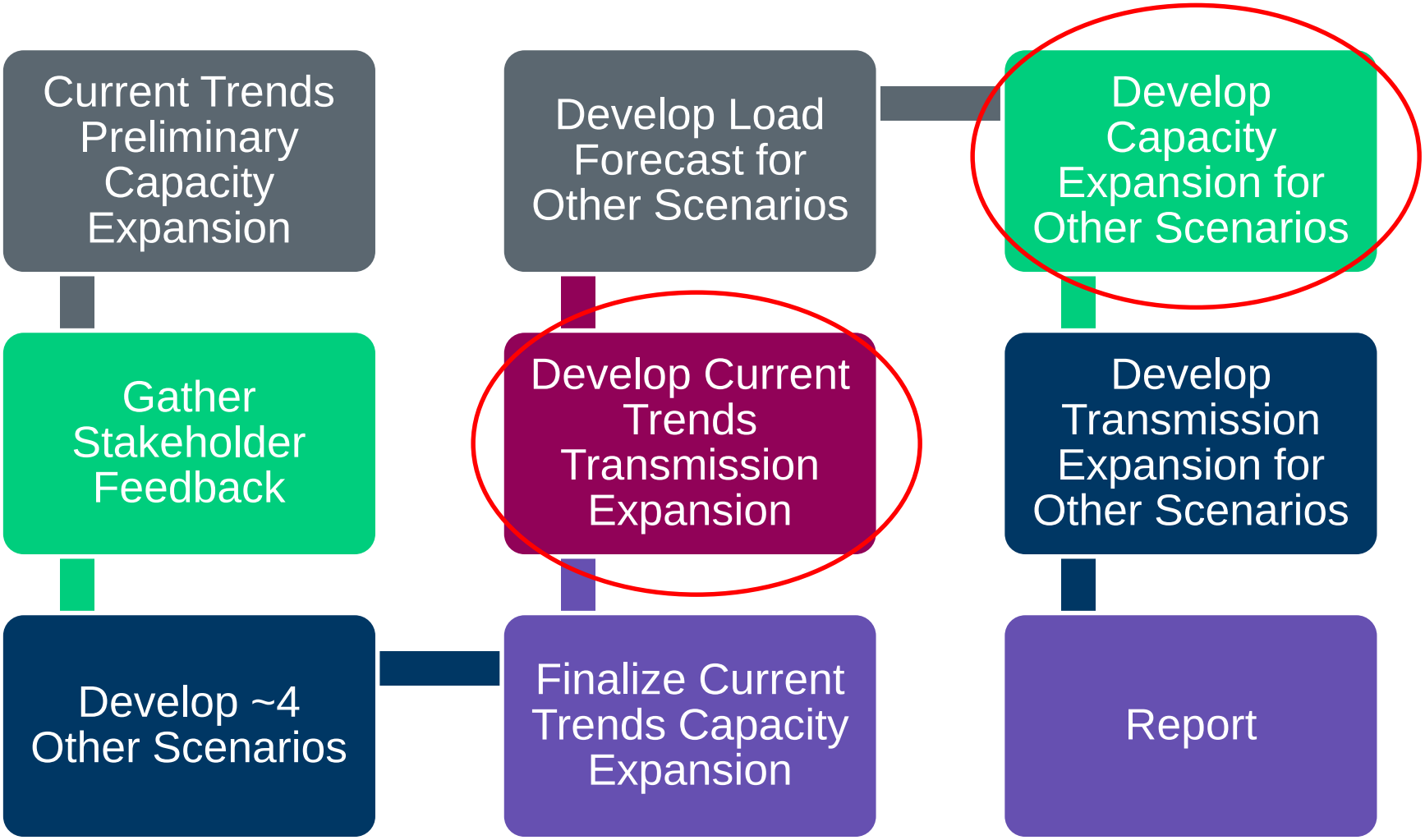
2020 LTSA Update

May 2020
RPG Meeting

2020 LTSA Process



2020 LTSA Overall Update

- Completed generation expansion analysis for four scenarios: Current Trends, Renewable Mandate, High BESS and High Industrial Load
- Completed preliminary transmission analysis for Current Trends

Generation Expansion Update

Julie Jin

Changes for Current Trends from September 2019 Update

- Improved battery storage modeling, such as, allowing partial builds, allowing battery storage to provide every type of ancillary service offline, etc.;
- Corrected CO2 emission price;
- Increased the solar annual cap from 1500 MW to 4000 MW;
- Added wind candidates in 38 counties which have operational wind farms.

