CAPSTF Analysis, Initial Results

Emmanuele Bobbio
Senior Lead Economist
Advanced Analytics, PJM
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Post-meeting version with updates

Updates made after 12/16 meeting

- Slide 21: The values shown were aggregate, now showing year 2030 as intended
- Slide 25: Updated legend and included note
- Slide 26: Updated legend
- Slide 34: The values shown were aggregate, now showing year 2030 as intended
- Slide 39: Updated to include run of river and MISO4
- Slide 40: NEW slide showing renewable generation from Slide 39 compared to the REC target in each year
- Slide 41: NEW slide showing nuclear generation
- Slide 42: clarified status quo sponsors.

Agenda

- Review modeling approach
- Discussion of industry trends and if/how reflect them in model
  - Supply chain restructuring, IRA timing, headwinds to new thermal, etc.
- Model assessment
- Market designs comparison of:
  - FCEM+RPM with states products (CPAWG's request case 2A)
  - ICCM with states products (case 2B)
  - FCEM+RPM with one regional REC (case 2C)

Disclaimers

- Fresh results, we continue to sift through the data (model is very rich)
- The model is meant to provide indications on *relative* impacts
- The study is not a forecast
- Assumptions reflect OPSI CPAWG's and stakeholders' indications and can be changed based on feedback

Disclaimer: The material contained in the data and modeling assumptions are for general informational purposes only, are not intended to constitute legal or other professional advice, and should not be relied on or treated as such. All assumptions used in this analysis were purely informed by stakeholder input and do not represent any PJM position. PJM makes no warranties, representations or undertakings about any of the content in the data and modeling assumptions (including, without limitation to, the quality, accuracy, completeness or fitness for any particular purpose of such content)

Key takeaways

- The REC price declines through 2030 due to IRA and technical improvement
- With state-specific RECs, some REC prices remain high in 2030
- An integrated procurement mechanism significantly lowers REC procurement costs (case 2A vs 2B)
- Adoption of a common REC product significantly lowers REC procurement costs (case 2A vs 2C)
- Given current assumptions, differences in *total* load payments across the three designs are generally small; ordering is sensitive to calibration details

1 of 4 Review of modeling approach

Main assumptions, time and space

- Frequency
  - Annual for forward markets (FCEM, ICCM, RPM, etc.)
  - Hourly for energy market
- Footprint
  - 20 zones + Illinois non-PJM portion (MISO 4)
  - 14 Jurisdictions

    36 distinct zones/jurisdictions (e.g. OH-AEP)
  - Transmission limits between zones
    - import limits into MISO 4 set to 0 when solving capacity market
  - Locations differ in fuel prices and renewables' capacity factors

Main assumptions, resources definition and behavior

- **Resources definition**
  - Representative at the state/zone/technology levels (e.g. OH-AEP-CT)
  - Perfectly dispatchable (e.g. ignore start-up costs and times)
- **Behavior**
  - Existing resources offer:
    - Marginal cost in energy market
    - net-ACR in forward markets
  - New resources offer net-CONE in forward markets (if they clear they become existing and offer net-ACR in subsequent years)
  - In FCEM+RPM, clean resources bid into RPM net of FCEM revenues
  - Only resources clearing in forward markets stay/enter

Main assumptions, expectation formation

- Investors and PJM formulate expectations on energy profits and capacity factors by simulating the energy market *virtually* given cleared resources in latest capacity auction, future demand, fuel prices, and anticipated policy retirements
- In the FCEM case, 2023 expected capacity prices are set using ICCM outcomes, and then updated averaging past expectations and realizations

  new expectation = 0.7 past expectation + 0.3 realization

Main assumptions, policy

- States RPS targets
- States mandates for offshore, batteries, solar
- NJ nuclear is subsidized
- CT can be built in OH, WV, KY, PA, IN, TN
- CC can be built in OH, WV, KY, PA, IN, TN, and IL
- CC with carbon capture and storage, anywhere (after 2027)
- Policies inducing the retirements of some units (e.g. CEJA)

Main assumptions, average ELCC

- Renewables ELCC change over time as per previously released indicative PJM projections for informational purposes only
- Thermal ELCC = 1 – eFORD from 2023/2024 BRA

	2023	2024	2025	2026	2027	2028	2029	2030
Onshore wind	0.150	0.160	0.150	0.140	0.130	0.120	0.110	0.110
Offshore wind	0.400	0.370	0.350	0.340	0.330	0.310	0.300	0.290
Solar (tracking)	0.540	0.540	0.510	0.470	0.440	0.400	0.370	0.320
Battery	0.830	0.820	0.750	0.740	0.730	0.770	0.800	0.890
Run of river	0.960	0.960	0.950	0.930	0.920	0.930	0.940	0.980
CC	0.964	0.964	0.964	0.964	0.964	0.964	0.964	0.964
CC (ccs)	0.964	0.964	0.964	0.964	0.964	0.964	0.964	0.964
CT	0.955	0.955	0.955	0.955	0.955	0.955	0.955	0.955
IC	0.955	0.955	0.955	0.955	0.955	0.955	0.955	0.955
Nuclear	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991
Steam coal	0.872	0.872	0.872	0.872	0.872	0.872	0.872	0.872
Steam gas	0.872	0.872	0.872	0.872	0.872	0.872	0.872	0.872
Pump storage	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
DR	1.090	1.090	1.090	1.090	1.090	1.090	1.090	1.090

Data inputs

- Energy Exemplar's Eastern Interconnection (EI) dataset for fuel prices, renewables' capacity factors, list of existing resources and their characteristics, transmission topology
  - Resources are representative to allow data sharing with stakeholders courtesy of Energy Exemplar
  - Existing nameplates by state/zone/technology aligned with IMM's Q3 2022 state of the market report
- New resources' characteristics are from EI and NREL's 2022 Annual Technology Baseline (CT's major maintenance is in VOM)

2 of 4 Discussion of industry trends and if/how to account for them into the model

Industry trends and model assumptions, fundamental costs

1. Cost pressures from supply chain restructuring and onshoring
   - Brattle's quad study: CC CONE is 35% higher than in NREL
     - ➡ We escalate FOM and CAPEX of all new resources by 35%
2. We use fuel prices from Energy Exemplar's Eastern Interconnection dataset predating 2022 energy shocks

(1) and (2) lead to higher capacity and REC prices and costs. With NREL's CONE (which is in line with 2023/2024 BRA), numbers are close to historical averages

Industry trends and model assumptions, policy

3. It will take time for the IRA to fully affect the queue (e.g., IHS)
   - 5pp CAPEX reduction per year down to 70% in 2028
4. Headwinds to new gas generation investments
   - Gas pipeline capacity
   - Investment uncertainty (e.g. policy)

   In the model we ignore these headwinds. New gas investments continue to be economic, mainly in PA

Other technical assumptions

5. Congestion in solar and onshore wind construction as in IHS
   - Six 500 MW projects per year and location (state/zone) with 5pp incremental costs (750MW in ComEd)
6. About 10.5GW-ICAP do not participate in RPM
   - Shift model VRR by 5GW-UCAP (or, we could adjust supply)

3 of 4 Model assessment

Results for 2023 with FCEM+RPM and state-specific RECs

Quantities

- Annual Load: 766,930 GWh
- Peak Load: 152,967 MW
- ICAP: 201,230 MW
- UCAP: 176,292 MW
- RECs: 97,994

Prices

- LMP ($/MWh): 37.4
- Capacity ($/MW-day): 121.7
- REC Price: $24.8

Payments (mil $)

- Energy: 28,694
- Congestion: -973
- Capacity: 7,830
- REC: 2,435

Total: $37,986 mil

System Costs (mil $)

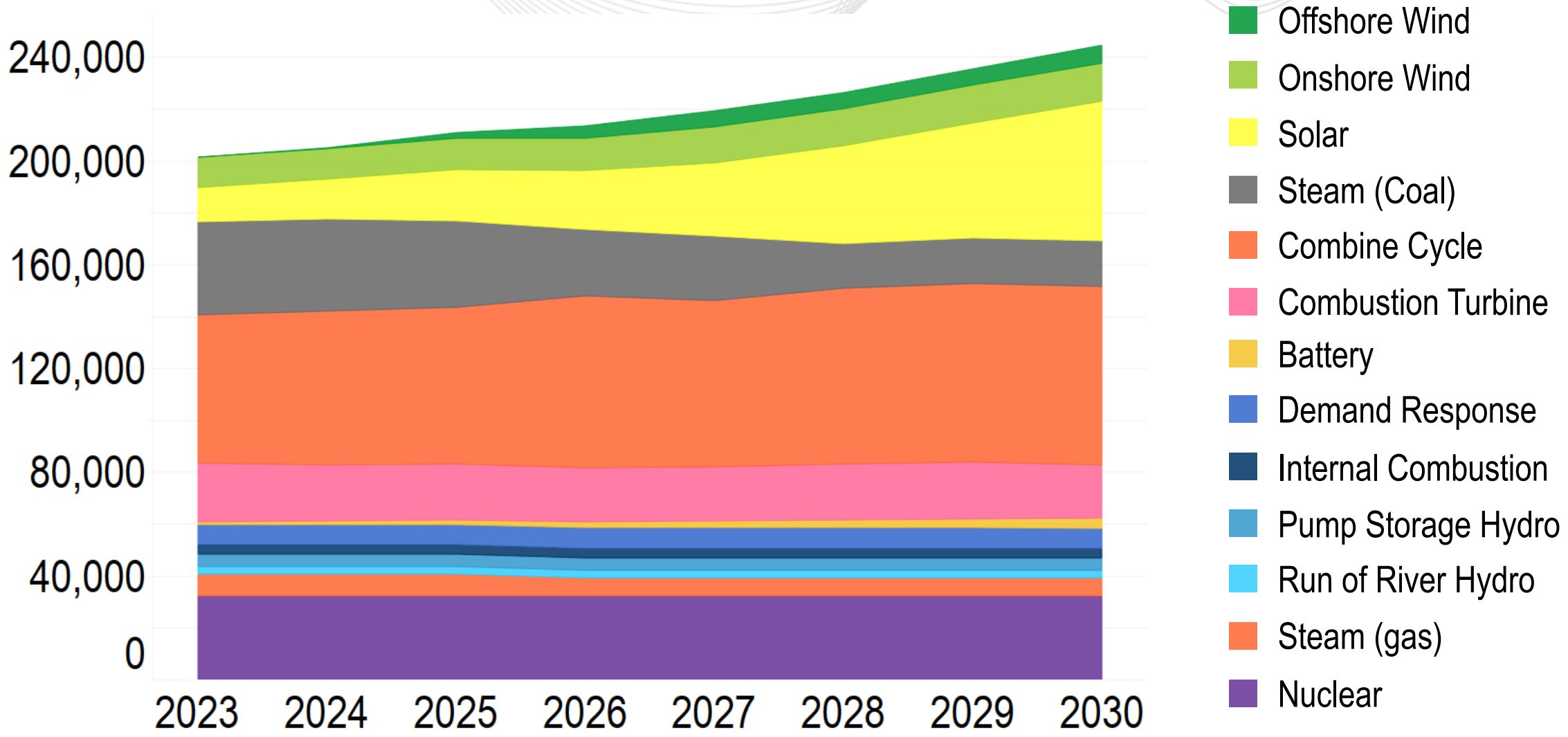
- ACR: 7,768
- CoNE: 1,039
- Production: 14,419

