The Value of Wind and Solar Power Forecasting Improvements

Carlo Brancucci

June 20th, 2017
UVIG Forecasting Workshop, Atlanta

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Solar Energy 129 (2016) 192–203

SOLAR ENERGY

www.elsevier.com/locate/solener

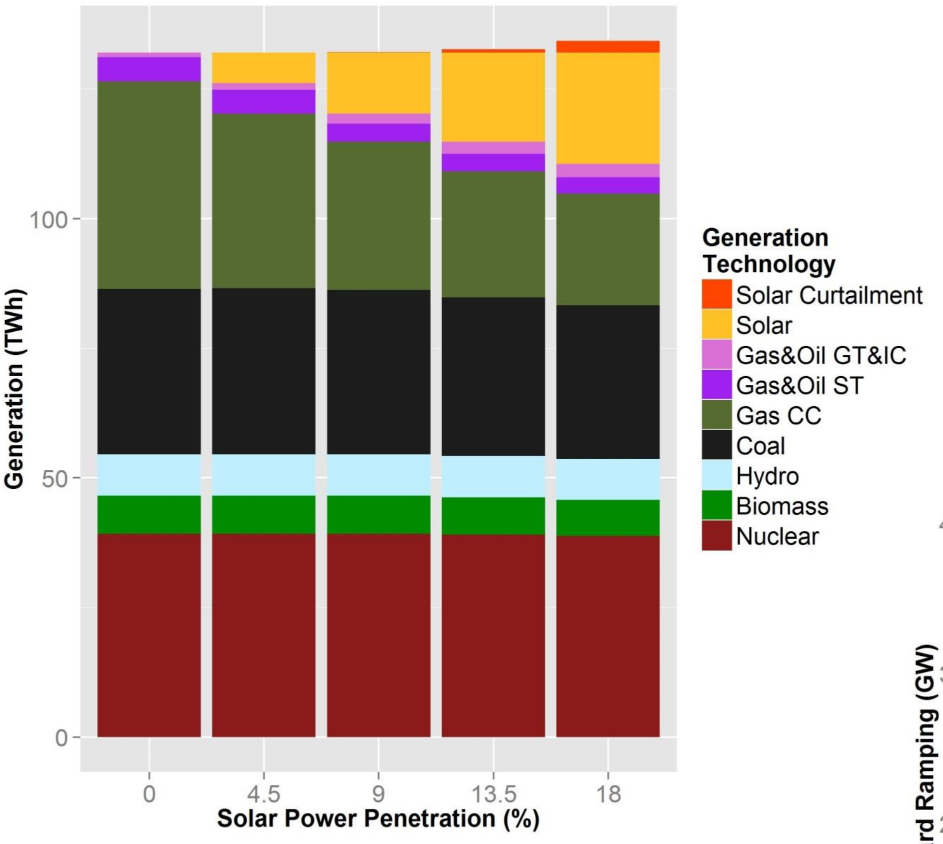
The value of day-ahead solar power forecasting improvement

Carlo Brancucci Martinez-Anido [a], Benjamin Botor [a], Anthony R. Florita [a], Caroline Draxl [a], Siyuan Lu [b], Hendrik F. Hamann [b], Bri-Mathias Hodge [a,*]

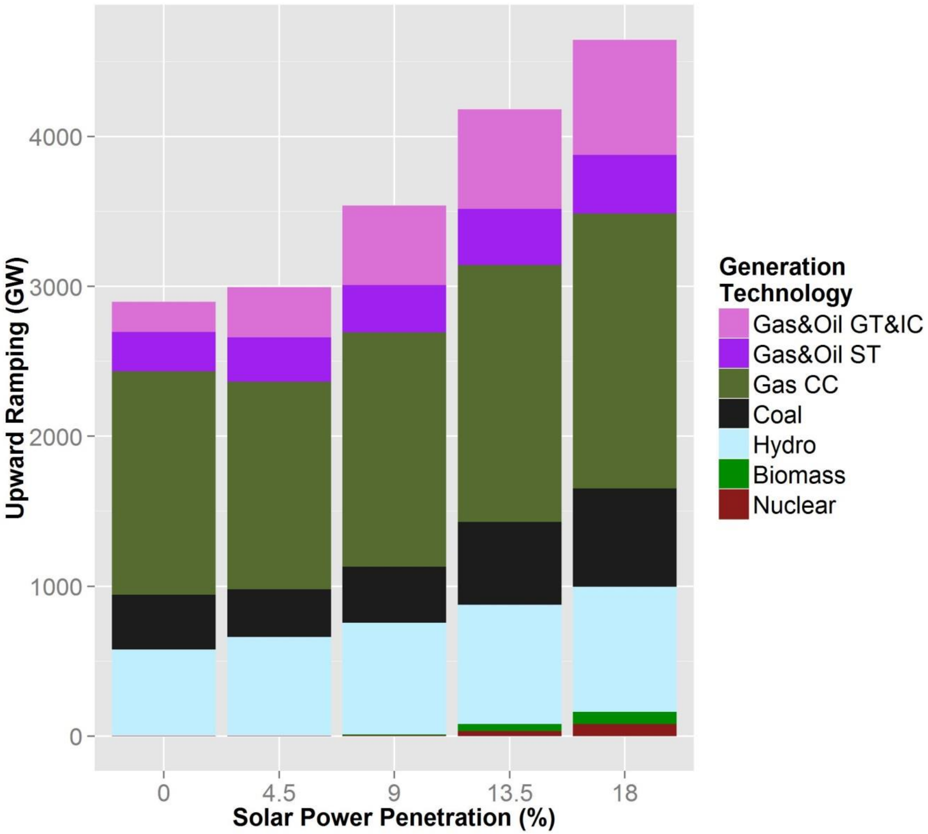
[a] National Renewable Energy Laboratory, Golden, CO 80401, USA
[b] IBM TJ Watson Research Center, Yorktown Heights, NY 10598, USA

"This article investigates the value of solar power forecasting improvements, both in terms of variable electricity generation costs and its impact on bulk power system operations. The study is performed by simulating the operation of the ISO-NE power system under a range of scenarios with varying solar power penetrations and solar power forecasting improvements."

