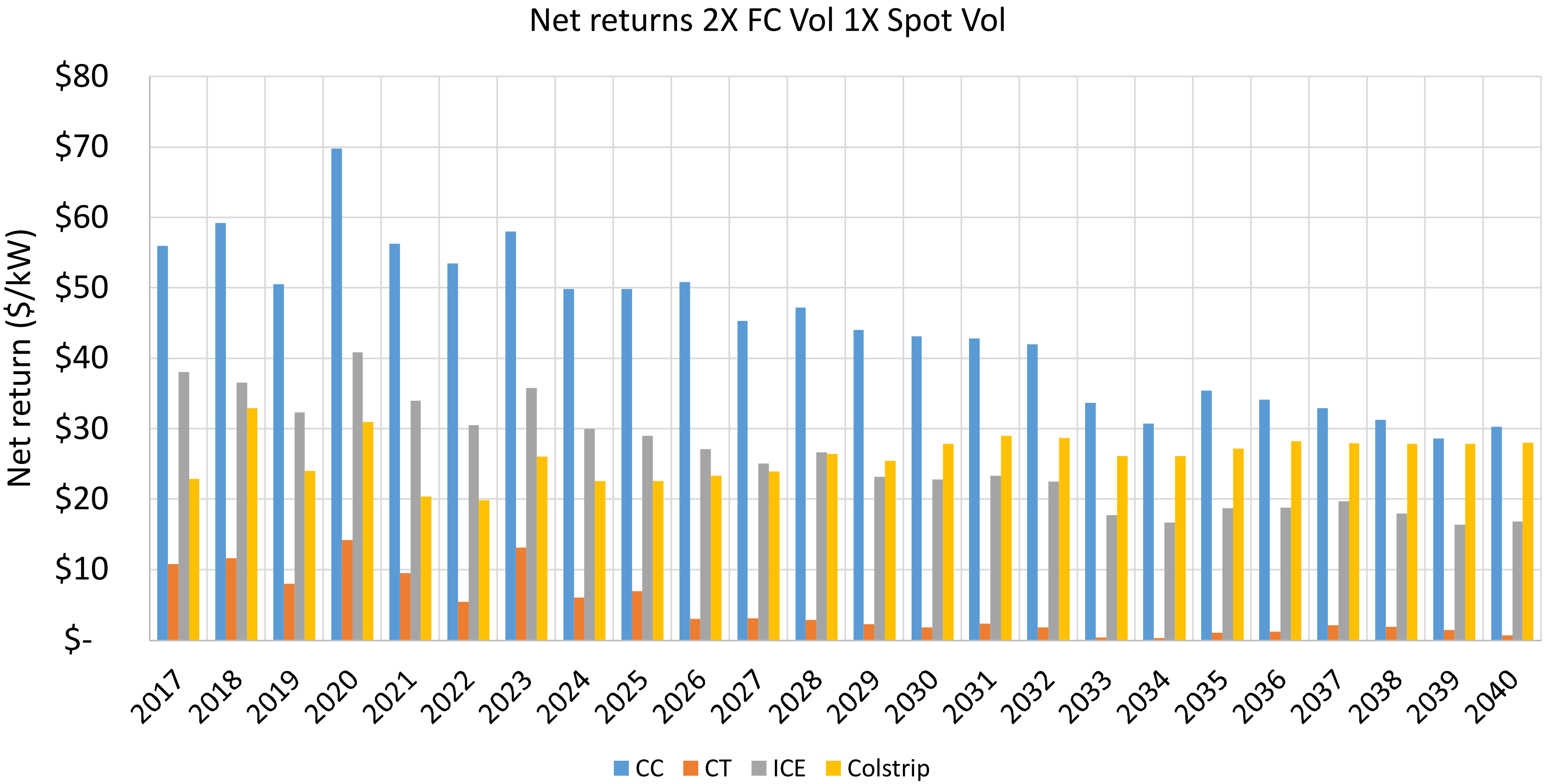
- All gas units lose money due to declining implied heat rates (lower power prices) and increasing gas prices
- ICEs lose less value than CCs due to their flexible generating characteristics
- Colstrip becomes more valuable than ICEs and CCs in the long run due to:
  - the “low” price of coal (relative to long-run increasing gas prices)