Total: $23,226 mil

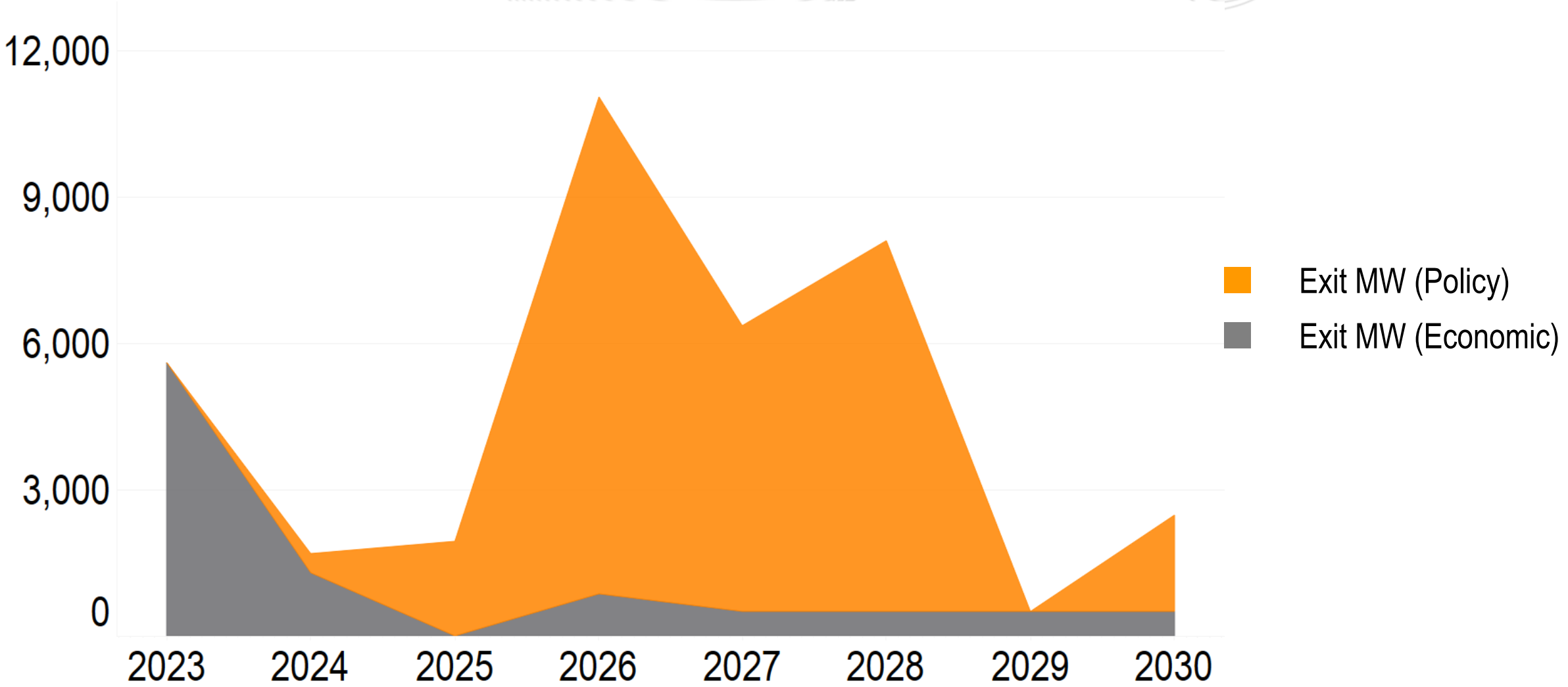
Emissions

- CO_2 (mil ton): 336.3
- NO_x (1000 ton): 110.2
- SO_x (1000 ton): 101.8

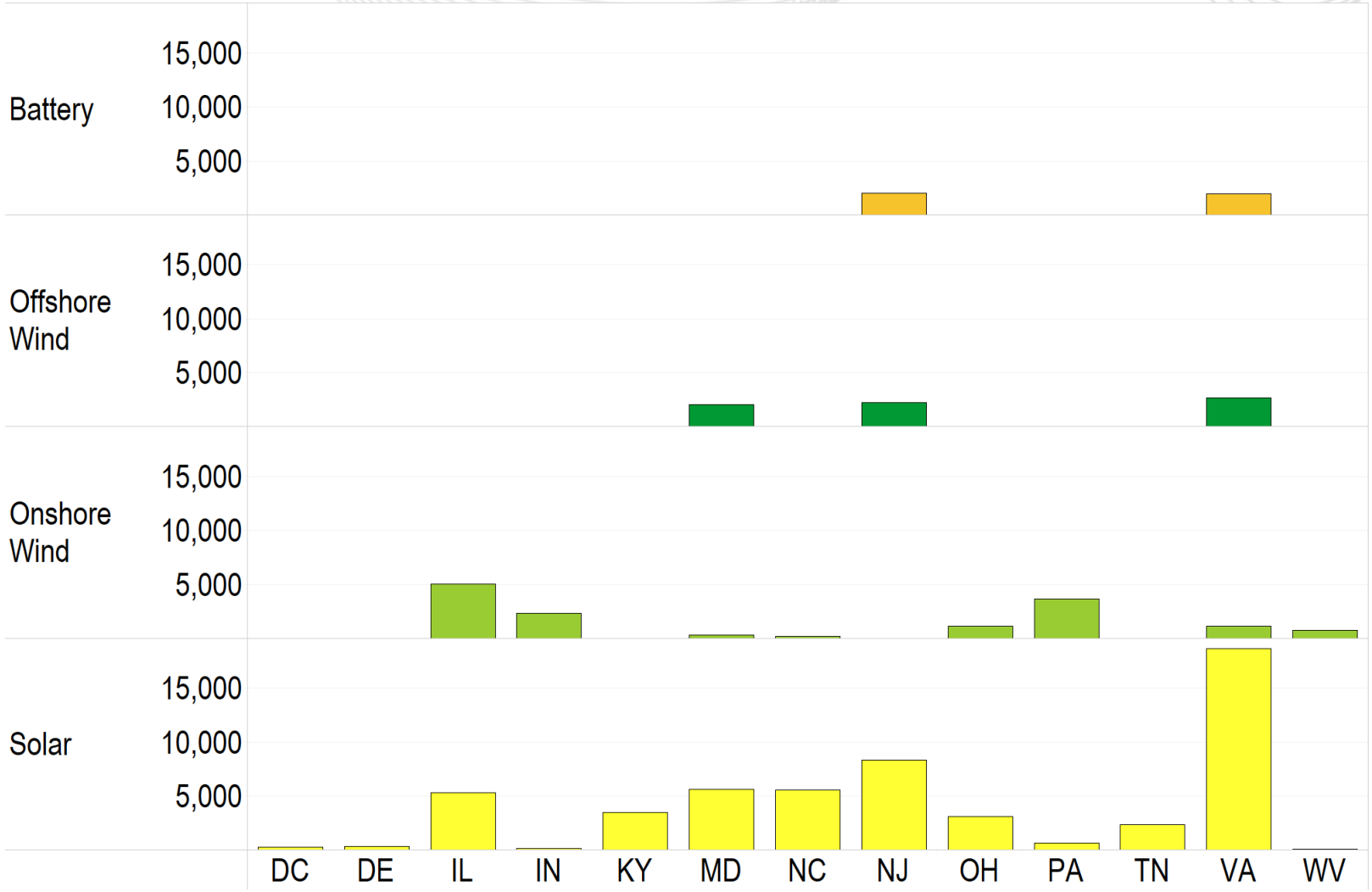
ICAP MW by Technology type – FCEM, state-specific RECs



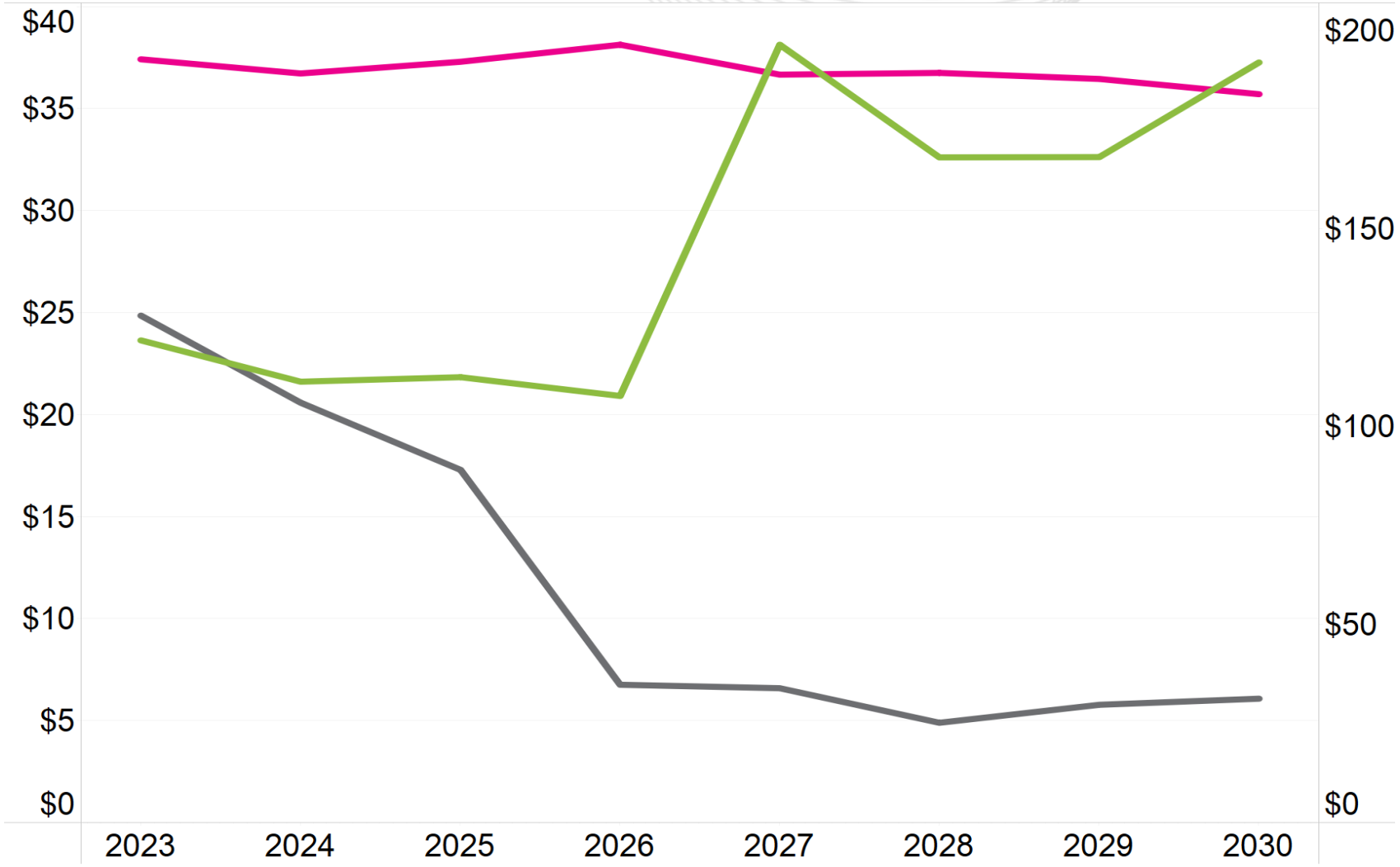
Exits: Economic and Policy: FCEM, state-specific RECs