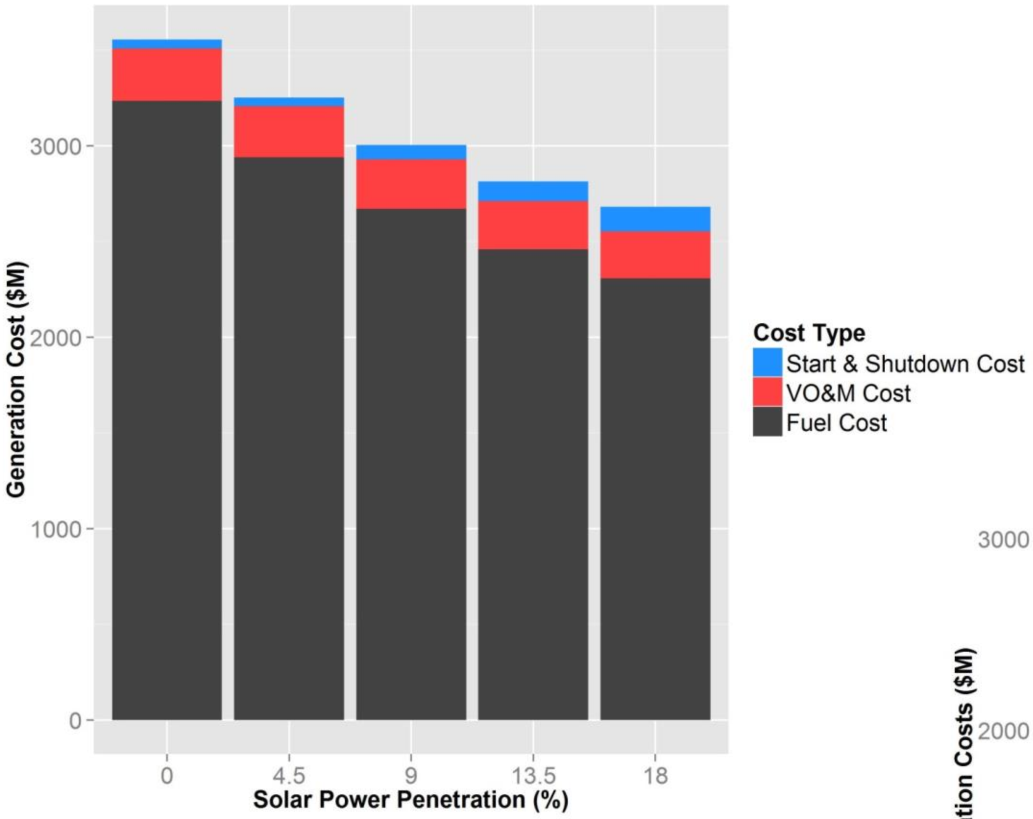
Generation Mix

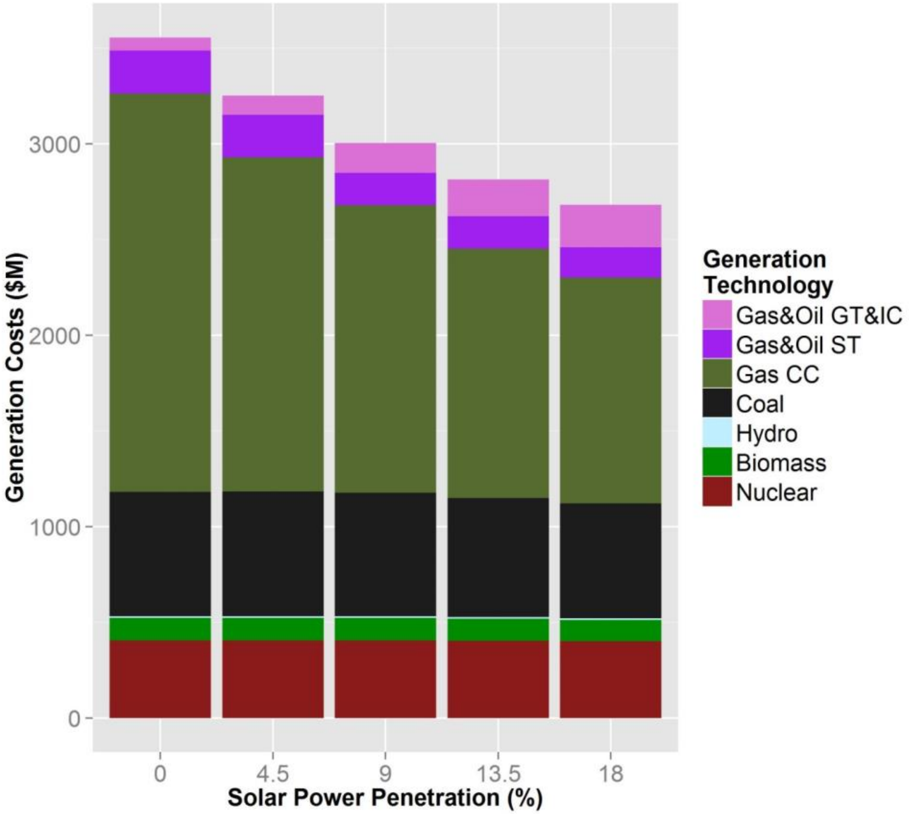


Generation Ramping

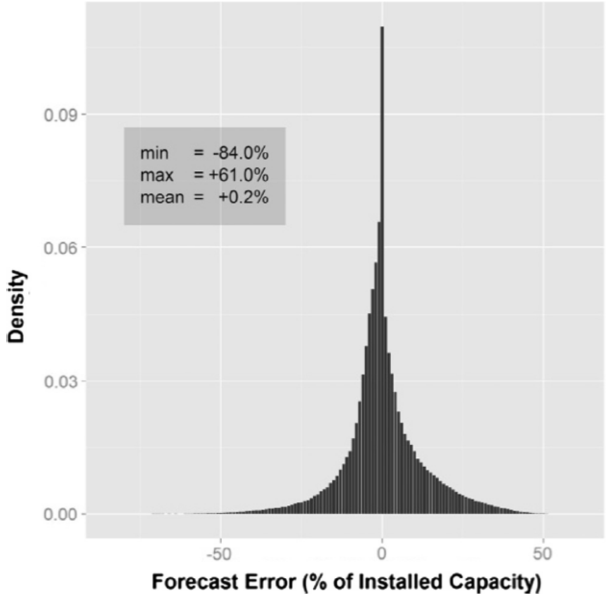


Production Costs

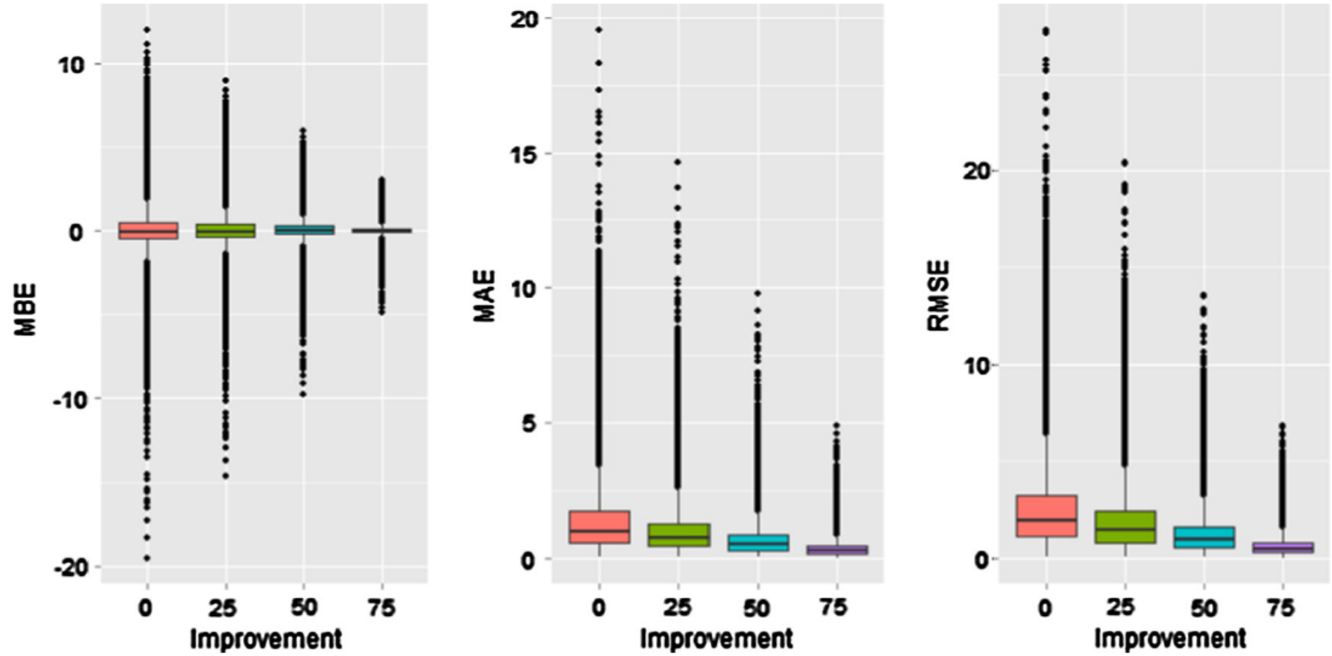




DA Solar Power Forecasts derived from a state-of-the-art numerical weather prediction model, the Weather Research and Forecasting (WRF) Model developed by NCAR.



Uniform Forecasting Improvements:



Generation

Solar Penetration (%)	4.5				9.0				13.5				18.0			
Forecast Improvement (%)	25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100
