

# FLEXIBLE OPERATION OF COAL BASED GENERATING UNITS

- A Strategy for low cost integration of renewable energy into grid

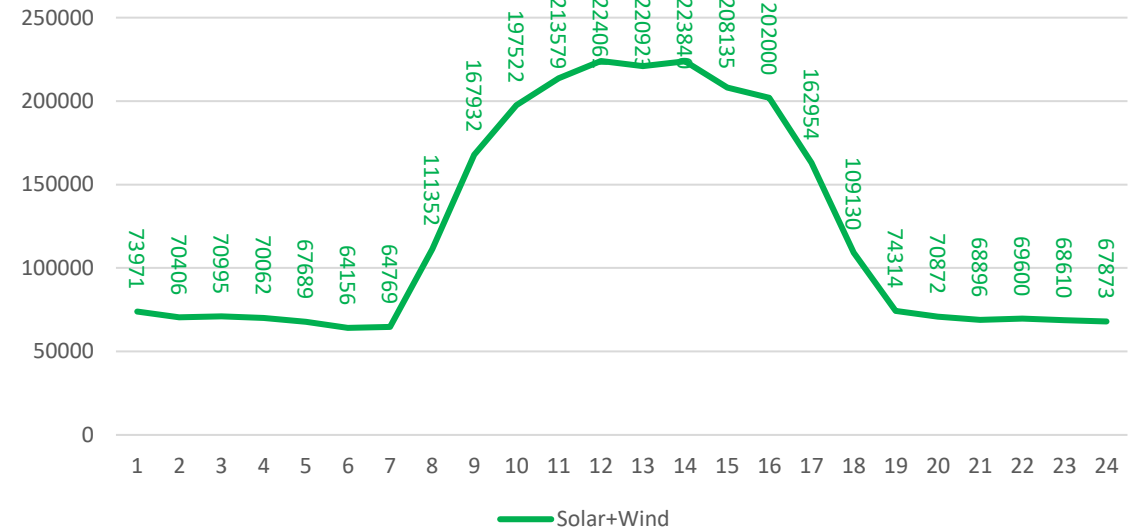
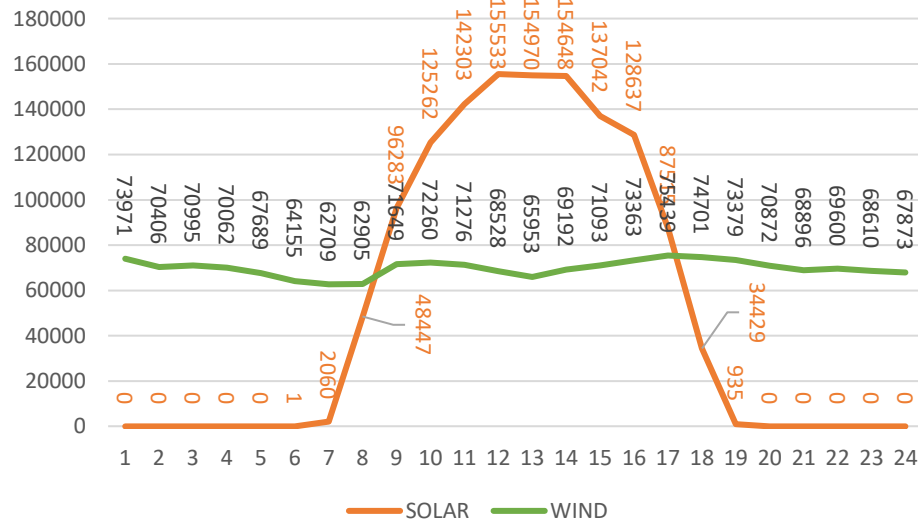
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## **TARGET OF 292 GW SOLAR AND 100 GE WIND**

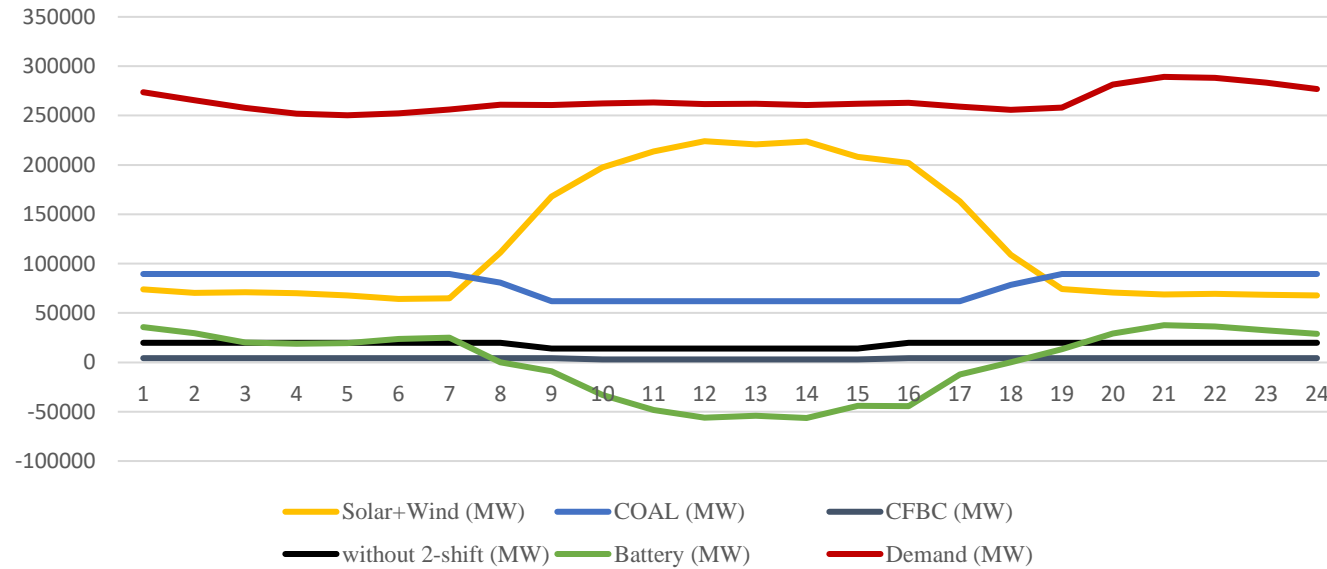
- ✓ The inconsistency and intermittency of solar & wind power has to be managed by other sources of generation in order to ensure the grid security, reliability and stability.
- ✓ Huge flexible power is required for the balancing of grid from sources like hydro power plants, pump storage system, thermal power plants, battery storage system etc.
- ✓ Flexible power can be obtained from coal based power plants by lowering technical minimum load.