Renewable ICAP MW – FCEM, state-specific, year 2030



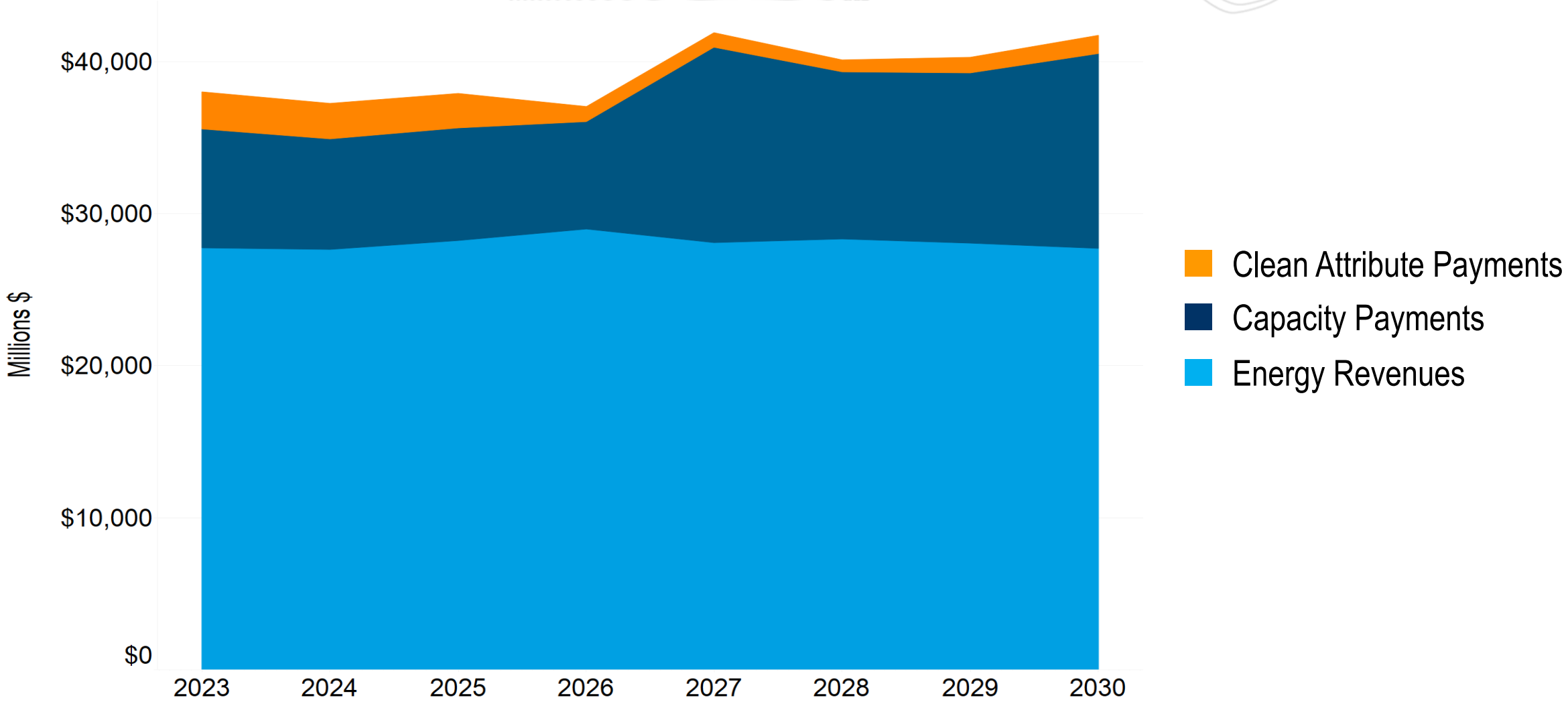
LMP, Capacity and REC Prices – FCEM, state-specific RECs



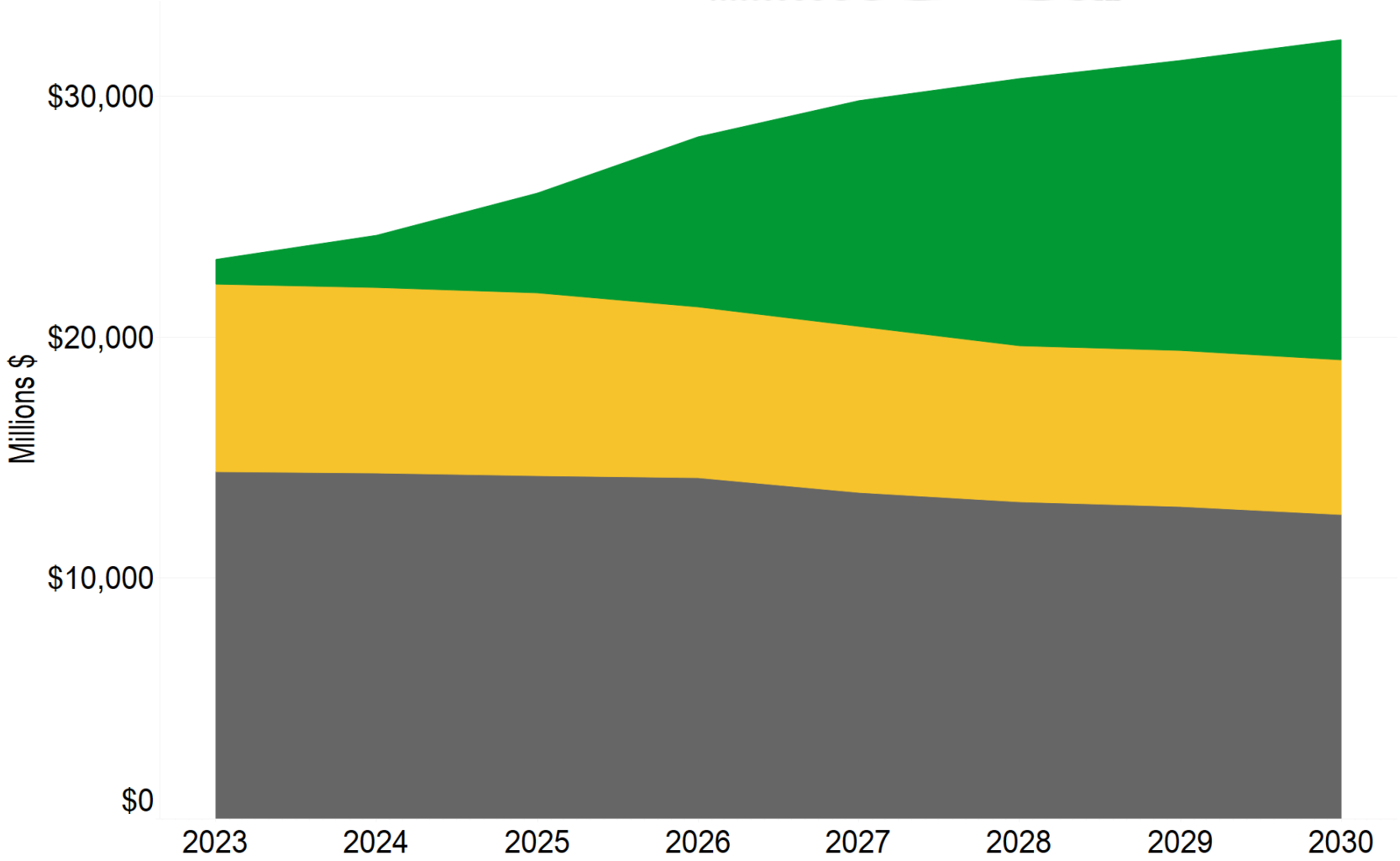
Energy price setting resource by technology type and year
FCEM, state-specific RECs

Steam (Coal)	44.4%	44.9%	44.2%	36.5%	34.6%	24.4%	24.2%	24.3%
Combine Cycle	37.9%	33.8%	33.8%	42.4%	42.7%	46.2%	47.5%	46.8%
CT	6.1%	10.8%	11.1%	10.6%	14.4%	19.2%	20.0%	20.5%
Steam (Gas)	7.8%	6.7%	7.1%	6.6%	4.4%	6.2%	4.1%	3.5%
Nuclear	3.7%	3.8%	3.8%	3.8%	3.9%	4.0%	4.2%	4.8%
Internal Combustion	0.0%	0.0%	0.0%					
Solar							0.0%	0.0%
Onshore Wind								0.0%
DR	0.0%	0.0%	0.0%					
	2023	2024	2025	2026	2027	2028	2029	2030