Coal (% change)	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.1	0.3	0.4	0.5	0.2	0.4	0.4	0.4
Gas CC (% change)	0.0	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.7	0.9	1.1	0.5	0.9	1.4	1.8
Gas & Oil ST (% change)	-0.1	-1.4	-0.8	-0.8	0.6	1.2	0.5	0.0	-1.3	-2.8	-3.9	-4.8	-1.9	-3.5	-5.3	-5.5
Gas & Oil GT & IC (% change)	-0.8	-1.8	-1.9	-1.7	-4.5	-7.5	-8.6	-10.2	-3.9	-8.8	-12.1	-13.7	-5.1	-10.5	-14.3	-17.5

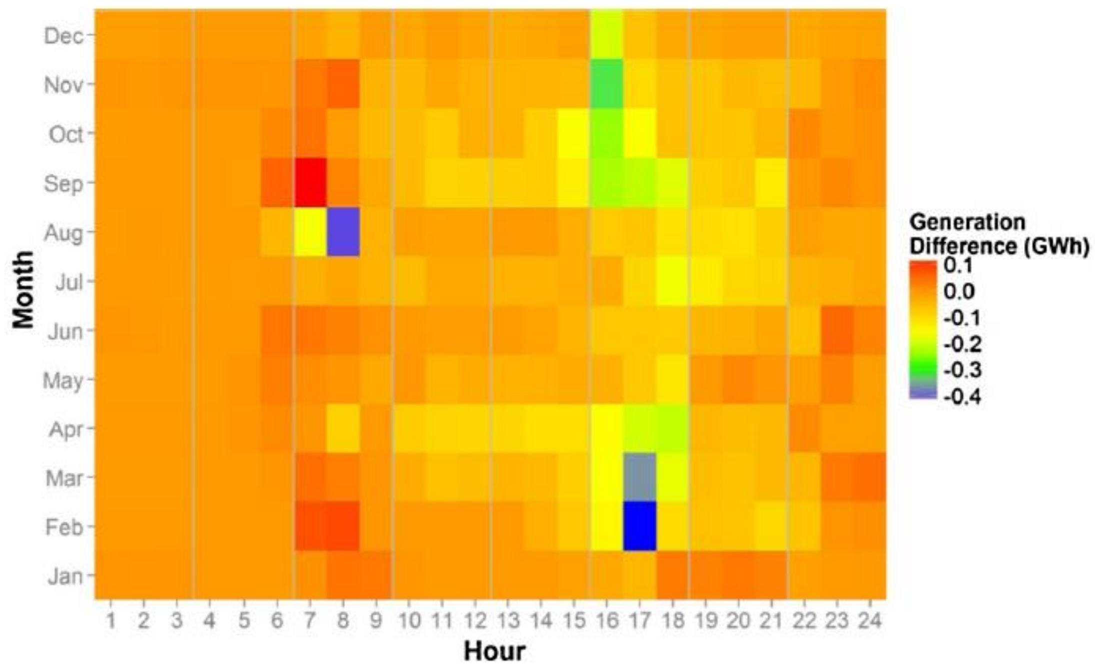


Fig. 9. Impact of 50% uniform solar power forecasting improvement on gas & oil GT & IC electricity generation.

Solar Power Curtailment

Impact of solar power forecasting improvement on solar power curtailment.

