Extent of Flexibilisation of Thermal Generating Unit in the year,2021-22

B.C.Mallick, Chief Engineer, CEA

Need for Flexibilisation

For balancing the grid (Load generation balance):

1. Off-peak and peak demand variation
2. Sudden increase of load in the grid
3. loss of grid connected load
4. Loss of generation in the system
5. Addition or reduction of RE generation

Installed capacity

S.No.	Installed Cap. (GW)	2017-18	2021-22
1	Hydro	45	51
2	Coal +Lignite	197	217
3	Gas	25	26
4	Nuclear	6.7	10
5	Solar	22	100
6	Wind	34	60
7	Biomass	9	10
8	Small Hydro	4	5
	Total	344	479

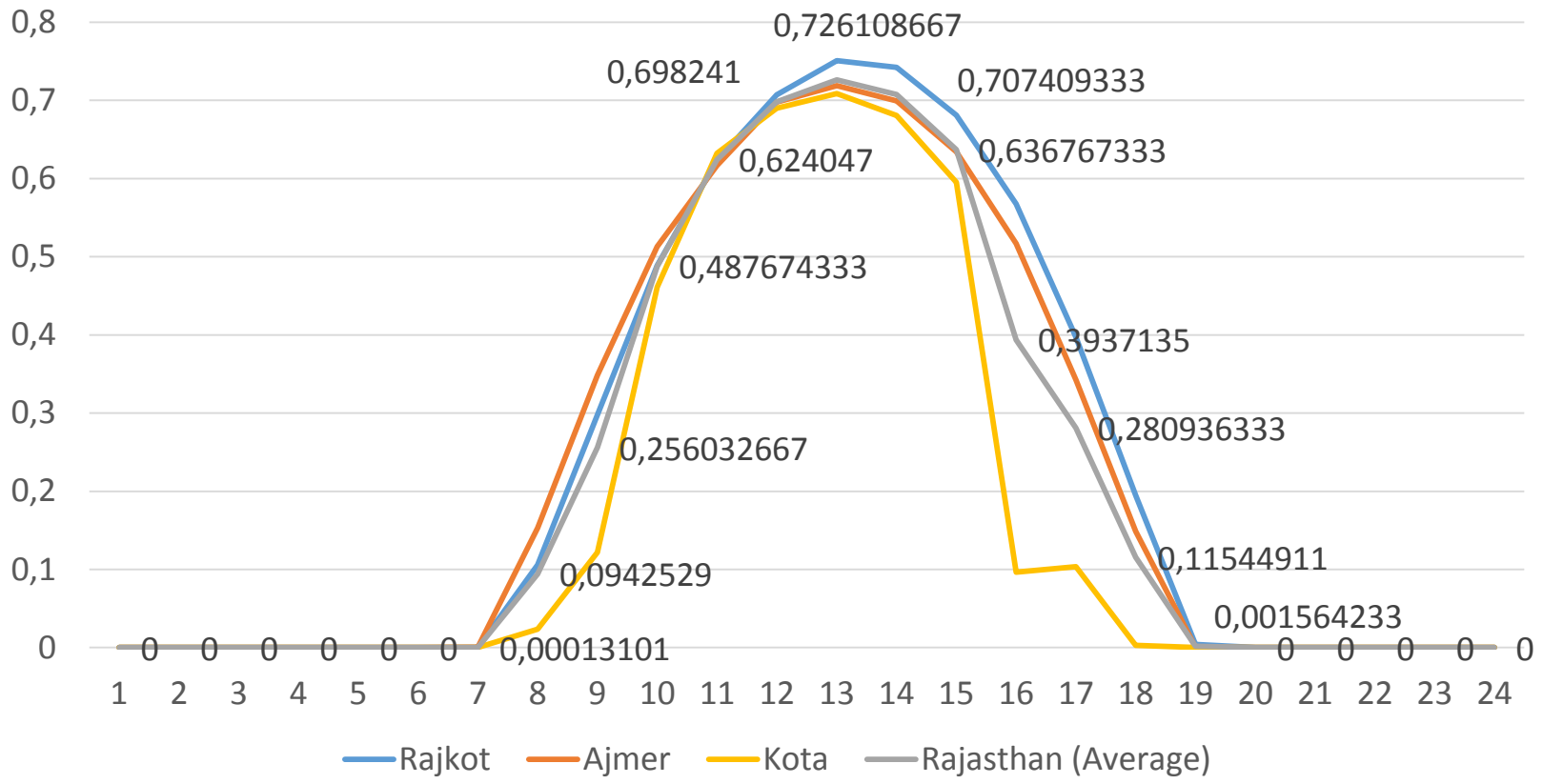
Collection of Data

- **Demand**: The national electricity demand for the year 2021-22 has been collected from 19th EPS.
- **Solar, Wind, Nuclear & Hydro:** The previous three-year generation (years 2014-15 to 2016-17) is averaged on hourly basis for the complete year. The average is then scaled based on the installed capacity in 2021-22.
- **Gas:** The generation data from gas in the year 16-17 has been scaled based on installed capacity of gas in 2021-22.