Total Load Payments – FCEM, state-specific RECs

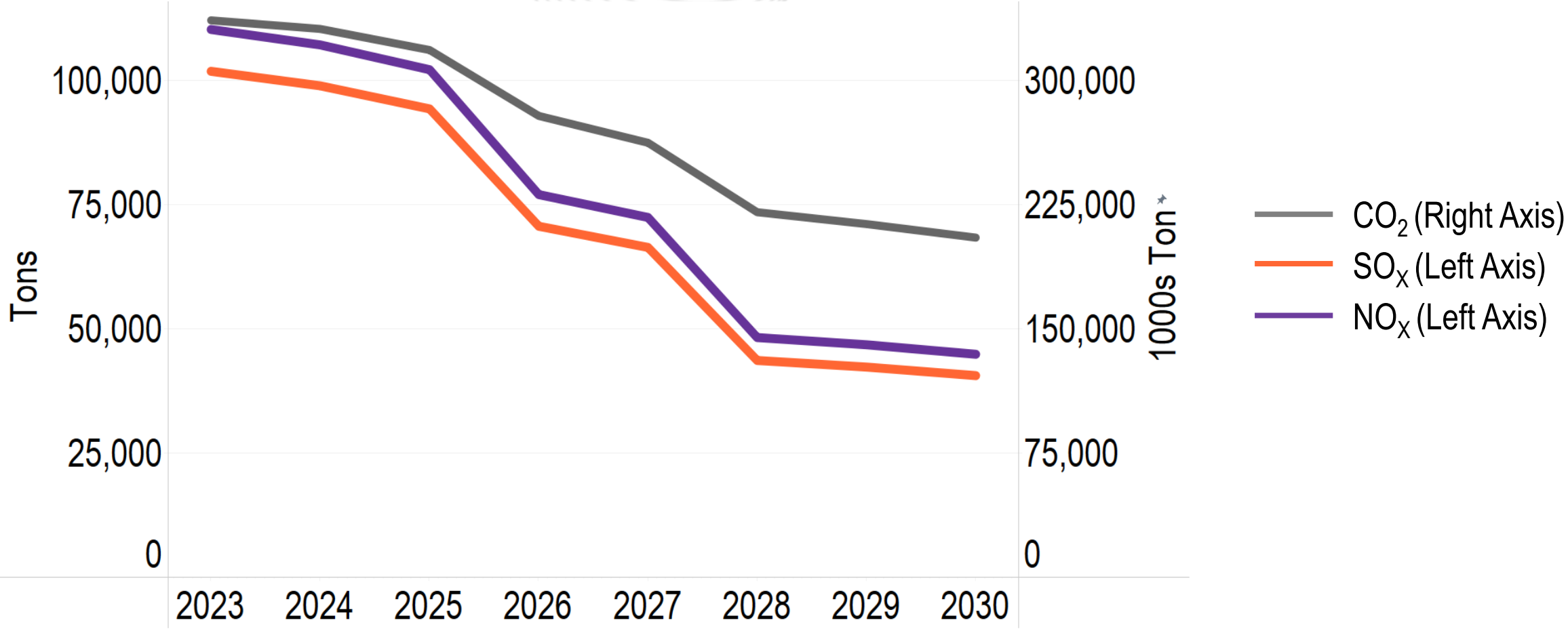


System Costs – FCEM, state-specific RECs



*Note: This excludes any capital costs of resources that entered before 2023

Emissions – FCEM, state-specific RECs

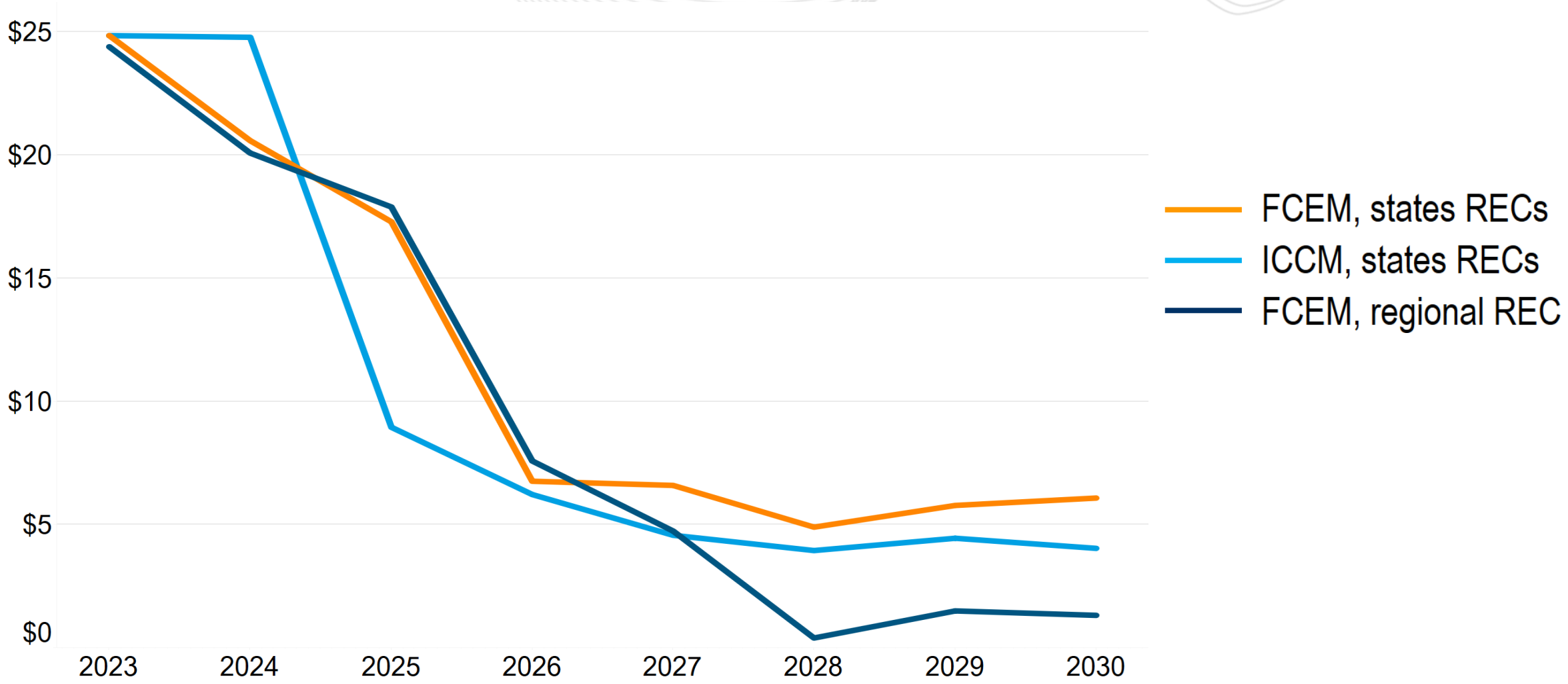


4 of 4 Market designs comparison, three cases

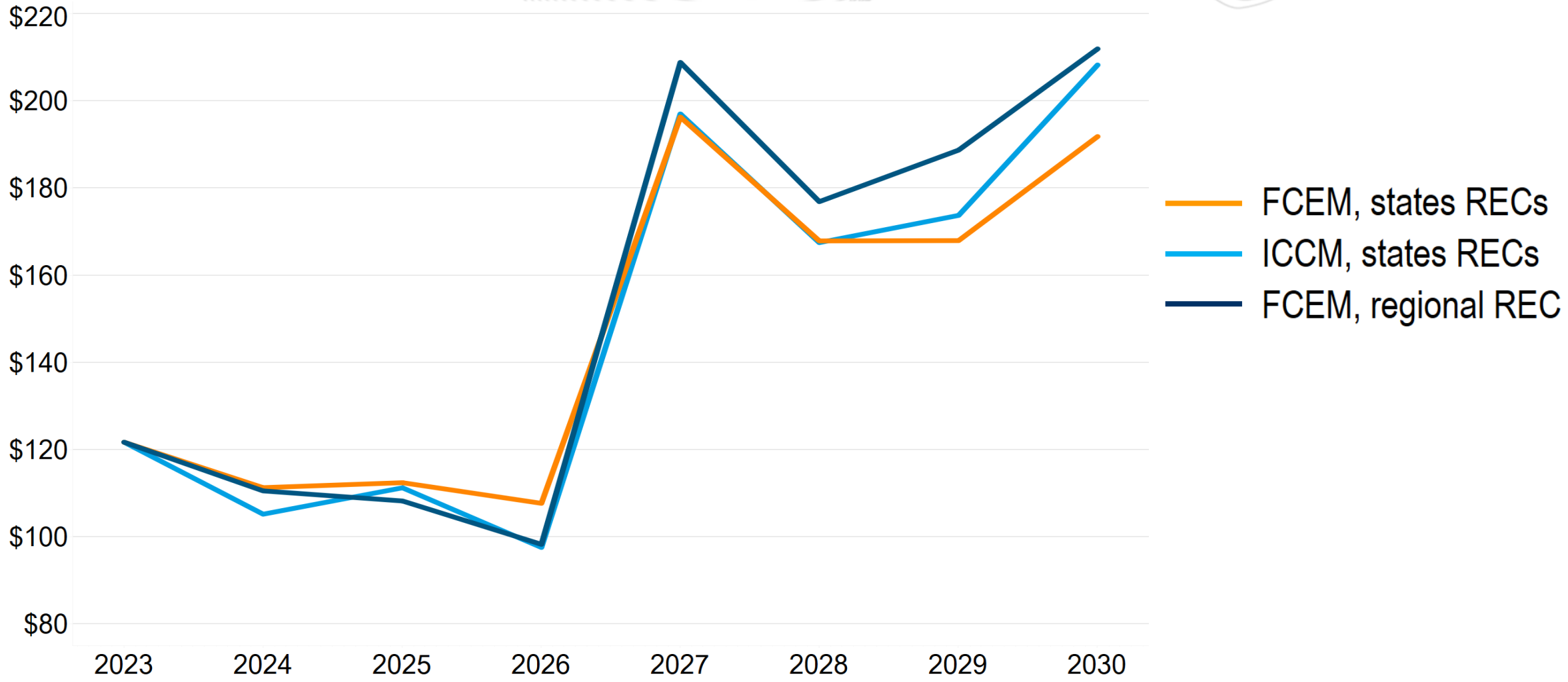
Three Market Designs, review

1. Sequential FCEM + RPM with states' RECs
   - Three year forward market to procure clean energy, followed by RPM to procure capacity
   - Different RECs products reflecting states' carve-outs
2. ICCM with states' RECs
   - One single mechanism co-optimizing the procurement of clean energy and capacity
   - Different RECs products reflecting states' carve-outs
3. Sequential FCEM + RPM with regional RECs
   - Like (1) but with one common REC product

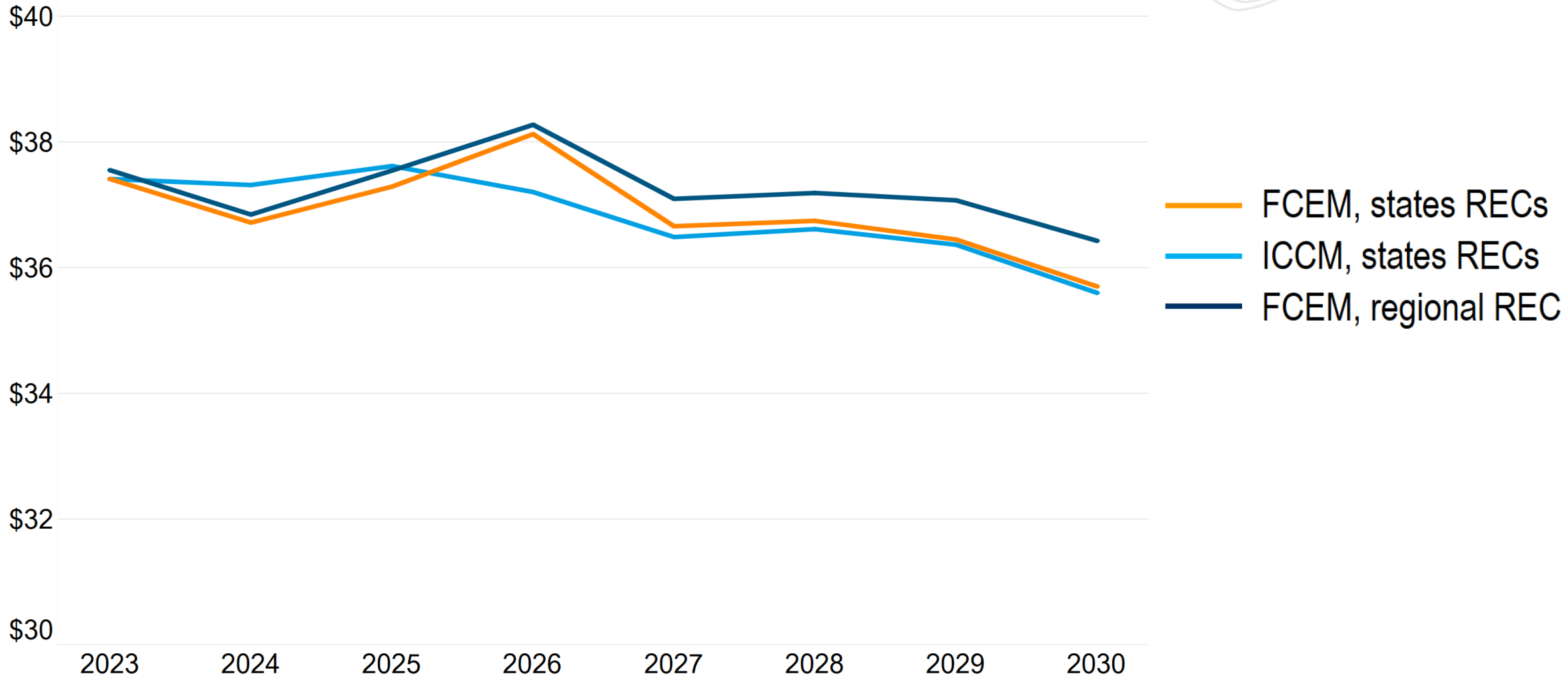
REC price ($/MWh weighted average across states' products)