Impact (% change)	Solar penetration (%)		
Forecast improvement (%)	9.0	13.5	18.0
25	−2.3	−1.2	−1.5
50	−4.0	−2.3	−2.7
75	−5.2	−3.5	−3.5
100	−5.4	−4.2	−3.8

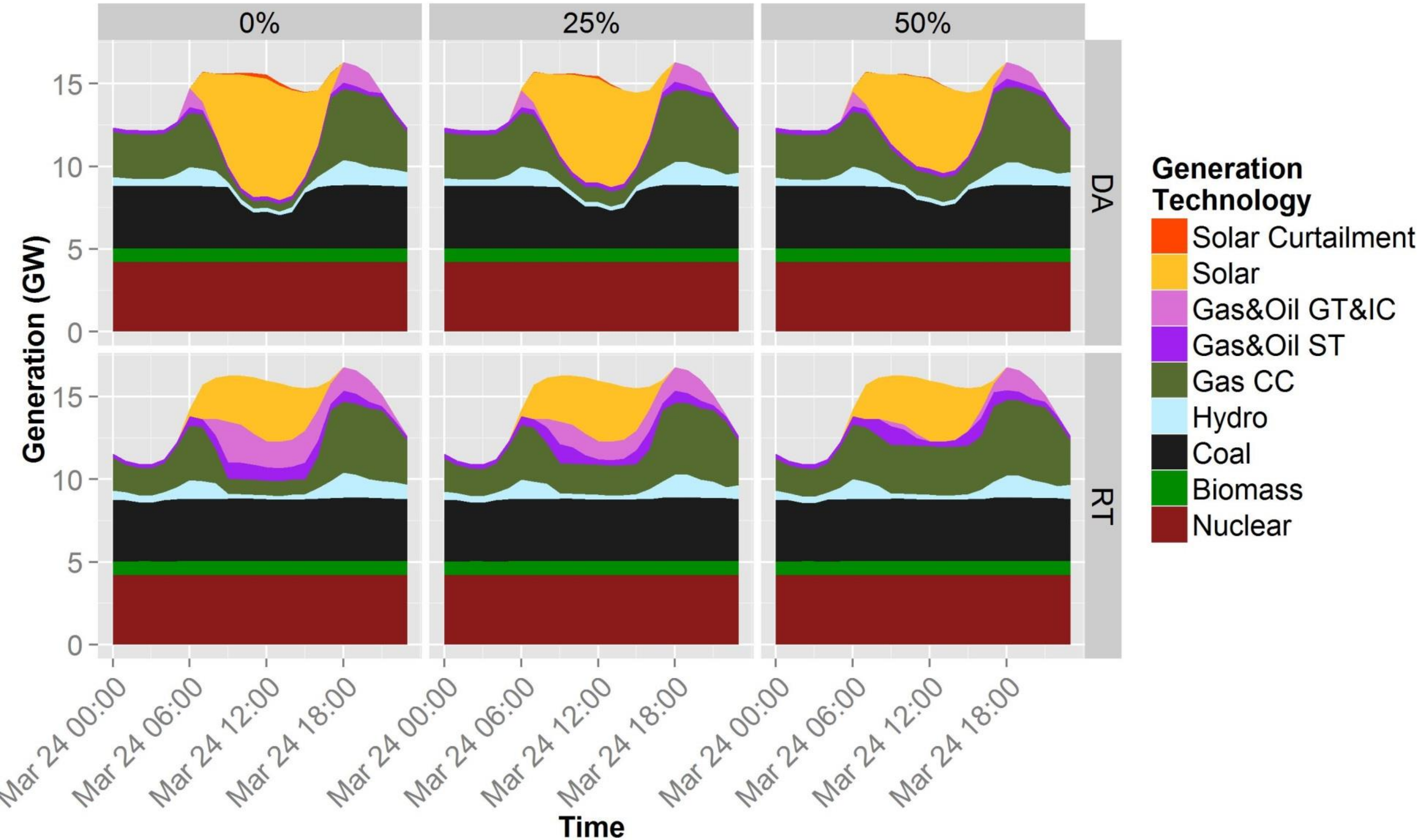
Ramping

Solar Penetration (%)	4.5				9.0				13.5				18.0			
Forecast Improvement (%)	25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100
Coal (% change)	-0.5	-0.7	-1.1	-1.7	-1.1	-3.5	-5.4	-6.0	-1.1	-2.9	-4.7	-5.2	-1.5	-3.0	-4.0	-4.5
Gas CC (% change)	-0.5	-0.7	-1.5	-1.7	-0.2	-1.2	-2.1	-2.4	-0.4	-1.0	-1.8	-1.9	-0.3	-0.8	-1.6	-1.5
Gas & Oil ST (% change)	-0.9	-3.2	-2.6	-2.8	-2.4	-3.3	-5.7	-7.7	-3.9	-8.5	-11.7	-14.2	-3.1	-7.7	-11.8	-16.8
Gas & Oil GT & IC(% change)	-0.2	-0.9	-1.1	-1.0	-2.4	-3.5	-3.5	-4.3	-1.6	-3.5	-4.6	-5.7	-2.9	-5.3	-6.9	-9.5