# MOST CRITICAL DAY IN 2029-30

**Most Critical day:** As projected the most critical day situation will be occurred in the grid in July, 2029 when flexible power requirement will be maximum for balancing the grid. The maximum renewable (Solar plus Wind) generation on the critical day will be 224 GW at 12 pm and minimum generation will be 64 GW at 6 am. The grid maximum and minimum demand will be 289178 MW and 250177 MW respectively.

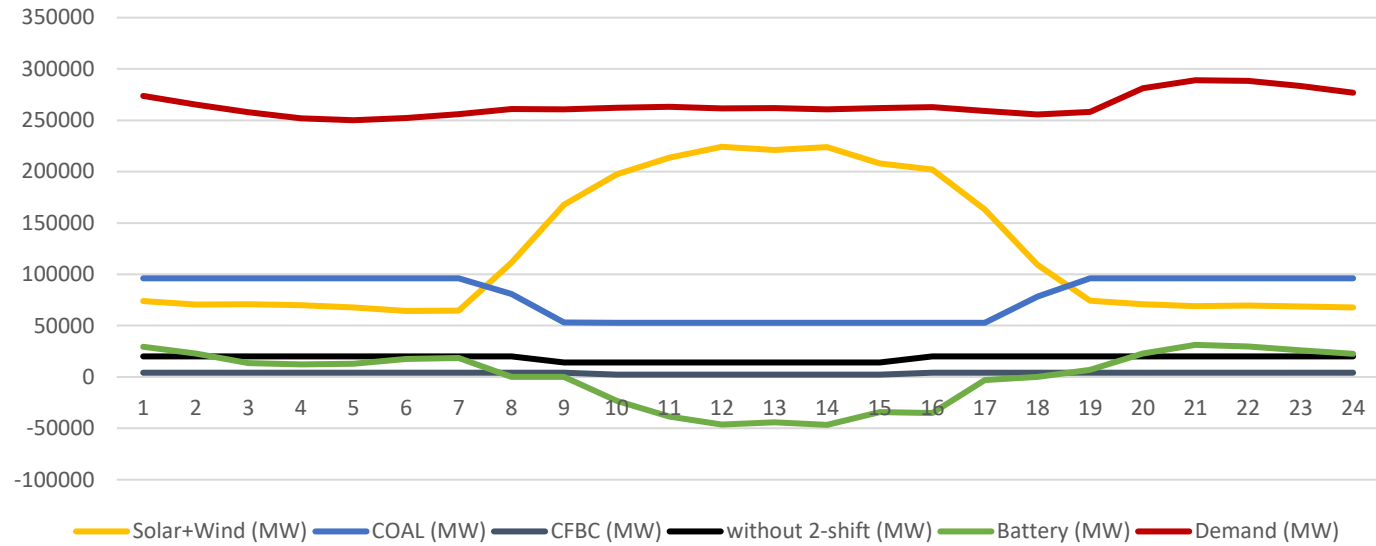


# BALANCING BY 70% FLEXING



	GAS (MW)	HYDRO (MW)	NUCLEAR (MW)	Solar+Wind (MW)	PSP Gen. (MW)	Pump Load (MW)	COAL Gen. (MW)	CFBC Gen. (MW)	Old plants Gen. (MW)	Battery (MW)	Demand (MW)
Max	4616	36657	9474	224061	17985	0	89510	4200	20000	37840	289178
Min	1847	21682	9474	64156	0	-18836	62000	2940	14000	-56425	250177
MTL(%)							69.27	70.00	70.00		

# BALANCING BY 55% FLEXING



	Gas Gen. (MW)	Hydro Gen. (MW)	Nuclear Gen. (MW)	Solar & Wind (MW)	PSP Gen. (MW)	Pump Load (MW)	Coal Gen. (MW)	CFBC Gen. (MW)	Old plants Gen. (MW)	Battery Gen./ Load (MW)	Demand (MW)
Max	4616	36657	9474	224061	17985	0	96008	4200	20000	31342	289178
Min	1847	21682	9474	64156	0	-18836	52880	2310	14000	-46675	250177
MTL(%)							55.08	55.00	70.00		

## CEA REPORT, 2023: FLEXIBILISATION OF COAL FIRED POWER PLANTS - A ROADMAP FOR ACHIEVING 40% TECHNICAL MINIMUM LOAD

Sl. no	Name of Plant	Unit Size MW	Unit No.	Utility	Agencies involved	Remarks
1	Dadri TPS	500	2	NTPC	IGEF, BHEL, NTPC,CEA	Conducted in June 2018. Achieved 40% load (2.5 hrs) & 0.86% ramp up and 0.5% ramp down at 40% load
2	Mouda TPS	500	2	NTPC	BHEL, NTPC,CEA	Conducted in May 2019. Achieved 40% load (1hr.) & 0.85% ramp up and 0.9% ramp down
3	Sagardighi TPS	500	3	WBPDC	BHEL, WBPDC, CEA	Conducted in June 2019. Achieved 40% load (1hr.) & 1.1% ramp up and 0.67% ramp down.
4	Ukai TPS	500	6	GSECL	USAID, BHEL, GSECL, CEA	Conducted in March 2020. Achieved 40% load (2.5 hrs) & 1 ramp up and 1.2 ramp down
5	MRB TPS	525	1	MPL	IGEF, BHEL, CEA	Conducted in July,2021. Achieved 40% load & 0.95% ramp up and 0.38% ramp down. 40% load (1hr.)
6	DSTPS	500	1	DVC	IGEF, BHEL, CEA	Conducted in March,22, 40 % achieved (1.5hrs), less than 1% ramp up and ramp down.
7	Ramagundam TPS	500	7	NTPC	DEA, CEA, NTPC	Successfully conducted 27.02.2023 to 02.03.2023, 40% load (2 hrs)
8	Raichur TPS	210	3	KPCL	DEA,CEA, KPCL	Successfully conducted Successfully conducted 27.02.2023 to 02.03.2023, 40% load (2 hrs)

## POTENTIAL FLEXIBLA POWER IN THE GRID

- The **coal-based capacity has been considered as 276 GW** in the year 2030 as per CEA's report on optimal generation capacity mix for 2029-30.
- About **30 GW very old capacity** and having difficulties in lowering load below 55% may opt for 2-shift operation.
- **Further, CFBC capacity of 6 GW** may continue to operate at 55% due to their technical constraint.

<b>Coal based capacity:</b>	<b>276.00 GW</b>
2-shifting:	30.00 GW (proposed)
CFBC	6.00 GW
40% Flexing capacity:	240.00 GW

# POTENTIAL FLEXIBLE POWER BY 40% FLEXING

## I. Lowering the technical minimum load of 240 GW

80% of available capacity 240 GW:	192 GW
55% generation (Ex-bus):	97.15 GW (APC 8%)
40% generation: (EX-bus):	70 GW (APC 9%)
Additional 27.26 GW flexible power will be available	

Lowering MTL (minimum technical load) of 240 GW capacity from 55% to 40% shall have potential of **27 GW** flexible power in the grid



# POTENTIAL FLEXIBLE POWER BY 2-SHIFTING

## II. 2 shift operation of old coal based power plants

Capacity for 2-shift operation:	30.00 GW
70% of available capacity:	21.00 GW
Flexible power available:	18.90 GW (APC 10%)

In the year, 2030 about 144 units of 30 GW total capacity having age more than 40 years may operate in 2-shift mode.