Updated Results for Current Trends

- Reserve margin in final year: 12%
- Built 20,823 MW gas generation
- Built 27,700 MW solar
- Built 40,200 MW wind
- Built 2,023 MW battery storage

Description	Units	2021	2025	2030	2035
CC Adds	MW	-	-	6,500	7,250
CT Adds	MW	-	-	-	7,073
Coal Adds	MW	-	-	-	-
Nuclear Adds	MW	-	-	-	-
Storage Adds	MW	-	606	997	420
Solar Adds	MW	4,000	15,200	5,400	3,100
Wind Adds	MW	3,000	12,000	15,000	10,200
Annual Capacity Additions	MW	7,000	27,806	27,897	28,043
Cumulative Capacity Additions	MW	7,000	34,806	62,703	90,746
Economic Retirements	MW	-	1,211	-	-
Cumulative Economic Retirements	MW	-	1,211	1,211	1,211
Reserve Margin	%	11	12	11	12
Coincident Peak	MW	83,594	89,989	98,129	106,579
Annual Energy	GWhs	454,288	505,245	567,464	633,575
Average LMP	$/MWh	43.22	61.76	72.84	85.39
Natural Gas Price	$/mmbtu	3.24	4.20	5.00	5.95
Average Market Heat Rate	MMbtu/MWh	13.33	14.69	14.57	14.34
Natural Gas Generation	%	53.87	38.95	35.17	35.45
Coal Generation	%	7.88	8.20	5.47	3.74
Wind Generation	%	24.44	32.52	39.16	41.43
Solar Generation	%	4.24	11.63	12.77	12.65
Scarcity Hours	HRS	9	24	29	35
Unserved Energy	GWhs	7.64	46.58	90.91	114.60

Note: For the four scenarios in this presentation, economic retirements are a subset of fixed-age retirements. These units are retiring before they would have retired using the fixed-age rule.

Updated Results for Current Trends -continue

- Unserved energy is seen in every study year. Shortages are shifted from 3-6 PM in 2021 to 4-9 PM in 2025 in summer, then shifted to 7-10 PM in 2030 through 2035 in summer and winter.
- Additional solar capacity is the main driver for the net load peak period shifts and potential shortages in winter.

Input Assumptions for Renewable Mandate

- High distributed solar projection presented at December 2019 SAWG meeting;
- Extended PTC/ITC throughout the study horizon;
- Based on the CO2 tax bills introduced in the U.S. Congress during 2019, $40/ton CO2 tax starting from 2021 was used in the case and escalated at 4.5%.

Results for Renewable Mandate

- Reserve margin in final year: 17%
- Built 18,146 MW gas generation
- Built 35,000 MW solar
- Built 44,800 MW wind
- Built 3,445 MW battery storage
- Unserved energy in 2025 through 2035. Shortages are seen around 8 PM in summer in 2025 through 2030. Shortages are seen during 7-10 PM in 2035 in both summer and winter.

Description	Units	2021	2025	2030	2035
CC Adds	MW	-	1,000	6,500	8,250
CT Adds	MW	-	-	100	2,296
Coal Adds	MW	-	-	-	-
Nuclear Adds	MW	-	-	-	-
Storage Adds	MW	-	1,108	1,951	387
Solar Adds	MW	4,000	16,000	15,000	-
Wind Adds	MW	3,000	12,000	15,000	14,800
Annual Capacity Additions	MW	7,000	30,108	38,551	25,733
Cumulative Capacity Additions	MW	7,000	37,108	75,658	101,391
Economic Retirements	MW	-	3,056	-	-
Cumulative Economic Retirements	MW	-	3,056	3,056	3,056
Reserve Margin	%	12	14	21	17
Coincident Peak	MW	82,817	88,897	97,160	106,189
Annual Energy	GWhs	451,026	499,771	563,141	629,391
Average LMP	$/MWh	56.00	71.76	85.62	125.41
Natural Gas Price	$/mmbtu	3.24	4.20	5.00	5.95
Average Market Heat Rate	MMbtu/MWh	17.27	17.07	17.13	21.06
Natural Gas Generation	%	59.78	45.47	40.31	46.60
Coal Generation	%	1.64	0.63	5.22	3.44
Wind Generation	%	24.55	32.77	36.84	34.46
Solar Generation	%	4.35	12.23	10.73	9.53
Scarcity Hours	HRS	-	4	5	20
Unserved Energy	GWhs	-	9.06	16.95	71.13

Results for Renewable Mandate - continue

- Combined cycle units are added in early years to replace some accelerated coal retirements caused by carbon tax while solar and wind new capacity additions reach their annual caps;
- In a high renewable penetration system, average emission of battery charging energy plus efficiency losses is still lower than combustion turbine, and battery storage is also more flexible than combustion turbine in providing ancillary service reserves, so battery storage becomes more competitive, the model adds more battery storage and less combustion turbines in the Renewable Mandate scenario than the Current Trends scenario.