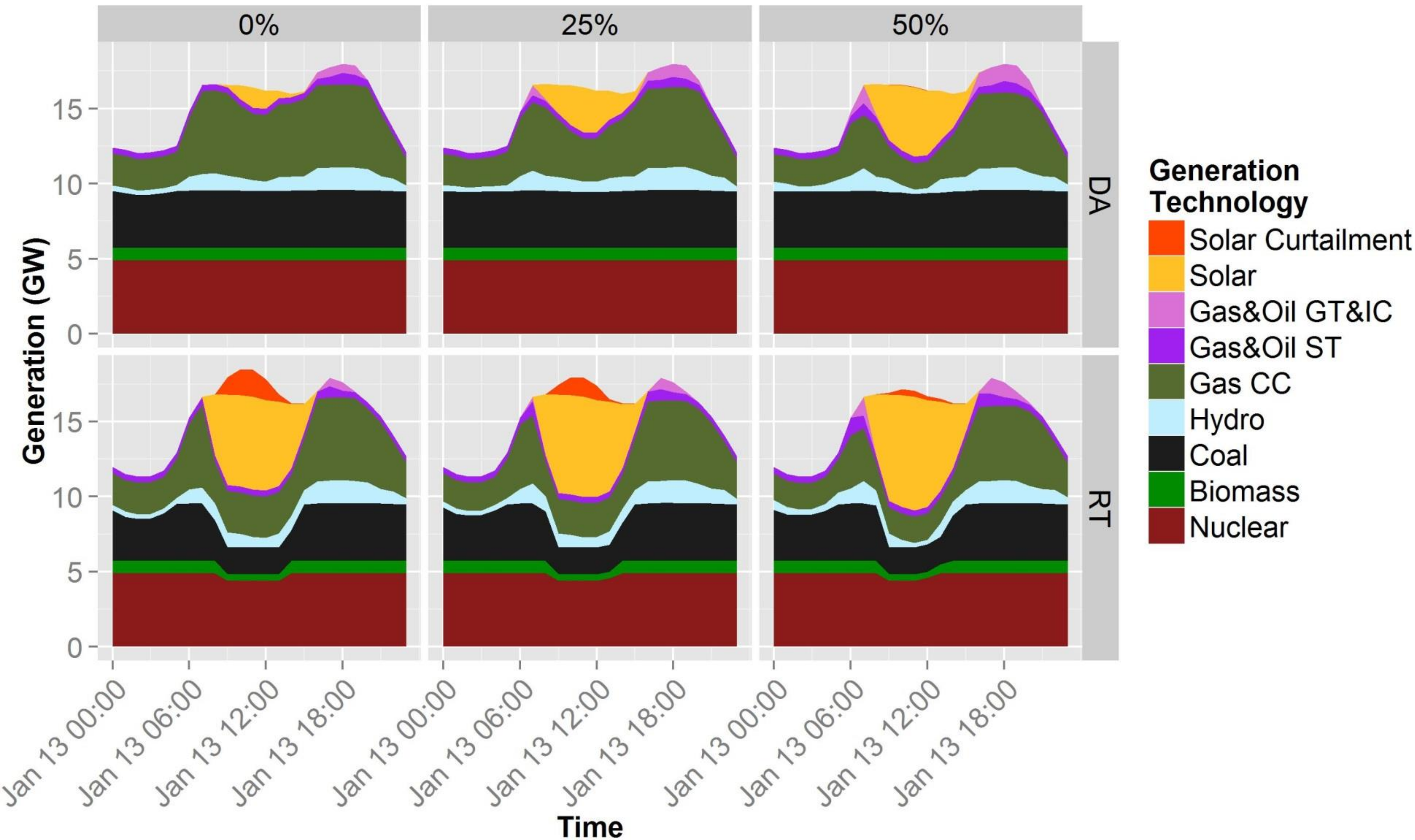
Start & Shutdown Costs

Solar Penetration (%)	4.5				9.0				13.5				18.0			
Forecast Improvement (%)	25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100
Gas CC (% change)	0.3	1.1	1.7	3.2	1.6	2.3	3.8	5.5	0.0	0.9	2.4	4.3	0.4	0.1	1.8	2.9
Gas & Oil GT & IC (% change)	-0.1	-1.0	-1.0	-1.4	-3.5	-4.9	-5.3	-6.2	-1.5	-3.5	-5.1	-6.3	-2.7	-4.9	-7.0	-9.9