The capacity of 30 GW have potential to supply 18.90 GW flexible power in the grid by 2-shifting.

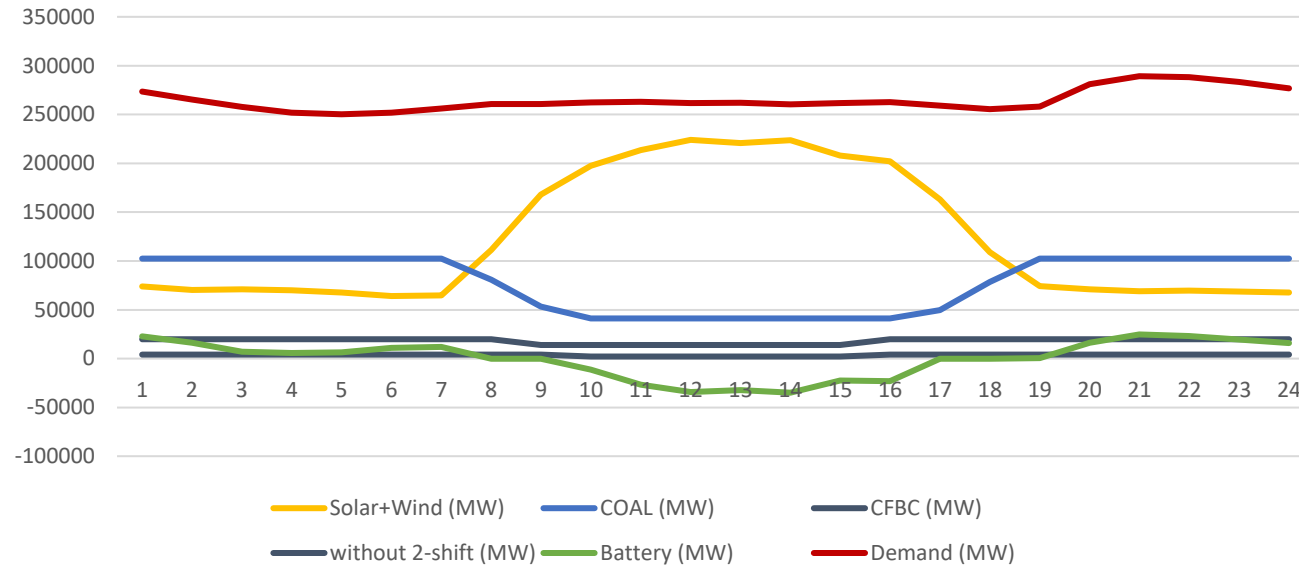
## POTENTIAL FLEXIBLE POWER

**III. Thus coal power plants have the potential of providing 46 GW flexible power by lowering 40% MTL along with 2-shift operation of old TPPs. (27.26 GW from lowering technical minimum load to 40% and 18.90 GW from 2-shifting).**

However, the availability of flexible power in the grid at any instant depends on followings:

- ✓ Grid demand at that time
- ✓ Solar and wind generation at that time
- ✓ Coal capacity synchronised (on bar) at that time
- ✓ Other generation available in the grid at that time and their flexing capability

## BALANCING WITH 40% FLEXING OF COAL GEN.



	Gas Gen. (MW)	Hydro Gen. (MW)	Nuclear Gen. (MW)	Solar & Wind (MW)	PSP Gen. (MW)	Pump Load (MW)	Coal Gen. (MW)	CFBC Gen. (MW)	Old plants Gen. (MW)	Battery Gen./ Load (MW)	Demand (MW)
Max	4616	36657	9474	224061	17985	0	102550	4200	20000	24800	289178
Min	1847	21682	9474	64156	0	18836	41025	2310	14000	-34820	250177
MTL(%)							40.00	55.00	70.00		

## MOST CRITICAL DAY BALANCING

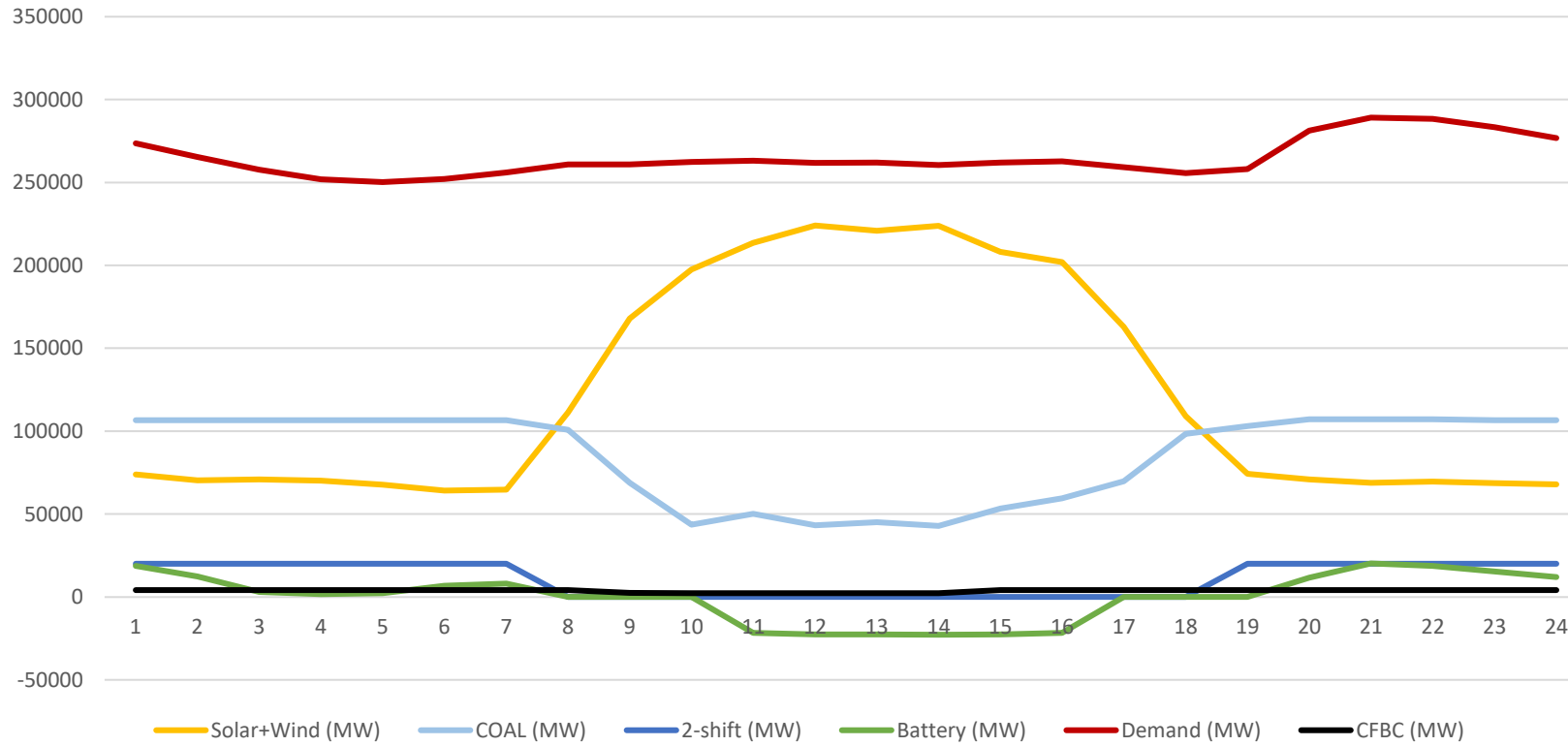
Balancing of most critical day needs maximum flexible power which has been shown in next three slides. Coal power plants are operating at different MTL resulting reduction of BSS capacity with increase MTL.