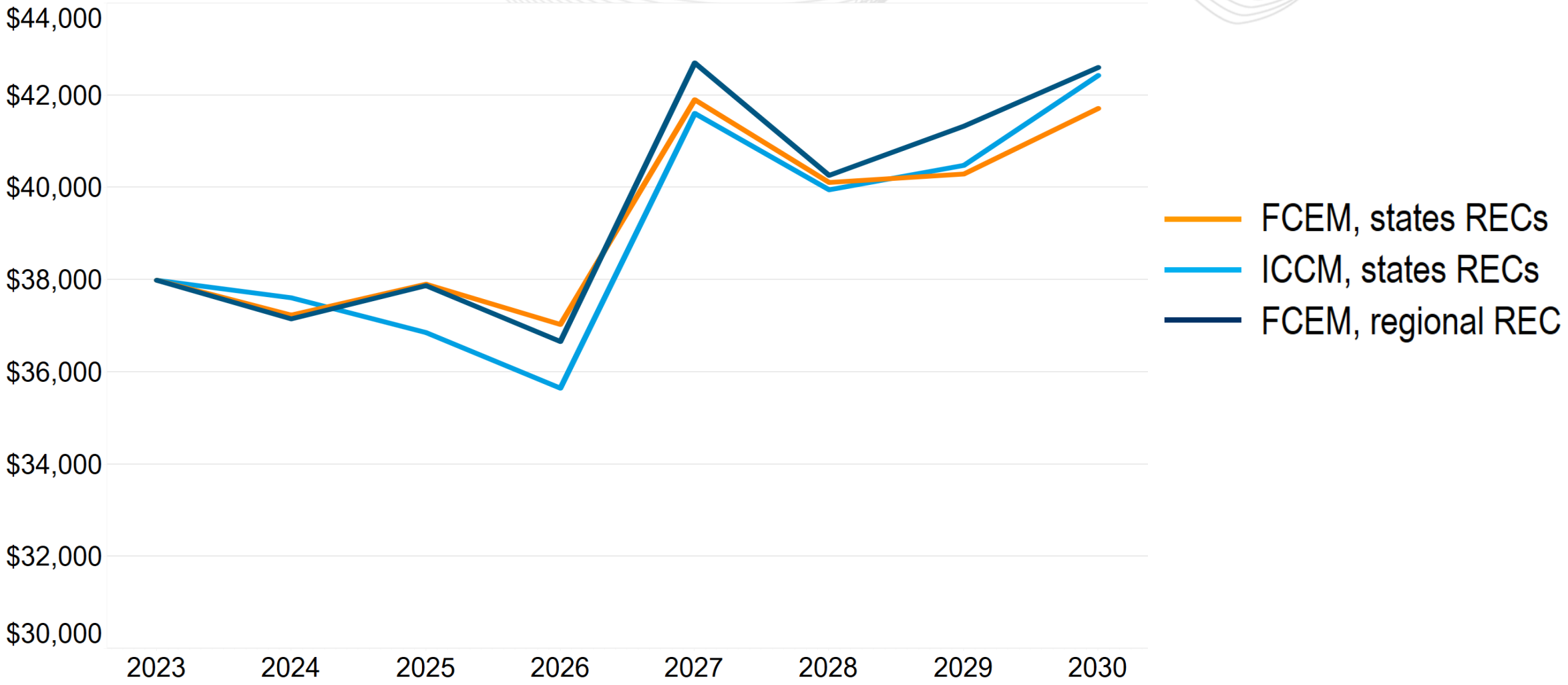
Capacity price ($/MW-day weighted average across zones)



Energy price (LMP load weighted zone/hour average)



Costs to Load (Million $: Energy, Capacity, RECs)

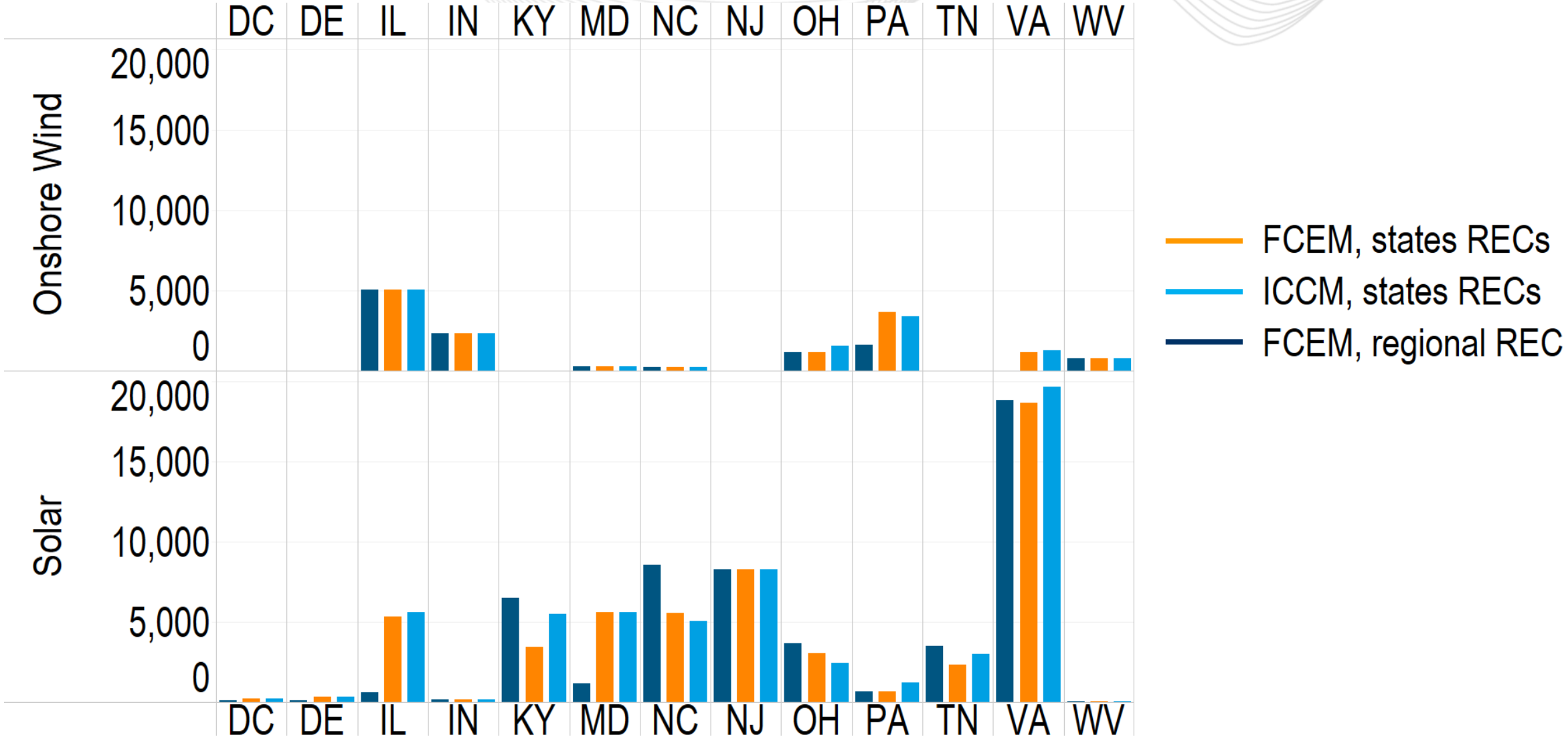


Why are differences minor? (PJM's preliminary understanding)

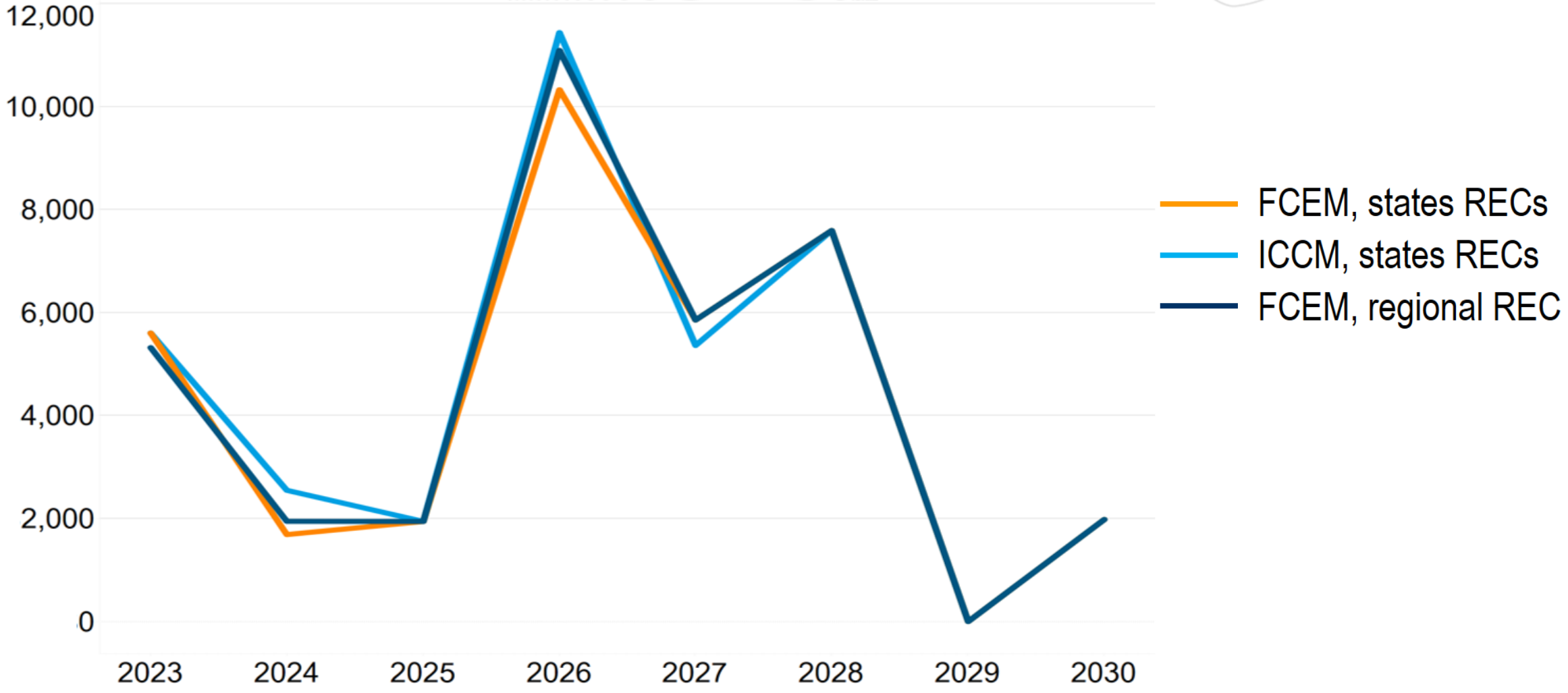
- Some resources remain fixed by mandates (offshore, batteries)
- State-specific RPS are mainly for solar which is more economic than onshore wind due to IRA. The only state with an onshore carve-out is Illinois where it is more economic
- Retirements are mainly dictated by policies
- Transmission constraint further restrict the ability to build resources where they are most economic