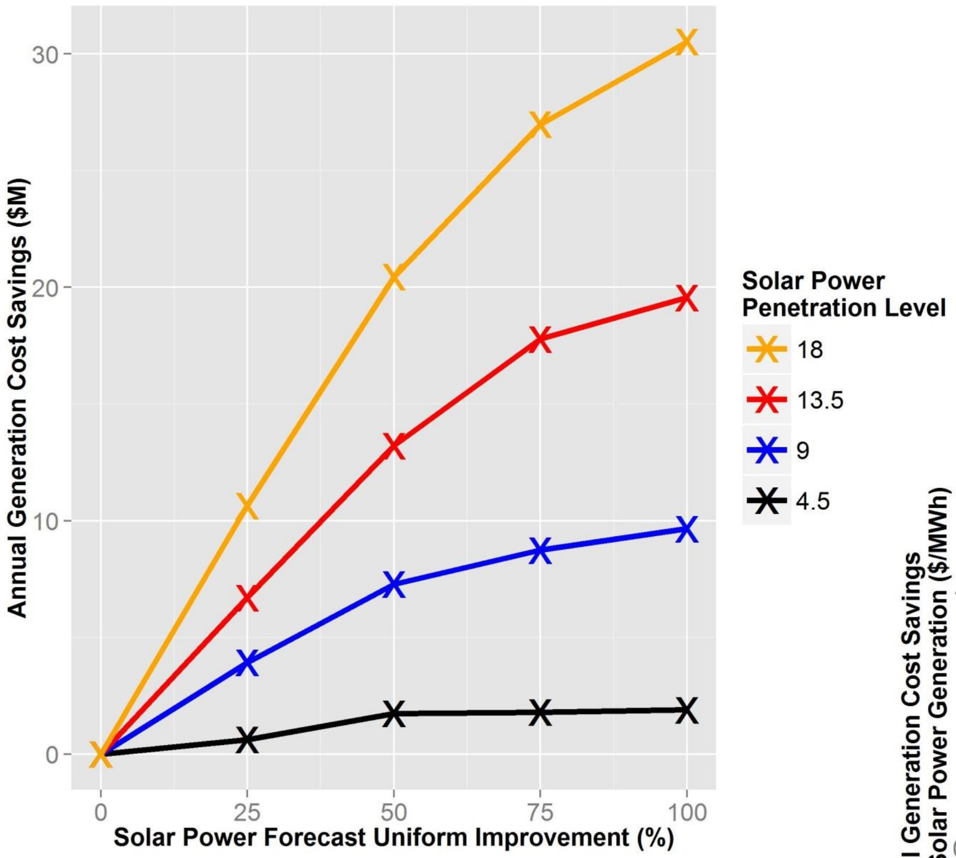
Over Forecasting

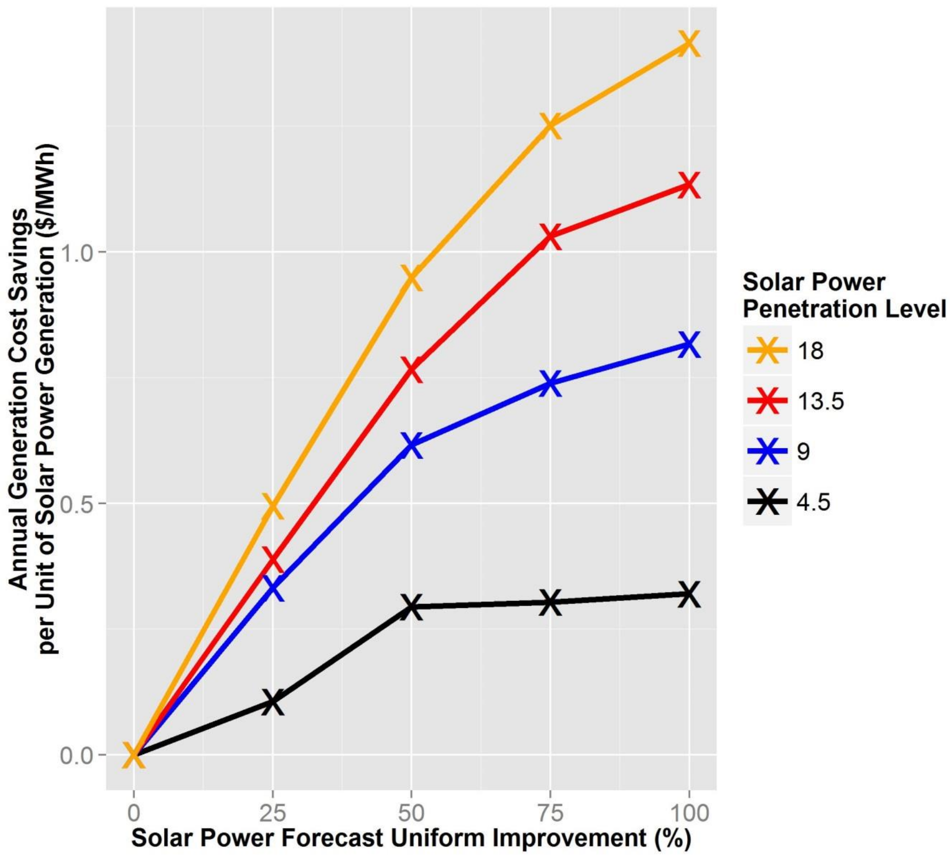


Under Forecasting



Cost Savings





Conclusions

- Electricity generation from the fast reacting and lower efficiency power plants, such as gas and oil GT and IC, was reduced when solar power forecasts were improved.

- Ramping of all generators, start and shutdown costs, and solar power curtailment also decreased with solar power forecasting improvements.

- All these impacts led to a reduction in overall operational electricity generation costs in the system that translates into an annual economic value of improving solar power forecasting.

- The marginal value of solar power forecasting improvement increased with solar power penetration, while it decreased with additional improvement levels.

IEEE TRANSACTIONS ON SUSTAINABLE ENERGY, VOL. 7, NO. 4, OCTOBER 2016 1525

Quantifying the Economic and Grid Reliability Impacts of Improved Wind Power Forecasting

Qin Wang, *Member, IEEE*, Carlo Brancucci Martinez-Anido, *Member, IEEE*, Hongyu Wu, *Senior Member, IEEE*, Anthony R. Florita, *Member, IEEE*, and Bri-Mathias Hodge, *Member, IEEE*

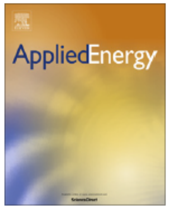
Applied Energy 184 (2016) 696–713

ELSEVIER

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy



The value of improved wind power forecasting: Grid flexibility quantification, ramp capability analysis, and impacts of electricity market operation timescales

CrossMark

Qin Wang, Hongyu Wu, Anthony R. Florita, Carlo Brancucci Martinez-Anido, Bri-Mathias Hodge *

National Renewable Energy Laboratory, Golden, CO 80401, USA

Generation Mixes by Energy for Base Case Scenarios

Generation Mix	CAISO	ISO-NE	MISO
Wind (%)	7.8	1.8	7
Hydro (%)	6.9	6.7	-
Solar (%)	6.9	0.3	-
Geothermal (%)	5.6	-	-
Biomass (%)	3.3	6.5	2.6
Natural Gas (%)	56.9	39.4	13.3
Coal (%)	0.9	4.7	63.2
Nuclear (%)	9.7	34	13.9
Oil (%)	2.0	5.3	-
Pumped Storage (%)	-	1.3	-
Total (%)	100	100	100

Wind Penetration Levels in 15 Wind Forecast Improvement Scenarios

Scenario #	1	2	3	4	5
Wind (%)	5.87	10.48	13.75	15.16	18.46
Scenario #	6	7	8	9	10
Wind (%)	21.77	23.46	27.69	31.86	33.53
Scenario #	11	12	13	14	15
Wind (%)	37.35	41.68	43.33	47.66	51.64

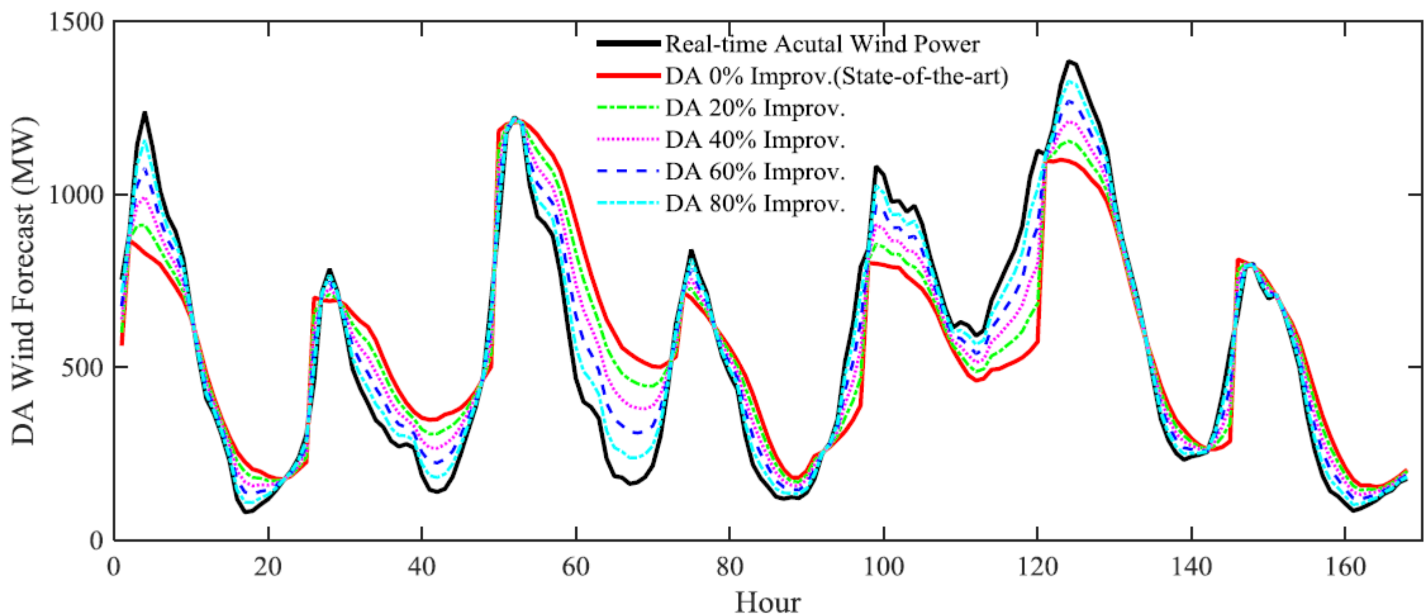
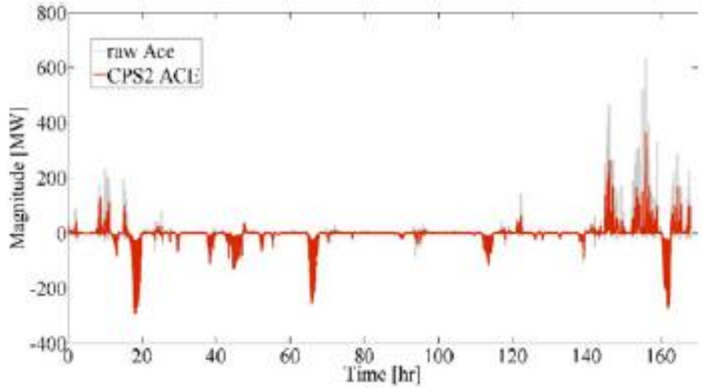
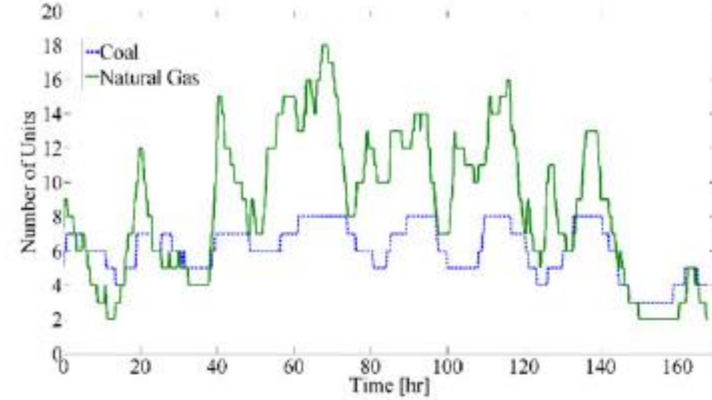