1. Trying to balance by operating coal plants, CFBC and old TPP at 70% MTL and requirement of Battery storage capacity is found **56425 MW**
2. Trying to balance by operating coal plants, CFBC and old TPP at 55%, 55% and 70% MTL respectively and requirement of Battery storage capacity is found **46675 MW**
3. Trying to balance by operating coal plants, CFBC and old TPP at 40%, 55% and 70% MTL respectively and requirement of Battery storage capacity is found **34820 MW**

## **MOST CRITICAL DAY BALANCING**

- Coal fired power plants- 40% MTL
- CFBC plants - 55% MTL
- Old plants - **2-shift** mode respectively

# MOST CRITICAL DAY



# COAL POWER PLANTS ON CRITICAL DAY

The balancing of most critical day by operating flexible coal plants, CFBC and old TPP at 40% MTL, 55% MTL and 2-shift needs Battery storage capacity of **22679 MW**.

	Gas Gen. (MW)	Hydro Gen. (MW)	Nuclear Gen. (MW)	Solar & Wind (MW)	PSP Gen. (MW)	Pump Load (MW)	Coal Gen. (MW)	CFBC Gen. (MW)	Old plants Gen. (MW)	Battery Gen./Load (MW)	Demand (MW)
Max.	4616	36657	9474	224061	17985	0	107110	4200	20000	20240	289178
Min.	1847	21682	9474	64156	0	-18836	42884	2310	0	-22679	250177
MTL(%)							40.04	55.00	0.00		
Max. Coal Gen. (flexible plants+CFBC+Old TPPs in MW)								131310			
Synchronised coal capacity (MW)								142515			
Coal Capacity needed (MW)								<b>180110</b>			
Ramp up rate (MW/Min.)								479			
Ramp down rate (MW/Min.)								531			
BSS Power (MW)								<b>22679</b>			

## COAL POWER PLANTS ON CRITICAL DAY

	70% MTL	55% MTL	40% MTL	40% MTL + 2-shifting
Max. Coal Gen. (flexible plants+CFBC+Old TPPs)	113710	120208	126750	131310
Synchronised coal capacity (MW)	123085	130072	137106	142515
Coal Capacity needed (MW)	<b>155781</b>	<b>164515</b>	<b>173308</b>	<b>180110</b>
Ramp up rate (MW/Min.)	275	427	479	479
Ramp down rate (MW/Min.)	312	459	459	531
BSS Power (MW)	<b>56425</b>	<b>46675</b>	<b>34820</b>	<b>22679</b>



# Cost Benefit Analysis

Year 2030 capacity (MW)		Capital and O&M Cost till 2070													
Coal Power Plants Capacity	Battery Capacity	Addl. Coal Power Plants							Battery						Total capex + O&M cost for coal plants and battery (Cr.) (8+14)
		Increased capacity (MW)	Increased Capex. (Cr.)	Capex for flexing (Cr.)	Increased Capex for R&M (Cr.)	O&M cost 20 L /MW addl. 20% for flexing (Cr.)	Capex plus O&M (Cr.) (4+5+6+7)	Year 2030 Battery Cost (Cr.)	Year,2040 Battery replacement cost (Cr.)	Year,2050 Battery replacement cost (Cr.)	Year,2060 Battery replacement cost (Cr.)	O&M cost 1% of capex.	capex plus O&M for Battery (Cr.) (9+10+11+12+13)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
70% Flexing	155781	56425	0	0	0	0	0	0	423188	366763	338550	338550	146705	1613755	1613755
55% Flexing	164515	46675	8734	74239	0	30569	69872	174680	350063	303388	280050	280050	121355	1334905	1509585
40% Flexing	173308	34820	17527	148980	10568	61345	168259	389151	261150	226330	208920	208920	90532	995852	1385003
40% Flexing alongwith 2-shifting	180110	22679	24329	206797	23153	85152	233558	548659	170093	147414	136074	136074	58965	648619	1197279

1. Present coal capacity = 211000 MW
2. Rate of kWh = 3.50 Rupees
3. No RE curtailment has been considered
4. Additional BSS capacity considered for peak support which will be charged by coal power generation only
5. About 10% losses in BSS system (power to Battery to power) which will increase operating cost of TPPs
6. Assumptions

### a. Coal power plants

- i). Coal plants life 40 year with intervention of R&M once
- ii). Capital cost for coal power plants R&M cost = 8.5 (Cr./MW)
- iii). R&M cost = 3.5 (Cr./MW)
- iv). Capex for 40% MTL = 30.0 (Cr./Unit)
- v). Capex. for 2-shifting = 100.0 (Cr./Unit)

### b. Battery storage

- i). Battery Life is 10 years
- ii) Capital cost(6 hrs. )

2030	7.5	(Cr./MW)
2040	6.5	(Cr./MW)
2050	6.0	(Cr./MW)
2060	6.0	(Cr./MW)

# COMPENSATION METHODOLOGY

# INCREASE IN FIXED COST

- a) Capital Expenditure (CAPEX):** One-time expenditure to be incurred in retrofitting of various measures to make the plant capable of low load operation.
- i. In case of old units (commissioned before 01.01.2004) which have not upgraded their plant control and instrumentation system previously, capex requirement may be around Rs 30 crores for each unit.
  - ii. An estimated capital investment of around Rs 10 crores will be required for each unit commissioned on or after 01.01.2004 and except units covered under para (iii).
  - iii. As per the OEM few measures are required to be implemented for regular 40% load operation of subcritical units though the same (40%) was demonstrated during PG test. Considering above it is proposed a capital investment of Rs.6 crores may be allowed to the subcritical generating units where investment approval received on or after 01.01.2011
  - iv. Unit will be eligible for increased fixed tariff irrespective of actual operation once measures are implemented and exhibits desired low load operation. Considering five (5) years payback period the impact has been estimated.
  - v. Power plant may be penalized proportionally (Fixed cost) for not exhibiting low load operation at least 85% of time when asked for.