Build patterns do not change much across market designs

Renewable ICAP by State, year 2030



Fossil Exits MW

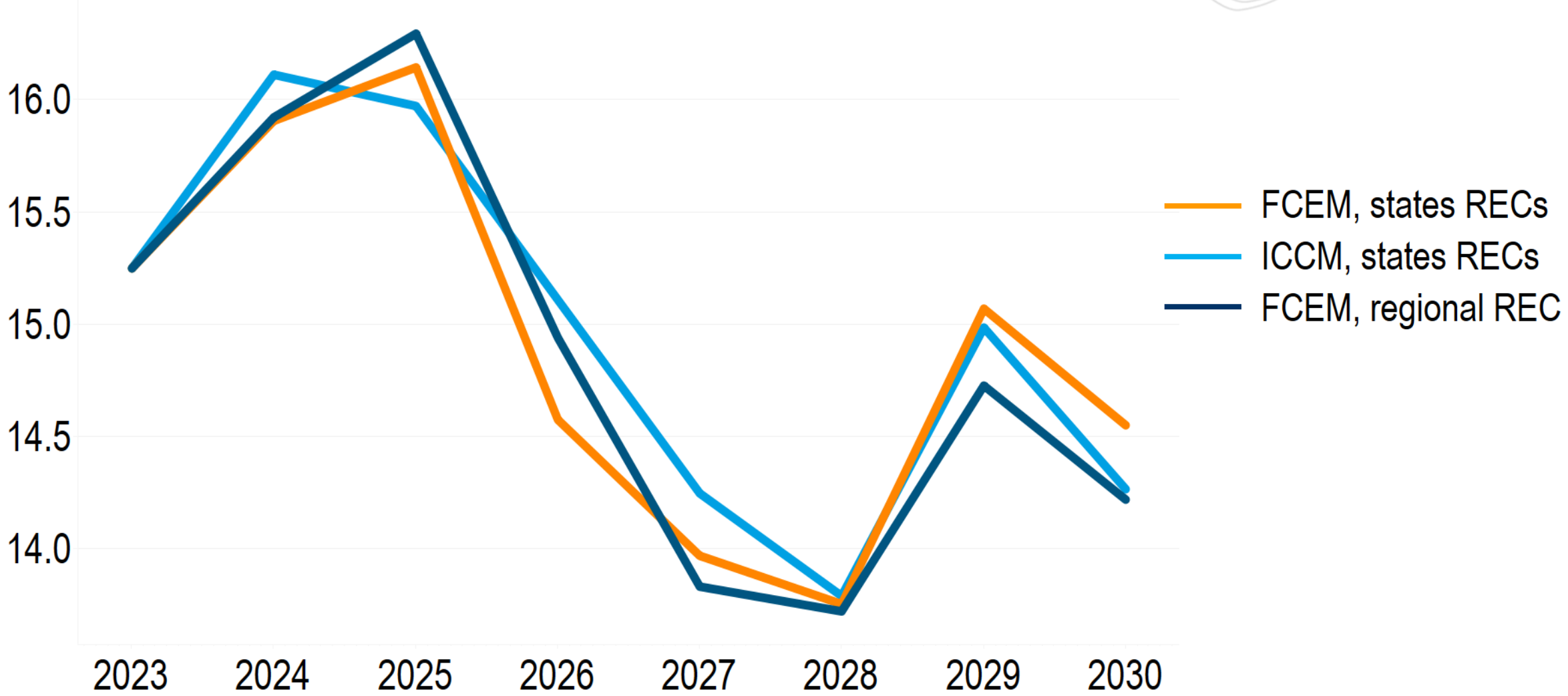


Why is ordering unstable? (PJM's preliminary understanding)

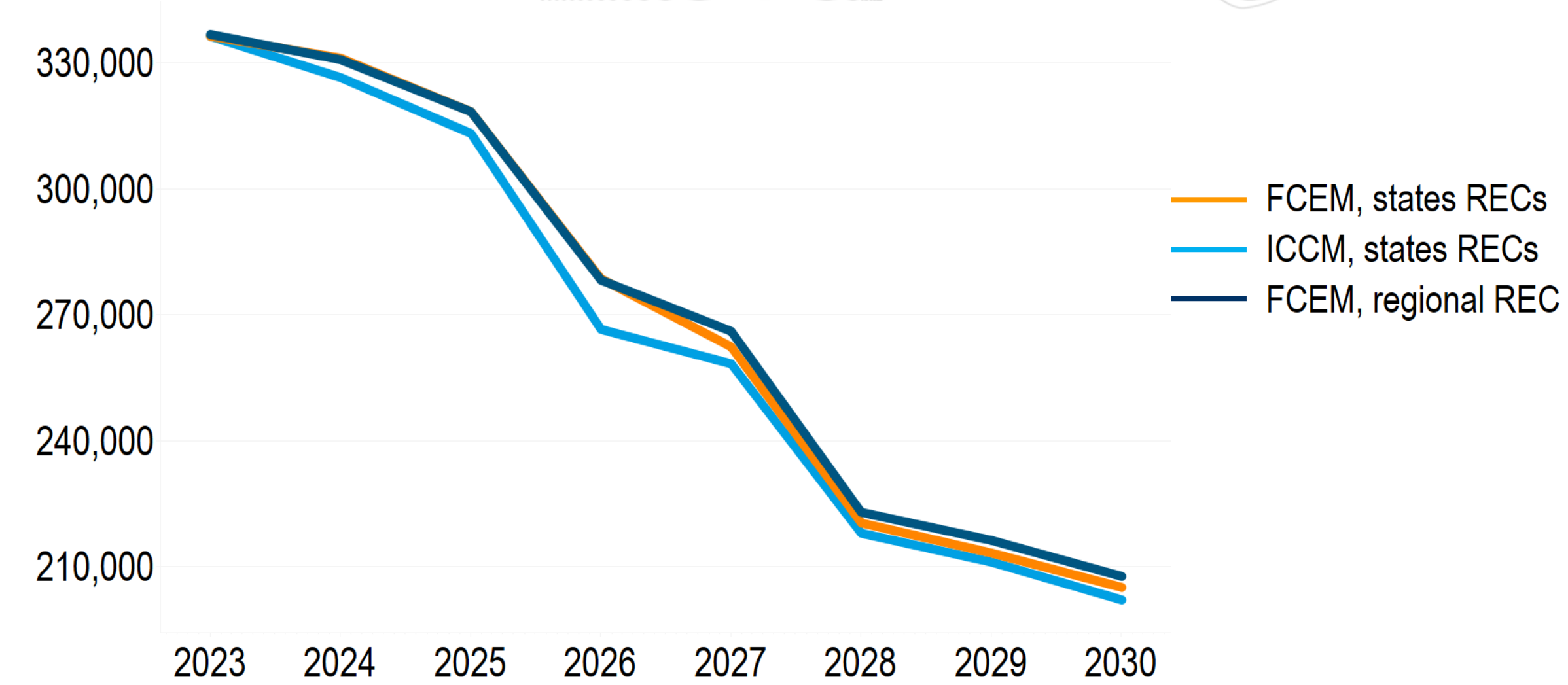
- The model simulate the interaction between markets under imperfect rationality
- It is *not* a co-optimization of the three market under perfect foresight
- Even in the ICCM, investors formulate expectations about EAS and can be wrong
- The ICCM minimizes offered costs (N-ACR , N-CONE) and does not account for how the resource mix it selects will impact future market outcomes
- When comparing the ICCM and FCEM in, say 2027, we are looking at markets with two different set of inputs. Different resources were selected between 2023-2026 via markets' interactions

Because differences across market designs are minor (see previous slides), these market ripples are enough to affect orderings which are sensitive to calibration and time window

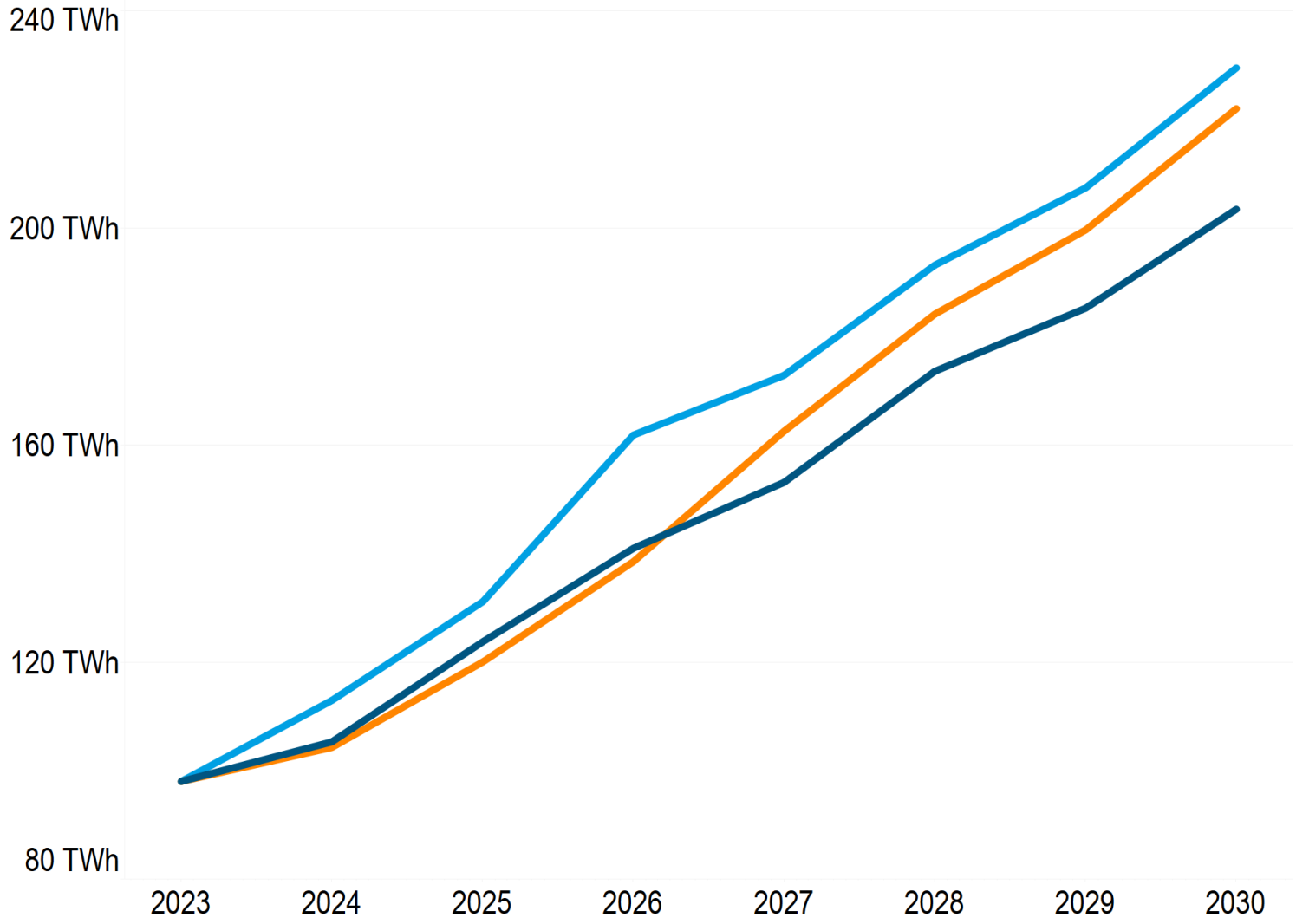
Capacity Reserve Margin %



CO_2 Emissions 1000s ton



Renewable Generation TWh



*Note: Includes renewable generation in MISO4

Renewable Generation, TWh

Year	REC target	FCEM, Regional RECs	FCEM, states RECs	ICCM, states RECs
2023	98.0	98.0	98.0	98.0
2024	112.9	105.3	104.3	112.9
2025	130.9	123.7	120.0	131.1
2026	147.1	141.0	138.5	161.8
2027	149.7	153.1	162.5	172.8
2028	164.6	173.6	184.1	193.1
2029	181.7	185.2	199.6	207.4
2030	197.6	203.4	222.0	229.5