Thermal returns under 4X spot volatility price scenario



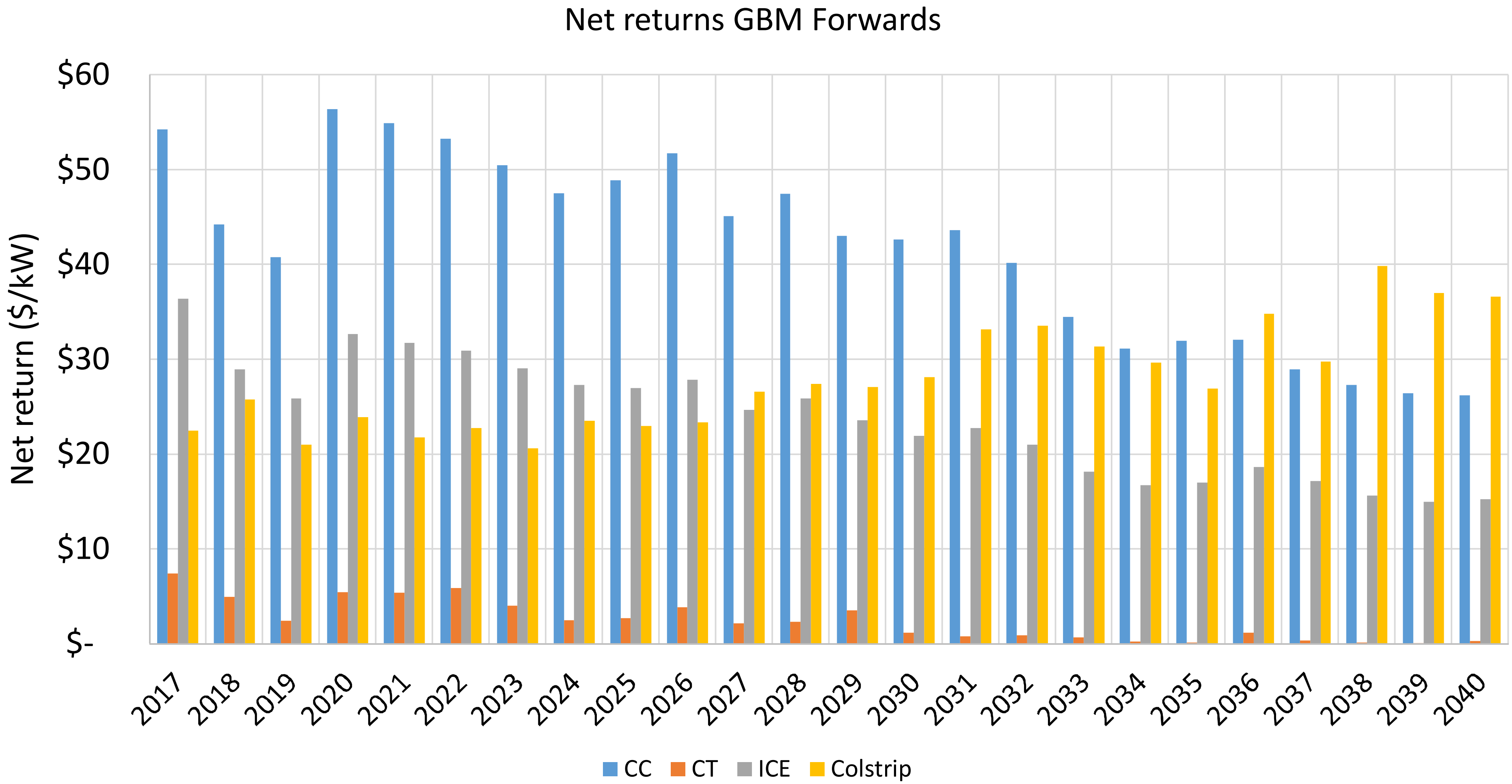
- ICEs do not lose value as drastically with higher spot volatilities because they are more flexible than CCs and can quickly adapt to price fluctuations
- Dispatchable Colstrip does not gain as much value due to its inflexibility

Thermal returns under 2X forward volatility price scenario



- Relative value of CCs, ICEs, and Colstrip closely resemble base case returns
- Total returns for all units are higher, consistent with higher upper ranges of simulated prices

Thermal returns under GBM price scenario



- GBM case (drastic monthly volatility): Relative value of CCs, ICEs, and Colstrip closely resemble returns under 2X forward volatility, but all units have larger returns due to larger price spread

Impact of price scenarios on thermal net returns

- Monthly volatility has **less effect** on the **relative** value of each unit
- Hourly volatility has **greater effect** on the **relative** value of each unit
  - Flexible units like CCs are most valuable because they can quickly dispatch and adapt to intra day price volatility
- Flexible units (ICEs) lose value at a lower pace than inflexible units (CCs) in volatile price conditions
- Geometric Brownian Motion (ARMA 1,1) based forward simulations are non mean reverting and lose volatility term structure
  - P5, P95 of a GBM forward simulation do not hold meaningful value

Key takeaways

- Renewables are proliferating throughout the WECC
- Increasing renewables lead to
  1. Greater regulation requirements
  2. Lower heat rates and volatile prices
- NorthWestern's current fleet is having a hard time providing ancillary services
- In the future, heat rates (power prices) will be lower and market prices will be more volatile → thermal units will operate on lower profit margin, making it difficult for them to compete, and flexible units like ICEs will retain the most value over time
- **In the future, it will be harder to meet ancillary requirements** due to:
  1. **Capacity characteristics**
     - Inflexible units can't economically provide reg and inc
     - ICEs and batteries are ideal portfolio additions because they are cheapest and most flexible
  2. **Market characteristics**
     - Declining heat rates (power prices) as a result of increasing fuel prices and renewable saturation make thermal units less profitable
     - ICEs are ideal thermal additions because they retain the most value, even under volatile price scenarios