Unit Size (MW)	Recovery period (years)	Capital cost (Rs Cr)	Increased in fixed charge per annum (Rs. Cr.)	Capital cost (Rs Cr)	Increased in fixed charge per annum (Rs. Cr.)
200	5	30	7.65	10	2.55
500	5	30	7.65	10	2.55
660	5	30	7.65	10	2.55
800	5	30	7.65	10	2.55

Unit Size (MW)	Recovery period (years)	Capital cost (Rs Cr)	Increased in fixed charge per annum (Rs. Cr.)
200/250	5	6	1.53
500	5	6	1.53
600	5	6	1.53

# INCREASE IN OPERATIONAL COST

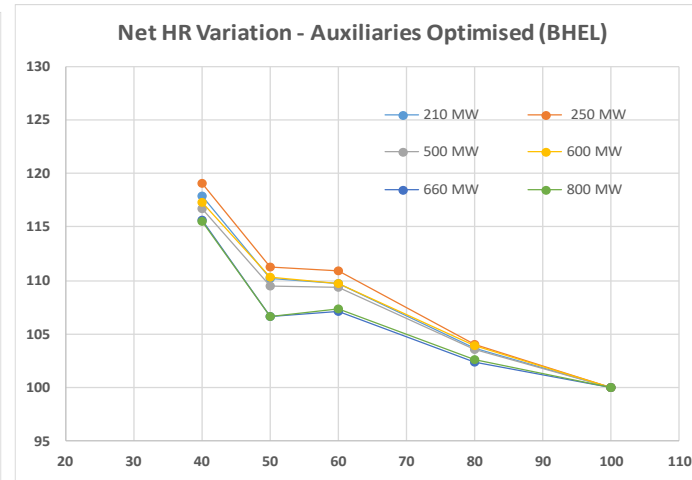
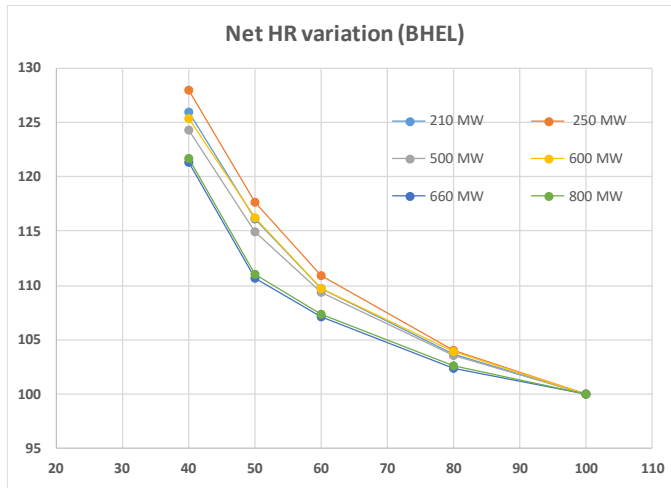
## **Operational Expenditure (OPEX):**

- i. Cost due to increase in Net Heat Rate
- ii. Cost due to Increased Life Consumption (damage costs)
- iii. Cost due to additional oil consumption for additional EFOR

# INCREASE IN OPERATIONAL COST

## i). INCREASE HEAT RATE

### Heat Balance study



After analyzing the HBD report of major OEMs (BHEL/GE/Siemens) and actual test report of low load operation unit size wise NHR degradation is given in table.

The study conducted by CEA indicates the impact of low load operation at 40% on variable part of tariff is around 16% for subcritical units (200/500MW) and around 15% for supercritical units( 660/800MW).

Capacity (MW)	Loading (%)	Net Heat Rate Increase (%)
<b>200</b>	<55 to 50	10.00
	<50 to 45	13.00
	<45 to 40	16.00
<b>500</b>	<55 to 50	10.90
	<50 to 45	13.60
	<45 to 40	16.00
<b>660</b>	<55 to 50	8.70
	<50 to 45	11.90
	<45 to 40	14.60
<b>800</b>	<55 to 50	8.60
	<50 to 45	12.00
	<45 to 40	15.00

# INCREASE IN OPERATIONAL COST

ii). **INCREASED O&M** : Flexible operation also leads to a higher rate of deterioration of plant's components

i. As flexible operation is new in India no reliable data is available regarding actual life consumption or damaged. In other country also no such assessment has been done as cost of flexible power is being kept under ancillary services and price is market based which may be high or less compared to actual.

ii. USAID-Intertek Study: An estimate of the increase in O&M Cost due to reduction in life of components at Ramagundam, Jhajjar TPS of NTPC and Ukai of GSECL. The study was based on the five to ten-year historical cost data of the units (all the costs are at 2017 levels for NTPC & 2018 for GSECL Units). No two units have the same costs due to variation in factors affecting the costs like coal, age of plant, operating practices, operator's skill and design.

iii. Engie Lab estimates: the capital expenditures and additional maintenance result in a 0.3% to 4.3% cost impact versus the total costs of a unit. The absolute non-fuel costs over a 10-year period are approximately But this estimate is based on the current level of flexibilization,(55% and above).

iv. Considering above the increase in annual O&M cost has been proposed as 9%, 14% and 20% at 50%, 45%, 40% loading respectively as increase in O&M costs shall depend on level of flexibilisation.

Capacity (MW)	Loading (%)	O&M cost Increase (%)
<b>200</b>	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00
<b>500</b>	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00
<b>660</b>	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00
<b>800</b>	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00

# INCREASE IN OPERATIONAL COST

## iii). ADDITIONAL OIL CONSUMPTION

Based on the increased EFOR the norms for specific oil consumption and increased compensation may be allowed as per the Table.

S. No.	Specific Oil Consumption	Increased ECR (p/kWh)
1	CERC Norms (Present): 0.5 ml/kWh	2.5
2	At 0.7 ml/kWh (40-50% load)	3.5
3	At 0.8 ml/kWh (30-40% load)	4.0

In addition, due to flexible operation there would be loss of availability on account of increased maintenance requirements and increased EFOR which will make it difficult for the generator to recover full capacity charges.