Nuclear Generation, TWh

Year	FCEM, Regional RECs	FCEM, states RECs	ICCM, states RECs
2023	277.0	277.0	277.0
2024	277.7	277.7	277.6
2025	276.7	276.7	276.4
2026	276.7	276.5	275.6
2027	276.7	275.2	273.5
2028	277.4	274.4	272.1
2029	276.8	271.0	269.0
2030	276.8	267.5	266.7

Next steps

- Refine model
- Remaining parts of CPAWG's request
  - Regional clean product
  - Voluntary participation
  - Capacity market with clean constraint (with or without FCEM)
- Status quo as per requests from CPAWG and Wilson Energy Economics (consultant on behalf of the consumer advocate offices in NJ, PA, MD, DC, and DE).
- IMM's request

Contact

Presenters:
Emmanuele Bobbio
Emmanuele.Bobbio@pjm.com

CAPSTF Analysis, Initial Results

Member Hotline

(610) 666 – 8980

(866) 400 – 8980

custsvc@pjm.com

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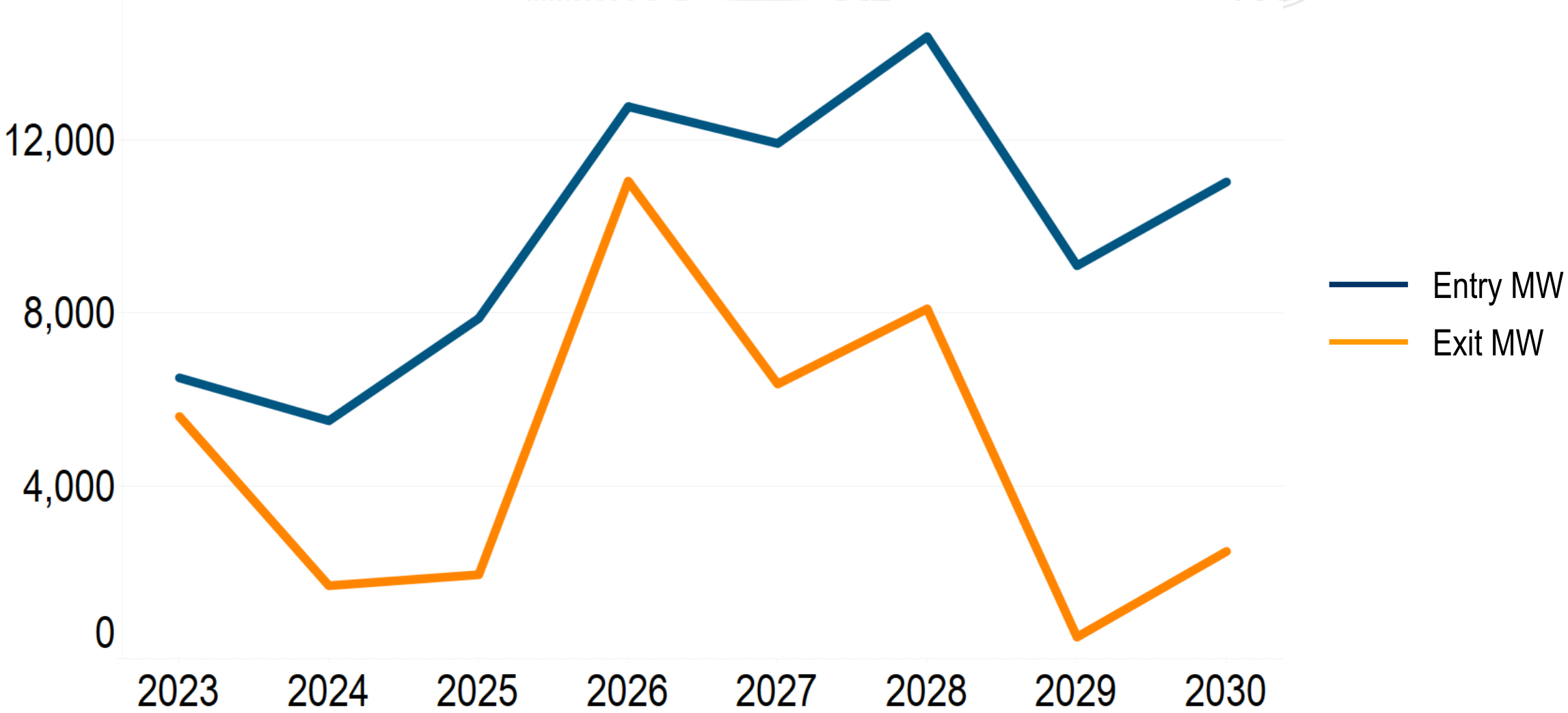
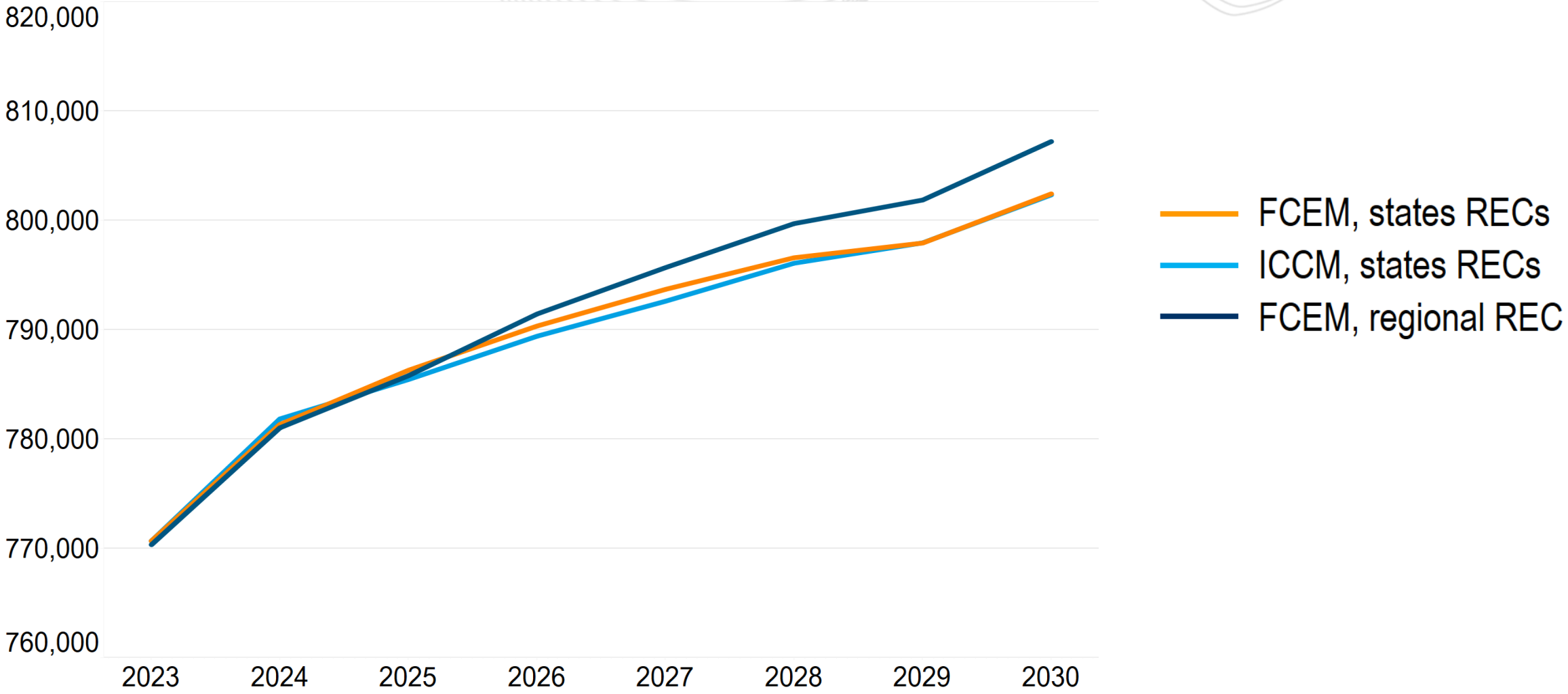
Appendix

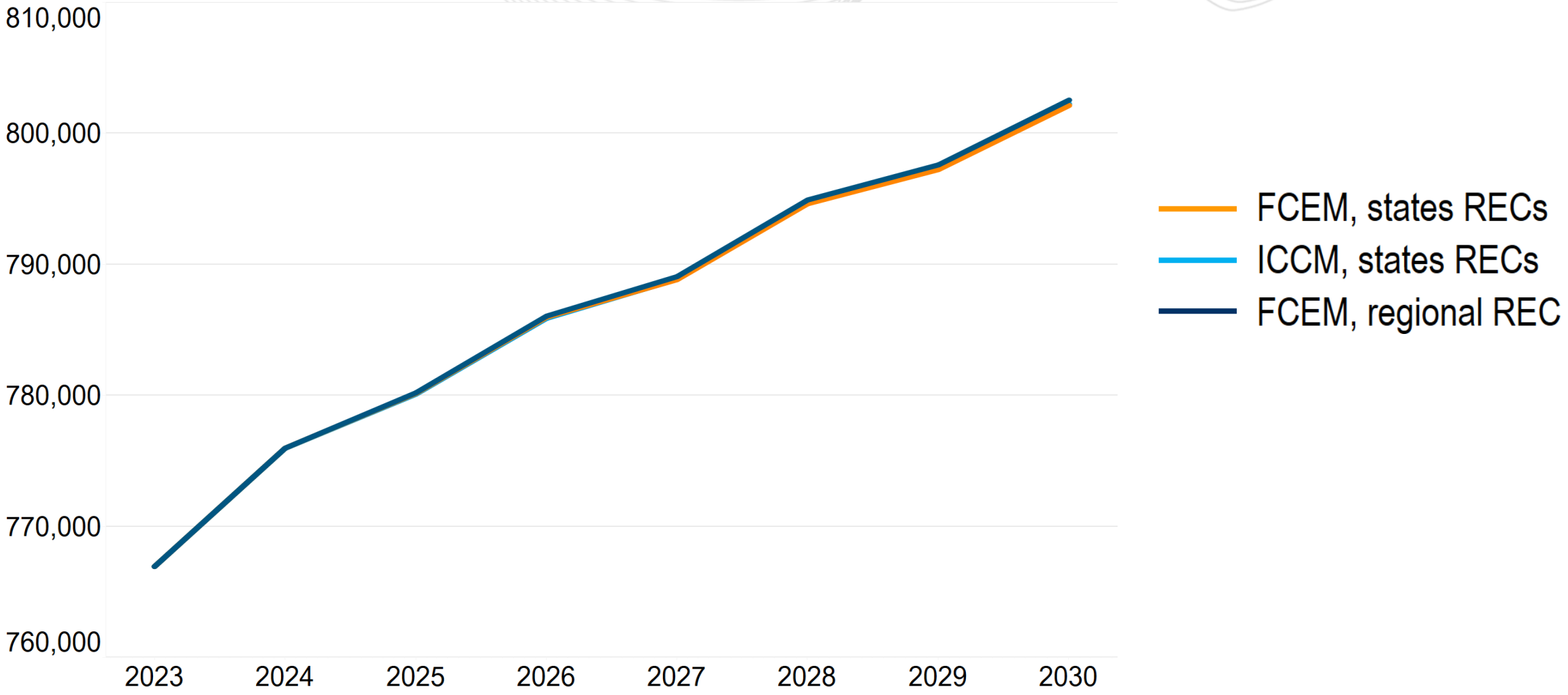
Total Entry and Exit – FCEM, state-specific RECs