Fig. 5. Example of the day-ahead wind power forecasting improvements.

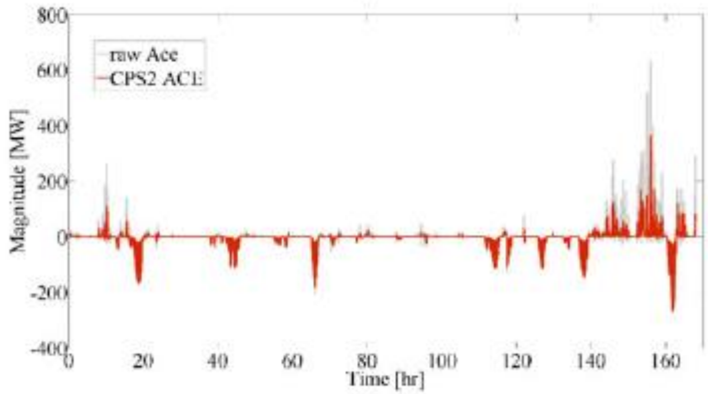


(a)



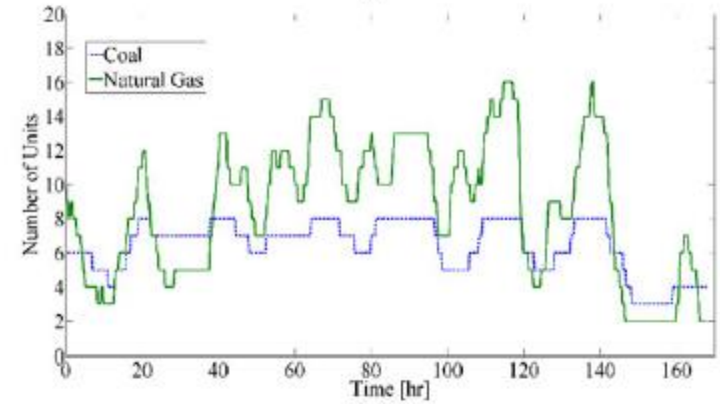
(a)

40% Improv.



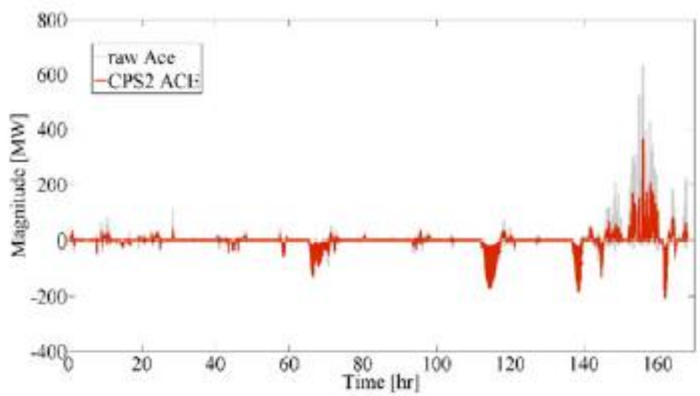
(b)

10

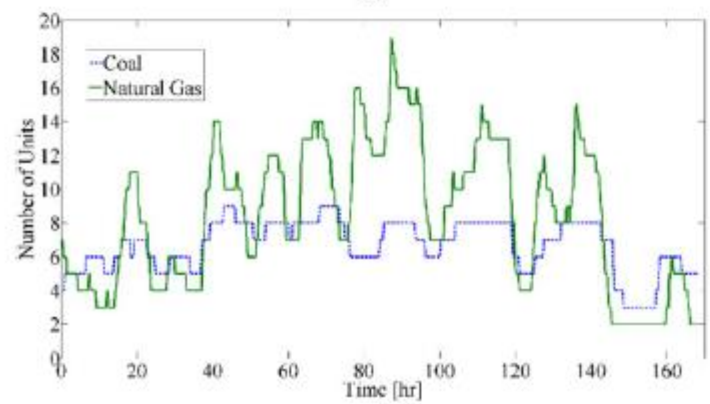


(b)

100% Improv.