# TARIFF INCREASE

Likely increase in tariff considering capital investment of Rs. 30 crores, increase of O&M cost, variable cost and EFOR cost

Unit Size (MW)	Loading (%)	Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	Fixed Tariff increase (Paisa/kWh)		EFOR compensation (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)
		Variable Tariff increase (Paisa/kWh)	Variable Tariff increase (Paisa/kWh)	due to increased O&M cost	due to increased capital cost		Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton
<b>200</b>	<55 to 50	13.68	22.57	6.70	7.68	1	29.06	37.95
	<50 to 45	17.78	29.34	10.42	7.68	1	36.88	48.44
	<45 to 40	21.89	36.11	14.88	7.68	1	45.45	59.67
<b>500</b>	<55 to 50	14.66	24.20	4.57	3.07	1	23.30	32.84
	<50 to 45	18.30	30.19	7.11	3.07	1	29.48	41.37
	<45 to 40	21.53	35.52	10.16	3.07	1	35.76	49.75
<b>660</b>	<55 to 50	11.17	18.42	4.12	2.56	1	18.85	26.10
	<50 to 45	15.27	25.20	6.40	2.56	1	25.23	35.16
	<45 to 40	18.74	30.92	9.14	2.56	1	31.44	43.62
<b>800</b>	<55 to 50	10.65	17.57	3.70	1.92	1	17.27	24.19
	<50 to 45	14.86	24.52	5.76	1.92	1	23.54	33.20
	<45 to 40	18.58	30.65	8.23	1.92	1	29.73	41.80



# TARIFF INCREASE

Likely incremental tariff (RS 10 crores capital investment)

Unit Size (MW)	Loading (%)	Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	Fixed Tariff increase (Paisa/kWh)		EFOR compensation (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Proposed total tariff (fixed & variable) increase (Paisa/kWh)
		Variable Tariff increase (Paisa/kWh)	Variable Tariff increase (Paisa/kWh)	Due to increased O&M cost	Due to increased Capital cost		Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	
<b>200</b>	<55 to 50	13.68	22.57	6.70	2.56	1.00	23.94	32.83	28.39
	<50 to 45	17.78	29.34	10.42	2.56	1.00	31.76	43.32	37.54
	<45 to 40	21.89	36.11	14.88	2.56	1.00	40.33	54.55	47.44
<b>500</b>	<55 to 50	14.66	24.20	4.57	1.02	1.00	21.25	30.79	26.02
	<50 to 45	18.30	30.19	7.11	1.02	1.00	27.43	39.32	33.38
	<45 to 40	21.53	35.52	10.16	1.02	1.00	33.71	47.70	40.71
<b>660</b>	<55 to 50	11.17	18.42	4.12	0.85	1.00	17.14	24.39	20.77
	<50 to 45	15.27	25.20	6.40	0.85	1.00	23.52	33.45	28.49
	<45 to 40	18.74	30.92	9.14	0.85	1.00	29.73	41.91	35.82
<b>800</b>	<55 to 50	10.65	17.57	3.70	0.64	1.00	15.99	22.91	19.45
	<50 to 45	14.86	24.52	5.76	0.64	1.00	22.26	31.92	27.09
	<45 to 40	18.58	30.65	8.23	0.64	1.00	28.45	40.52	34.49

# TARIFF INCREASE

Likely Incremental Tariff for units where investment approval received on or after 01.01.2011 (Rs 6 crores capital investment)

Unit Size (MW)	Loading (%)	Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	Fixed Tariff increase (Paisa/kWh)		EFOR compensation (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Proposed total tariff (fixed & variable) increase (Paisa/kWh)
		Variable Tariff increase (Paisa/kWh)	Variable Tariff increase (Paisa/kWh)	Due to increased O&M cost	Due to increased Capital cost		Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	
<b>200</b>	<55 to 50	13.68	22.57	6.70	1.54	1	22.92	31.81	27.37
	<50 to 45	17.78	29.34	10.42	1.54	1	30.74	42.30	36.52
	<45 to 40	21.89	36.11	14.88	1.54	1	39.31	53.53	46.42
<b>500</b>	<55 to 50	14.66	24.20	4.57	0.61	1	20.84	30.38	25.61
	<50 to 45	18.30	30.19	7.11	0.61	1	27.02	38.91	32.97
	<45 to 40	21.53	35.52	10.16	0.61	1	33.30	47.29	40.30
<b>660</b>	<55 to 50	11.17	18.42	4.12	0	1	16.29	23.54	19.92
	<50 to 45	15.27	25.20	6.40	0	1	22.67	32.60	27.64
	<45 to 40	18.74	30.92	9.14	0	1	28.88	41.06	34.97
<b>800</b>	<55 to 50	10.65	17.57	3.70	0	1	15.35	22.27	18.81
	<50 to 45	14.86	24.52	5.76	0	1	21.62	31.28	26.45
	<45 to 40	18.58	30.65	8.23	0	1	27.81	39.88	33.85

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## ASSUMPTIONS

1. General:
  - i. Average PLF: 60%,
  - ii. PAF: 85%,
  - iii. Debt to equity ratio: 70:30,
  - iv. Return on equity: 15.5%,
  - v. Interest on loan: 10%,
  - vi. Depreciation rate: 5.28%,
  - vii. Specific oil consumption: 0.5 ml/kWh,
  - viii. Price of oil: Rs 35/lt,
  - ix. GCV of oil: 10000 kcal/lt,
  - x. GCV of Coal: 3800 kcal/kg.
  - xi. Landing cost of coal
    - a) Rs. 2000.00 per ton (estimated average cost of coal at pithead plants)
    - b) Rs. 3300.00 per ton (estimated average cost of coal at non-pithead plants)
  - xii. Weighted average cost of capital for annuity calculations : 10%
2. Unit size 200 MW O&M Cost Rs 36.56 lakh/MW, Heat rate 2430 kcal/kWh.
3. Unit size 500 MW O&M Cost Rs 24.97 lakh/MW, Heat rate 2390 kcal/kWh
4. Unit size 660 MW O&M Cost Rs 22.47 lakh/MW, Heat rate 2280 kcal/kWh.
5. Unit size 800 MW O&M Cost Rs 20.22 lakh/MW, Heat rate 2200 kcal/kWh

## **REGULATION ON TECHNICAL MINIMUM LOAD**

CEA has also notified a Regulation regarding Flexible operation of coal based Thermal Power Generating Units on 30.1.2023.