Input Assumptions for High BESS

- High electric vehicle adoption: 5.9 million electric light duty vehicles by 2035, 77% of bus and heavy trucks driving miles driven by electric bus and trucks by 2035;
- Low battery capital cost projection from NREL*

*https://www.nrel.gov/docs/fy19osti/73222.pdf

High BESS Model Run Sequence

Initial Run

- High EV adoption
- Low battery storage capital cost

Fix solar and add co-located storage

- Fix new solar resources from the initial run (21 GW)
- Add co-located battery storage for every new solar site, battery storage size assumed to be 50% of every solar farm capacity (10.8 GW)

Final Run

- Rerun the model with the additional co-located battery storage and fixed new solar resources
- The model decides what the rest of the capacity additions are for every type of generation technology

Results for High BESS

- Reserve margin in final year: 6%
- Built 34,217 MW gas generation
- Built 22,200 MW solar
- Built 35,000 MW wind
- 12,911 MW battery storage in total
- Unserved energy in 2030 through 2035. Shortages are seen during 7-10 PM in 2030 and during 7-11 PM in 2035 in both summer and winter.

Description	Units	2021	2025	2030	2035
CC Adds	MW	-	-	9,000	15,000
CT Adds	MW	-	-	3,181	7,036
Coal Adds	MW	-	-	-	-
Nuclear Adds	MW	-	-	-	-
Storage Adds	MW	1,850	8,050	2,150	861
Solar Adds	MW	4,000	14,300	3,400	500
Wind Adds	MW	3,000	12,000	15,000	5,000
Annual Capacity Additions	MW	8,850	34,350	32,731	28,397
Cumulative Capacity Additions	MW	8,850	43,200	75,931	104,328
Economic Retirements	MW	-	2,266	75	-
Cumulative Economic Retirements	MW	-	2,266	2,341	2,341
Reserve Margin	%	10	9	9	6
Coincident Peak	MW	83,787	91,024	102,686	120,057
Annual Energy	GWhs	457,573	517,290	615,279	714,240
Average LMP	$/MWh	29.25	36.43	64.62	94.68
Natural Gas Price	$/mmbtu	3.24	4.20	5.00	5.95
Average Market Heat Rate	MMbtu/MWh	9.02	8.67	12.93	15.90
Natural Gas Generation	%	54.15	40.26	40.31	46.60
Coal Generation	%	7.92	8.07	5.22	3.44
Wind Generation	%	24.21	32.10	36.84	34.46
Solar Generation	%	4.22	11.05	10.73	9.53
Scarcity Hours	HRS	-	-	12	21
Unserved Energy	GWhs	-	-	24.53	67.21

Results for High BESS - continue

- Compared to the Current Trends scenario:
  - A lot of combined cycle units are added to serve high electric vehicle charging demand at night. Since these combined cycle units can serve load during day time as well, less solar is added;
  - Less wind is added because co-located battery storage units are charged by solar generation during daytime, discharge at night and squeeze out some new wind capacity;
  - The standalone and co-located battery storage units provide the flexibility that combustion turbines can provide, so less combustion turbine capacity is added.

Input Assumptions for High Industrial Load

- Added 778 MW and 1,245 MW LNG by 2035 at Corpus Christi and Brownsville respectively;
- Added 3,560 MW industrial load in Delaware Basin by 2035.