(c)



(c)

Production Cost Savings

THE REAL-TIME GENERATION COST REDUCTIONS (% OF TOTAL PRODUCTION COSTS) WITH DIFFERENT WIND FORECAST IMPROVEMENT AND WIND PENETRATION LEVELS

		Wind Forecast Improvement (%)				
Scenario		20	40	60	80	100
CAISO	#2	0.30	0.80	0.59	0.75	0.63
	#6	0.43	0.95	1.62	2.15	2.09
	#9	1.11	1.55	2.78	3.83	4.20
	#14	1.40	3.06	3.87	4.98	5.84
ISO-NE	#2	0.05	0.17	0.10	0.11	0.11
	#6	0.02	0.06	0.15	0.23	0.40
	#10	0.35	0.43	0.47	0.55	0.68
	#15	0.50	1.15	1.65	2.25	2.25
MISO	#2	0.12	0.17	0.40	0.61	0.73
	#6	0.31	0.72	1.08	1.37	1.69
	#10	0.35	1.26	1.61	2.19	2.67
	#15	0.94	1.97	2.86	3.30	4.33

Energy Storage & Forecasting Improvements

ANNUAL LOAD FROM PUMPED-STORAGE RESOURCE FOR ALL ISO-NE CASES (GWH)

	Wind Forecast Improvement (%)					
Scenario	0	20	40	60	80	100
# 1	192.1	177.3	195.5	177.6	168.4	173.1
# 2	245.6	234.5	229	222.5	212.6	209.1
# 3	269.3	266.9	253.5	240.8	240.2	236.4
# 4	282.7	291.5	277.8	262.6	270.2	254.1
# 5	336.2	344.6	336.7	307	308.1	316.7
# 6	394.4	395.3	391.7	379.8	369.2	359.8
# 7	599.8	423.6	410.9	407.7	401.1	395.8
# 8	502.8	487.6	483.9	466.3	465.3	459.7
# 9	574.8	565.5	553	548.1	536.1	531.2
# 10	423.9	590.4	588.7	576.5	567.9	562.4
# 11	660.8	651.4	643.5	638.4	630.9	628.2
# 12	727.8	720.3	713.9	710.6	702.2	701.3
# 13	749.4	741.5	738.5	732	723.8	721.8
# 14	799.1	790.1	781.1	780.1	775	774.5
# 15	835.5	829.5	824.3	819.3	815.4	808.6

COMPARE THE COST SAVINGS WITH AND WITHOUT PUMPED-STORAGES FOR ISO-NE SCENARIO #3 AND #14 CASES

		Wind Forecast Improvement (%)				
Scenario		20	40	60	80	100
#3	With PS	0.09	0.01	0.06	0.13	0.14
	Without PS	0.13	0.44	0.44	0.36	1.00
#14	With PS	0.50	1.15	1.65	2.25	2.25
	Without PS	0.9	1.6	2.25	2.56	3.38

Day-Ahead (DA) vs. 4-Hour-Ahead (4HA)

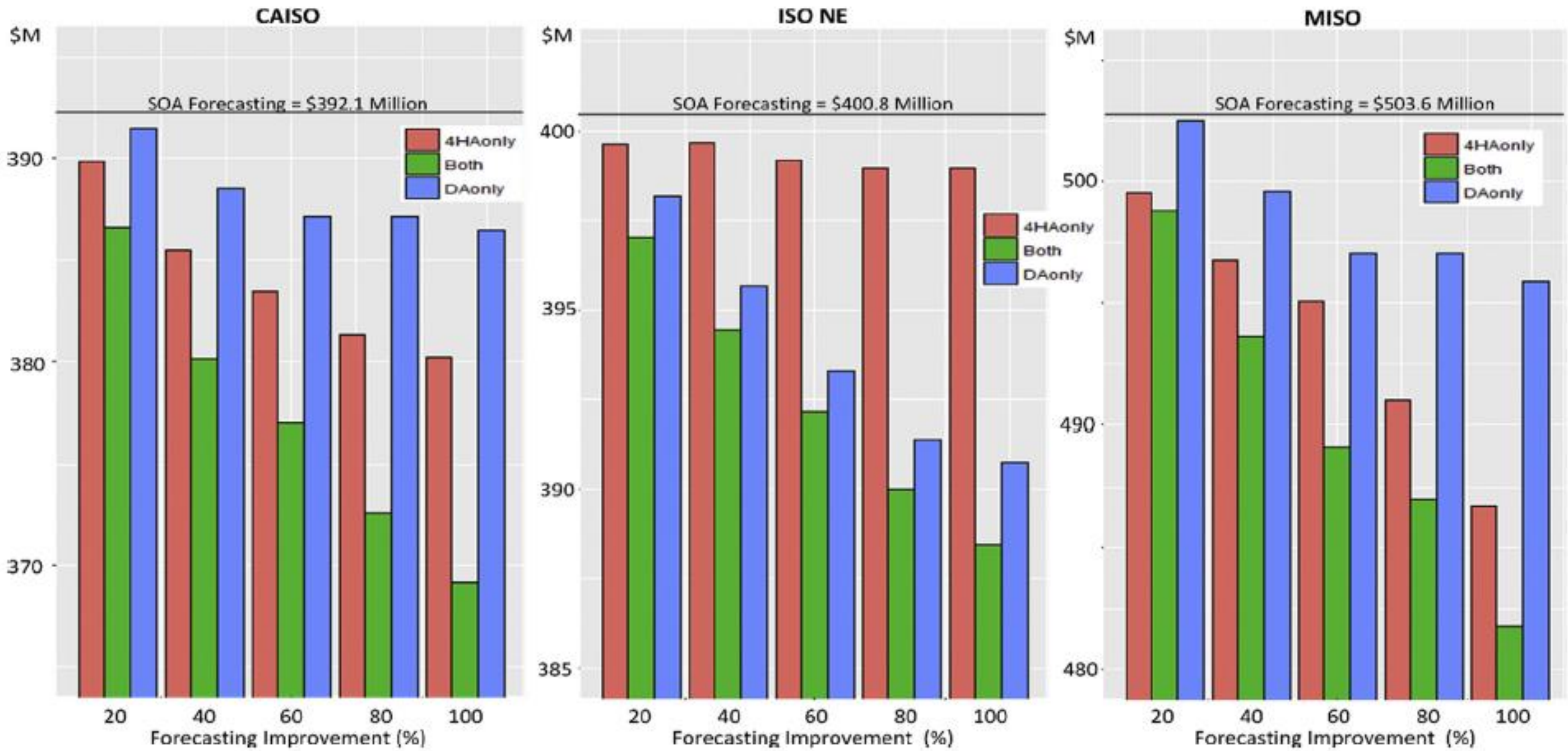


Fig. 10. Cost comparisons in three independent system operators in Scenario #10 ($M).

Conclusions

- The value of wind power forecasting improvements depends on the generation mix, existence of energy storage, and wind penetration.
- Start and shutdown costs of conventional generations, and wind power curtailment decrease with wind power forecasting improvements.
- Wind power forecasting improvements have a positive impact on power system's reliability.
- Wind power forecasting improvements at different market operation timescales will have different impacts on power system operations.

Thank you very much!

Questions?

carlo.brancuccimartinez-anido@nrel.gov