1. The 55% minimum load and 2% ramp rate operating requirement shall have to be implemented by all thermal generating units (Central/State/Pvt) within one year of the notification of the regulation.
2. Power plants shall implement measures, if required, as per the phasing plans by the respective power plants owners to operate thermal unit at 40% minimum load with following ramp rate:
  - 1% per minute - 40% to 55% and 55% to 40% load
  - 2% per minute - 55% to 70% and 70% to 55% load
  - 3% per minute - 70% to 100% and 100% to 70% load



Thank You

# CEA REPORT, 2023: FLEXIBILISATION OF COAL FIRED POWER PLANTS - A ROADMAP FOR ACHIEVING 40% TECHNICAL MINIMUM LOAD

## TWO-SHIFT OPERATION

**Category 1 - Operate during Peak Demand period:** These plants will have to deliver the peak loads with full available capacity during the peak hours (about 6 to 7 hrs.), with increased demand and reduced or no solar.

**Category 2 - Shutting down during Peak Solar Generation Period:** In this category plants will be under shut down during of solar peak generation period (10 am to 4 pm or 10 am to 5 pm) and units will generate in the evening peak with hot startup.

### **Case study:**

- i) CESC Limited is operating the 2x67.5MW, BHEL make units of Southern Replacement TPS, commissioned in 1990 and 1991 respectively, in single/two shift mode for last 5 to 6 years, depending on merit order and system/network requirement. Running hours varies from 6 to 18 hours per day and type of start is hot or warm or cold depending on the number of hours of shutdown. No retrofitting (hardware/software) was done for single/two shift operation.
- ii) Another example of two-shift operation of Tamil Nadu where thermal power plants are operating from 5 pm to 11 am, daily hot startup.

Generation Dispatch on Max VRE (Solar+wind) day in July 2029

Hour	GAS (MW)	HYDRO (MW)	NUCLEAR (MW)	Solar+Wind (MW)	PSP Generation (MW)	Pump Load (MW)	COAL (MW)	CFBC (MW)	without 2-shift (MW)	Battery (MW)	Demand (MW)	RE curtailment (MWh)	Ramp rate (MW/Min.)
1	4540	31912	9474	73971	4234	0	89510	4200	20000	35814	273,655	0	0
2	4531	31954	9474	70406	5808	0	89510	4200	20000	29448	265,331	0	0
3	4531	31878	9474	70995	7030	0	89510	4200	20000	20093	257,712	0	0
4	4531	31893	9474	70062	3390	0	89510	4200	20000	18,892	251,952	0	0
5	4531	31891	9474	67689	3501	0	89510	4200	20000	19,382	250,177	0	0
6	4533	31815	9474	64156	4507	0	89510	4200	20000	23,908	252,102	0	0
7	4533	32183	9474	64769	6256	0	89510	4200	20000	25,137	256,062	0	-146
8	4531	30599	9474	111352	0	0	80742	4200	20000	0	260,898	0	-312
9	1847	28979	9474	167932	0	-18836	62000	4200	14000	-8824	260,771	0	0
10	1847	26383	9474	197522	0	-18836	62000	2940	14000	-33047	262,282	0	0
11	1847	26318	9474	213579	0	-18836	62000	2940	14000	-48229	263,093	0	0
12	1847	22193	9474	224061	0	-18836	62000	2940	14000	-55969	261,710	0	0
13	1847	23622	9474	220923	0	-18836	62000	2940	14000	-53940	262,029	0	0
14	1847	21682	9474	223840	0	-18836	62000	2940	14000	-56425	260,521	0	0
15	1847	26339	9474	208135	0	-18836	62000	2940	14000	-43964	261,935	0	0
16	1847	26312	9474	202000	0	-18836	62000	4200	20000	-44227	262,770	0	0
17	1847	29771	9474	162954	0	-18836	62000	4200	20000	-12268	259,141	0	275
18	4531	30091	9474	109130	0	-220	78475	4200	20000	0	255,681	0	184
19	4616	32276	9474	74314	10190	0	89510	4200	20000	13532	258,113	0	0
20	4616	35385	9474	70872	17985	0	89510	4200	20000	29227	281,270	0	0
21	4616	36657	9474	68896	17985	0	89510	4200	20000	37840	289,178	0	0
22	4616	36602	9474	69600	17985	0	89510	4200	20000	36269	288,256	0	0
23	4616	36431	9474	68610	17985	0	89510	4200	20000	32553	283,379	0	0
24	4616	34097	9474	67873	17985	0	89510	4200	20000	29045	276,800	0	0
										-5753.89		0	
Max	4616	36657	9474	224061	17985	0	89510	4200	20000	37840	289178		275
Min	1847	21682	9474	64156	0	-18836	62000	2940	14000	-56425	250177	0	-312
MTL(%)							69.27	70.00	70.00				



Generation Dispatch on Max VRE (Solar+wind) day in July 2029

Hour	GAS (MW)	HYDRO (MW)	NUCLEAR (MW)	Solar+Wind (MW)	PSP Generation (MW)	Pump Load (MW)	COAL (MW)	CFBC (MW)	without 2-shift (MW)	Battery (MW)	Demand (MW)	RE curtailment (MWh)	Ramp rate (MW/Min.)
1	4540	31912	9474	73971	4234	0	96008	4200	20000	29316	273,655	0	0
2	4531	31954	9474	70406	5808	0	96008	4200	20000	22950	265,331	0	0
3	4531	31878	9474	70995	7030	0	96008	4200	20000	13595	257,712	0	0
4	4531	31893	9474	70062	3390	0	96008	4200	20000	12394	251,952	0	0
5	4531	31891	9474	67689	3501	0	96008	4200	20000	12884	250,177	0	0
6	4533	31815	9474	64156	4507	0	96008	4200	20000	17410	252,102	0	0
7	4533	32183	9474	64769	6256	0	96008	4200	20000	18639	256,062	0	-254
8	4531	30599	9474	111352	0	0	80742	4200	20000	0	260,898	0	-459
9	1847	28979	9474	167932	0	-18836	53176	4200	14000	0	260,771	0	-5
10	1847	26383	9474	197522	0	-18836	52880	2310	14000	-23297	262,282	0	0
11	1847	26318	9474	213579	0	-18836	52880	2310	14000	-38479	263,093	0	0
12	1847	22193	9474	224061	0	-18836	52880	2310	14000	-46219	261,710	0	0
13	1847	23622	9474	220923	0	-18836	52880	2310	14000	-44190	262,029	0	0
14	1847	21682	9474	223840	0	-18836	52880	2310	14000	-46675	260,521	0	0
15	1847	26339	9474	208135	0	-18836	52880	2310	14000	-34214	261,935	0	0
16	1847	26312	9474	202000	0	-18836	52880	4200	20000	-35107	262,770	0	0
17	1847	29771	9474	162954	0	-18836	52880	4200	20000	-3148	259,141	0	427
18	4531	30091	9474	109130	0	-220	78475	4200	20000	0	255,681	0	292
19	4616	32276	9474	74314	10190	0	96008	4200	20000	7034	258,113	0	0
20	4616	35385	9474	70872	17985	0	96008	4200	20000	22729	281,270	0	0
21	4616	36657	9474	68896	17985	0	96008	4200	20000	31342	289,178	0	0
22	4616	36602	9474	69600	17985	0	96008	4200	20000	29771	288,256	0	0
23	4616	36431	9474	68610	17985	0	96008	4200	20000	26055	283,379	0	0
24	4616	34097	9474	67873	17985	0	96008	4200	20000	22547	276,800	0	0
										-4663.41		0	
Max	4616	36657	9474	224061	17985	0	96008	4200	20000	31342	289178		427
Min	1847	21682	9474	64156	0	-18836	52880	2310	14000	-46675	250177	0	-459
MTL(%)							55.08	55.00	70.00				