Results for High Industrial Load

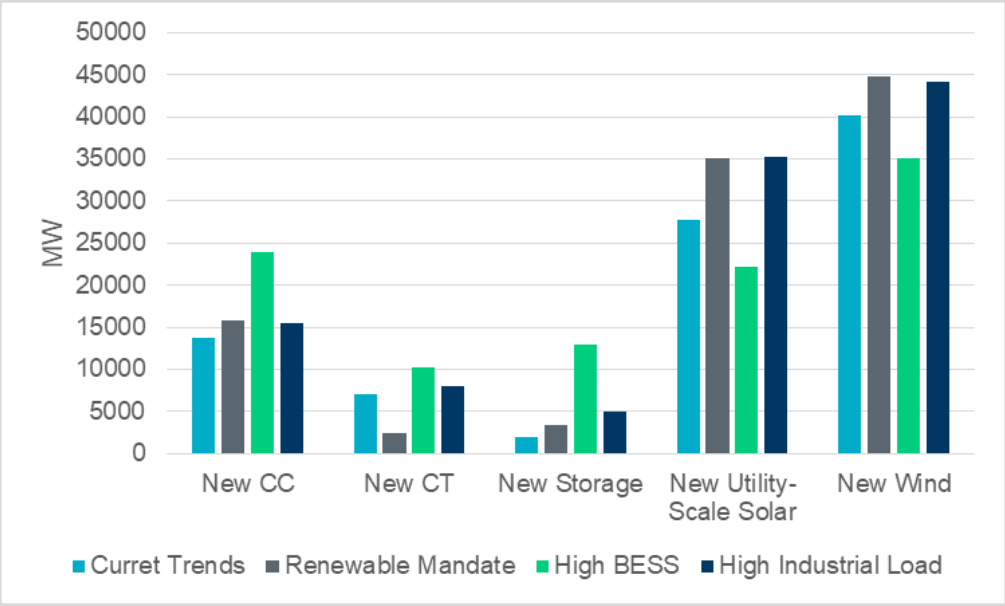
- Reserve margin in final year: 15%
- Built 23,558 MW gas generation
- Built 35,300 MW solar
- Built 44,200 MW wind
- 4,900 MW battery storage in total
- Unserved energy in every study year. Shortages are seen only in summer before 2025, and during 7-10 PM in 2030 through 2035 in both summer and winter.

Description	Units	2021	2025	2030	2035
CC Adds	MW	1,000	3,000	6,000	5,500
CT Adds	MW	-	-	948	7,110
Coal Adds	MW	-	-	-	-
Nuclear Adds	MW	-	-	-	-
Storage Adds	MW	-	1,600	2,100	1,200
Solar Adds	MW	4,000	15,800	4,700	10,800
Wind Adds	MW	3,000	12,000	15,000	14,200
Annual Capacity Additions	MW	8,000	32,400	28,748	38,810
Cumulative Capacity Additions	MW	8,000	40,400	69,148	107,958
Economic Retirements	MW	-	-	391	120
Cumulative Economic Retirements	MW	-	-	391	511
Reserve Margin	%	10	11	9	15
Coincident Peak	MW	84,847	95,235	103,540	112,162
Annual Energy	GWhs	465,263	550,296	614,861	682,486
Average LMP	$/MWh	33.44	45.17	65.00	81.94
Natural Gas Price	$/mmbtu	3.24	4.20	5.00	5.95
Average Market Heat Rate	MMbtu/MWh	10.31	10.75	13.00	13.76
Natural Gas Generation	%	58.07	43.40	39.69	35.32
Coal Generation	%	7.73	7.77	5.20	3.44
Wind Generation	%	21.49	29.82	36.40	40.56
Solar Generation	%	3.46	10.97	11.79	14.43
Scarcity Hours	HRS	1	4	12	21
Unserved Energy	GWhs	0.17	9.32	39.11	77.69

Results for High Industrial Load - continue

- Combined cycle capacity is added in early years to serve additional industrial load while both solar and wind reach their annual caps;
- Since additional industrial load is 24/7 load, and much more wind and solar capacities are added in this scenario than the Current Trends scenario, more battery storage is needed to firm up variable wind and solar generation.

Summary- Generation Capacity Additions by 2035



- Wind and solar are complementary, that is, if the model adds more solar, it adds more wind as well, and vice versa;
- New gas generation will be likely needed to serve charging demand of electric vehicles at night.

Next Step

- Generation expansion analysis for the Existing Transmission Constraints scenario

Current Trends Transmission Expansion Update

Hong Xiao

Agenda

- Generator siting methodology
- Transmission modeling
- Preliminary results
- Next steps

Generator Siting

- Existing generation to be retired
  - Gas and coal
  - Fixed age and acceleration
- Future wind and solar
  - Location-specific hourly profiles
  - Station in same or nearby county
- Future storage
  - Stand-alone
  - Co-located with solar

Generator Siting: Thermal Generation

- Siting considerations
  - Emissions restrictions
  - Local policy
  - Nodal prices and annual income
    - Generator siting for 2035 may be adjusted after transmission analysis completed for 2030
- Potential sites
  - Retired generation plants (and those to be retired)
  - Existing generating plants (CCTs and/or CTs)
  - Generator sites proposed for future development of similar technology
  - Other greenfield sites with water availability