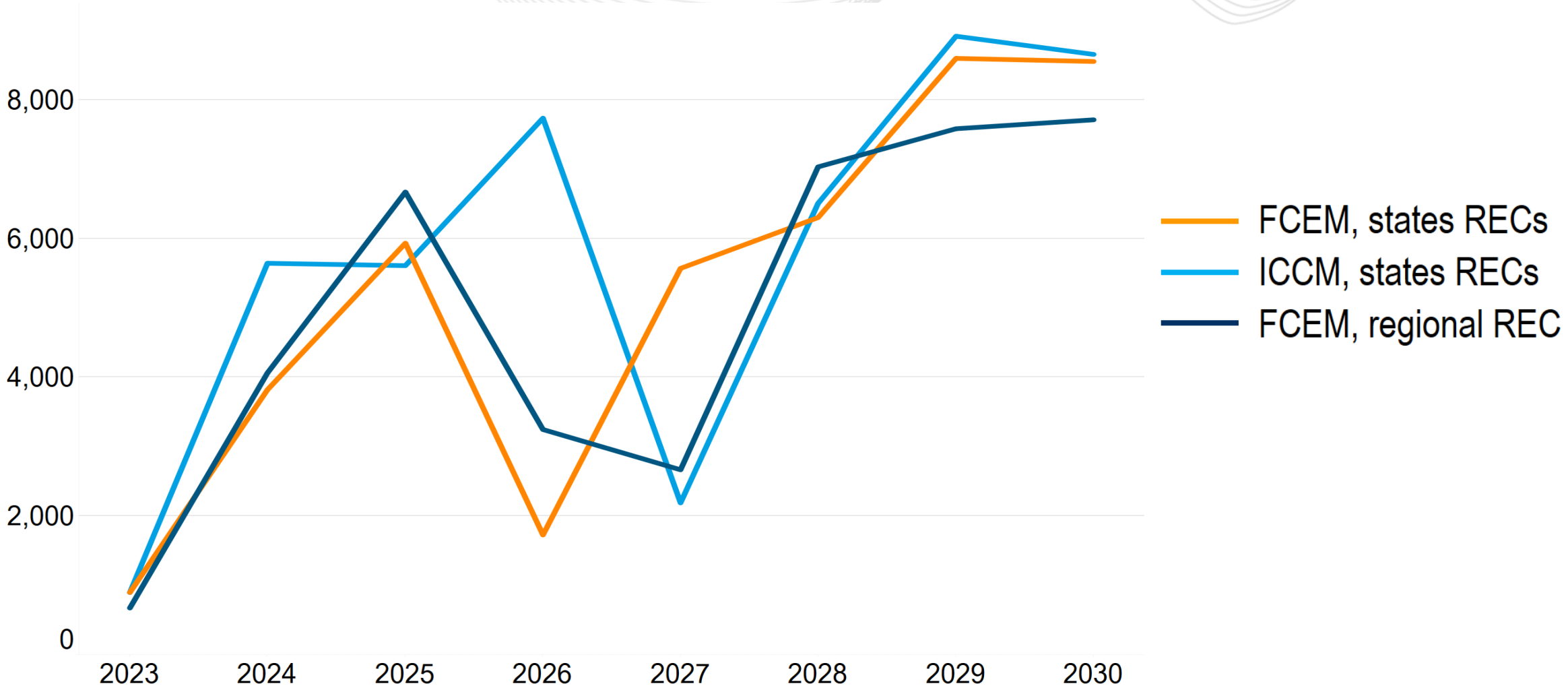
Annual Generation MW



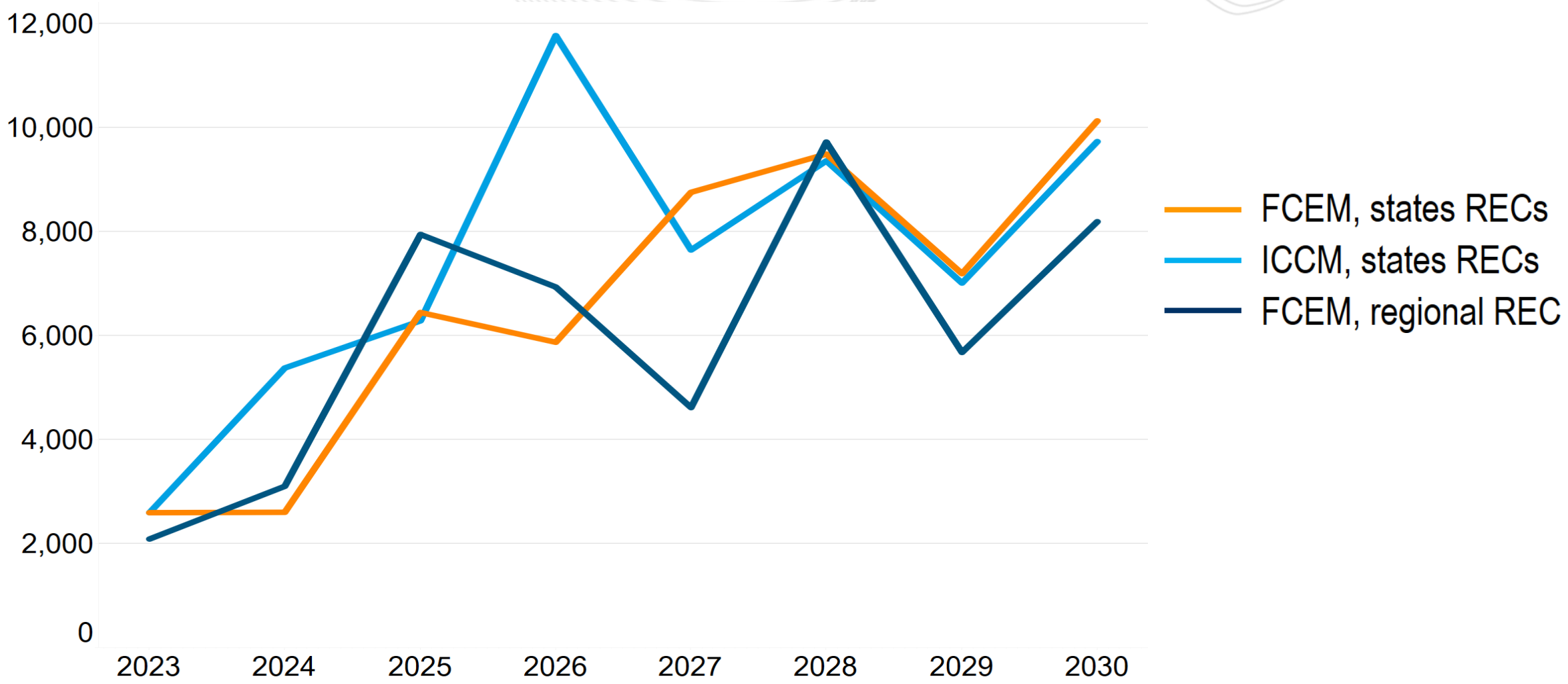
Annual Load MW



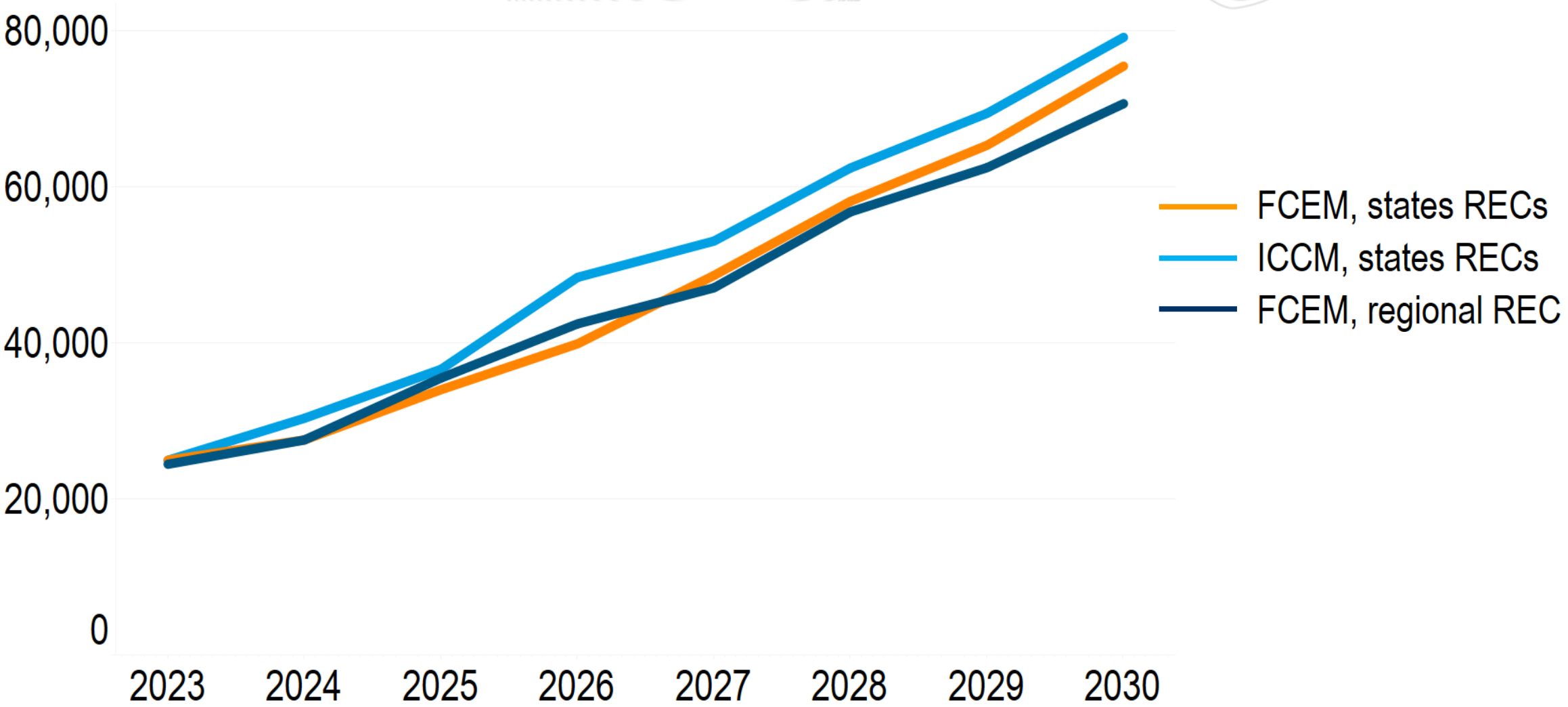
Net-Entry MW



Renewables Entry MW



Renewable Nameplate ICAP MW



System Costs (Million $)