Generation Dispatch on Max VRE (Solar+wind) day in July 2029

Hour	GAS (MW)	HYDRO (MW)	NUCLEAR (MW)	Solar+Wind (MW)	PSP Generation (MW)	Pump Load (MW)	COAL (MW)	CFBC (MW)	without 2-shift (MW)	Battery (MW)	Demand (MW)	RE curtailment (MWh)	Ramp rate (MW/Min.)
1	4540	31912	9474	73971	4234	0	102550	4200	20000	22774	273,655	0	0
2	4531	31954	9474	70406	5808	0	102550	4200	20000	16408	265,331	0	0
3	4531	31878	9474	70995	7030	0	102550	4200	20000	7053	257,712	0	0
4	4531	31893	9474	70062	3390	0	102550	4200	20000	5852	251,952	0	0
5	4531	31891	9474	67689	3501	0	102550	4200	20000	6342	250,177	0	0
6	4533	31815	9474	64156	4507	0	102550	4200	20000	10868	252,102	0	0
7	4533	32183	9474	64769	6256	0	102550	4200	20000	12097	256,062	0	-363
8	4531	30599	9474	111352	0	0	80742	4200	20000	0	260,898	0	-459
9	1847	28979	9474	167932	0	-18836	53176	4200	14000	0	260,771	0	-203
10	1847	26383	9474	197522	0	-18836	41025	2310	14000	-11442	262,282	0	0
11	1847	26318	9474	213579	0	-18836	41025	2310	14000	-26624	263,093	0	0
12	1847	22193	9474	224061	0	-18836	41025	2310	14000	-34364	261,710	0	0
13	1847	23622	9474	220923	0	-18836	41025	2310	14000	-32335	262,029	0	0
14	1847	21682	9474	223840	0	-18836	41025	2310	14000	-34820	260,521	0	0
15	1847	26339	9474	208135	0	-18836	41025	2310	14000	-22359	261,935	0	0
16	1847	26312	9474	202000	0	-18836	41025	4200	20000	-23252	262,770	0	145
17	1847	29771	9474	162954	0	-18836	49732	4200	20000	0	259,141	0	479
18	4531	30091	9474	109130	0	-220	78475	4200	20000	0	255,681	0	401
19	4616	32276	9474	74314	10190	0	102550	4200	20000	492	258,113	0	0
20	4616	35385	9474	70872	17985	0	102550	4200	20000	16187	281,270	0	0
21	4616	36657	9474	68896	17985	0	102550	4200	20000	24800	289,178	0	0
22	4616	36602	9474	69600	17985	0	102550	4200	20000	23229	288,256	0	0
23	4616	36431	9474	68610	17985	0	102550	4200	20000	19513	283,379	0	0
24	4616	34097	9474	67873	17985	0	102550	4200	20000	16005	276,800	0	0
											-3576.19	0	
Max	4616	36657	9474	224061	17985	0	102550	4200	20000	24800	289178		479
Min	1847	21682	9474	64156	0	18836	41025	2310	14000	-34820	250177	0	-459
MTL(%)							40.00	55.00	70.00				

Generation Dispatch on Max VRE (Solar+wind) day in July 2029

Hour	GAS (MW)	HYDRO (MW)	NUCLEAR (MW)	Solar+Wind (MW)	PSP Generation (MW)	Pump Load (MW)	COAL (MW)	CFBC (MW)	2-shift (MW)	Battery (MW)	Demand (MW)	RE curtailment (MWh)	Ramp rate (MW/Min.)
1	4540	31912	9474	73971	4234	0	106610	4200	20000	18714	273,655	0	0
2	4531	31954	9474	70406	5808	0	106610	4200	20000	12348	265,331	0	0
3	4531	31878	9474	70995	7030	0	106610	4200	20000	2993	257,712	0	0
4	4531	31893	9474	70062	3390	0	106610	4200	20000	1792	251,952	0	0
5	4531	31891	9474	67689	3501	0	106610	4200	20000	2282	250,177	0	0
6	4533	31815	9474	64156	4507	0	106610	4200	20000	6808	252,102	0	0
7	4533	32183	9474	64769	6256	0	106610	4200	20000	8037	256,062	0	-98
8	4531	30599	9474	111352	0	0	100742	4200	0	0	260,898	0	-531
9	1847	28979	9474	167932	0	-18836	68891	2485	0	0	260,771	0	-422
10	1847	26383	9474	197522	0	-18836	43583	2310	0	0	262,282	0	108
11	1847	26318	9474	213579	0	-18836	50090	2310	0	-21689	263,093	0	-116
12	1847	22193	9474	224061	0	-18836	43151	2310	0	-22489	261,710	0	34
13	1847	23622	9474	220923	0	-18836	45179	2310	0	-22489	262,029	0	-38
14	1847	21682	9474	223840	0	-18836	42884	2310	0	-22679	260,521	0	173
15	1847	26339	9474	208135	0	-18836	53265	4200	0	-22489	261,935	0	103
16	1847	26312	9474	202000	0	-18836	59463	4200	0	-21690	262,770	0	171
17	1847	29771	9474	162954	0	-18836	69732	4200	0	0	259,141	0	479
18	4531	30091	9474	109130	0	-220	98475	4200	0	0	255,681	0	76
19	4616	32276	9474	74314	10190	0	103042	4200	20000	0	258,113	0	68
20	4616	35385	9474	70872	17985	0	107110	4200	20000	11627	281,270	0	0
21	4616	36657	9474	68896	17985	0	107110	4200	20000	20240	289,178	0	0
22	4616	36602	9474	69600	17985	0	107110	4200	20000	18669	288,256	0	-8
23	4616	36431	9474	68610	17985	0	106610	4200	20000	15453	283,379	0	0
24	4616	34097	9474	67873	17985	0	106610	4200	20000	11945	276,800	0	0

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Max.	4616	36657	9474	224061	17985	0	107110	4200	20000	20240	289178	0	479
Min.	1847	21682	9474	64156	0	-18836	42884	2310	0	-22679	250177	0	-531

MTL(%)							40.04	55.00	0.00				
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