Transmission Model

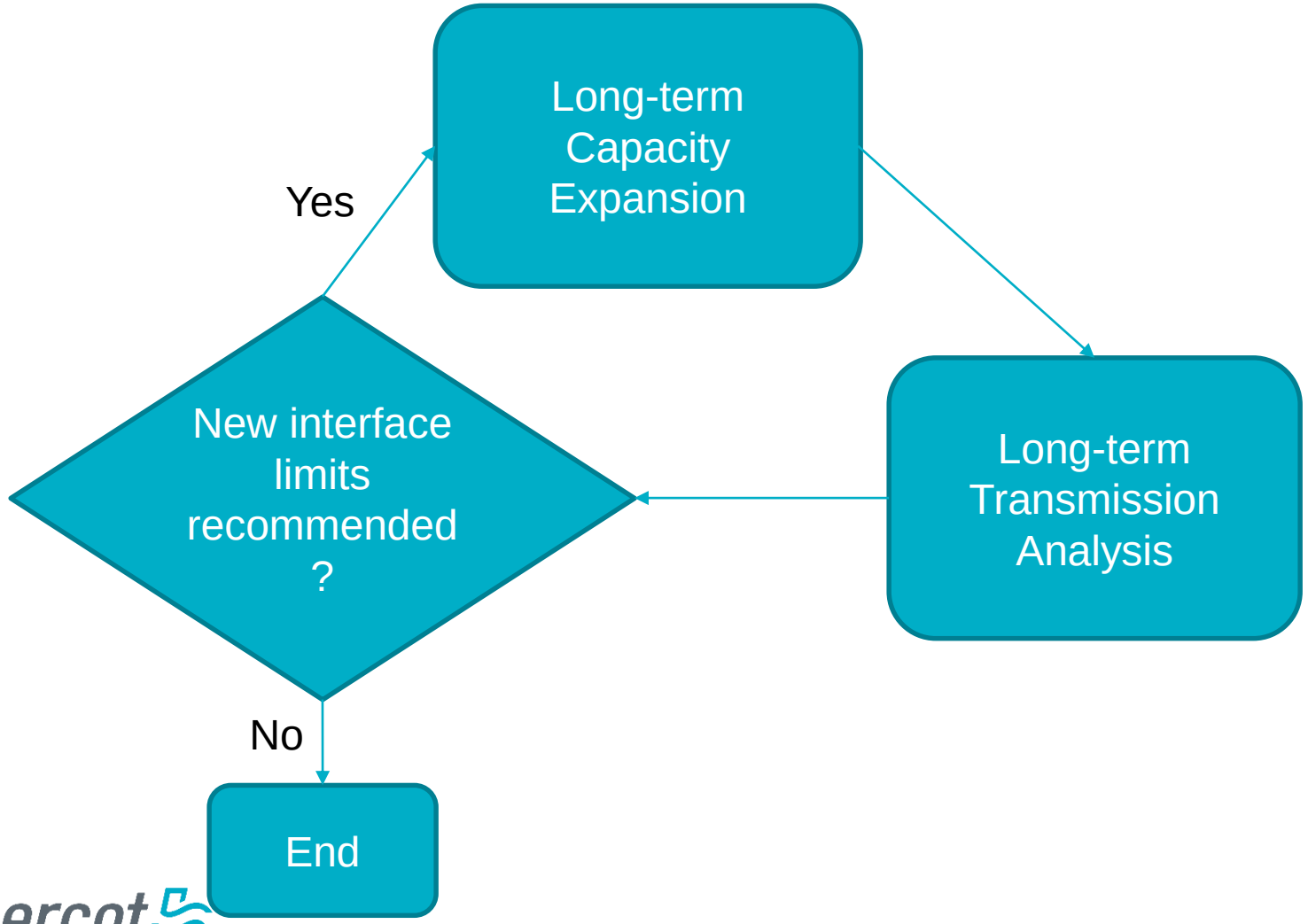
- Based on final scenario (2024) from 2019 RTP economic analysis
- Updates
  - All recent RPG-approved transmission projects
  - Other transmission projects as needed (e.g., Tier 4 projects modeled in 2019 RTP reliability analysis)
- Thermal constraints
  - n-0 and n-1
  - 100 kV and above
- Generic transmission constraints

Preliminary Observations and Next Steps

- Both the West Texas Export and Lobo to North Edinburg interfaces are congested more than 50% of hours in preliminary simulations for both 2030 and 2035
- Next steps
  - Finalize thermal generator siting
  - Complete transmission model in base cases with additional generic transmission constraints
  - Identify transmission projects
  - Determine whether one more generation-transmission expansion iteration is necessary

Appendix

Iterative Process of Capacity Expansion and Transmission Analysis



Questions

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