- **Small Hydro, Biomass:** Since no reliable data is available for these small renewable sources, straight-line assumptions has been used. Small Hydro is taken as 1000 MW and Biomass as 2000 MW as constant values.
- **Coal:** Generation from coal- fired (coal + lignite) is a derived quantity and is calculated after subtracting all other types of generation (hourly generation) from anticipated hourly demand for the year 2021-22.

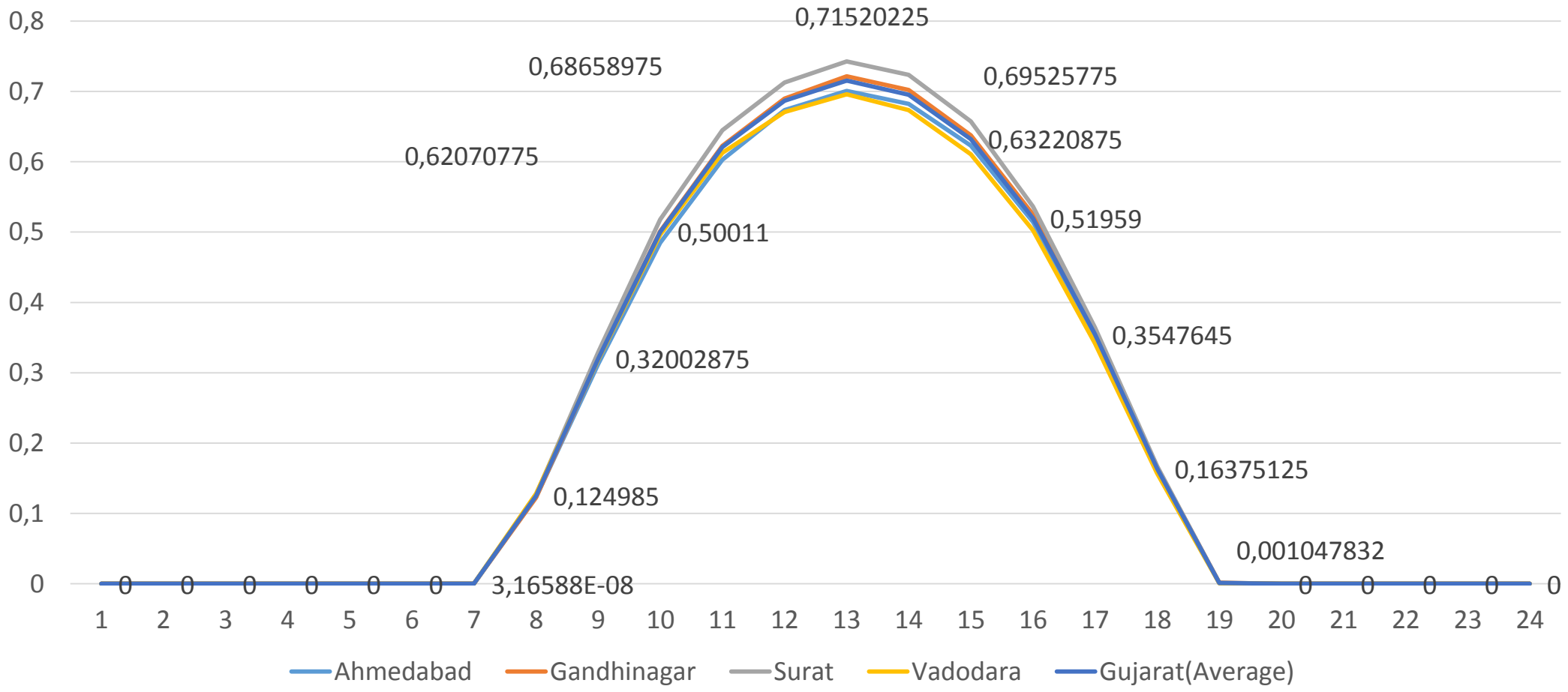
Hourly Demand and Generation in 2021-22

- **Monthly Peak Demand day**: the demand, RE generation, minimum load of thermal plant, ramp rate on monthly peak demand days have been analysed.
- **Monthly Maximum RES Generation day**: the demand, RE generation, minimum load of thermal plant, ramp rate on monthly maximum RES generation days have been analysed.
- **Max. RES generation:** It is found from the analysis that maximum RE generation of 107798 MW will be available on **25th June**, 2021.

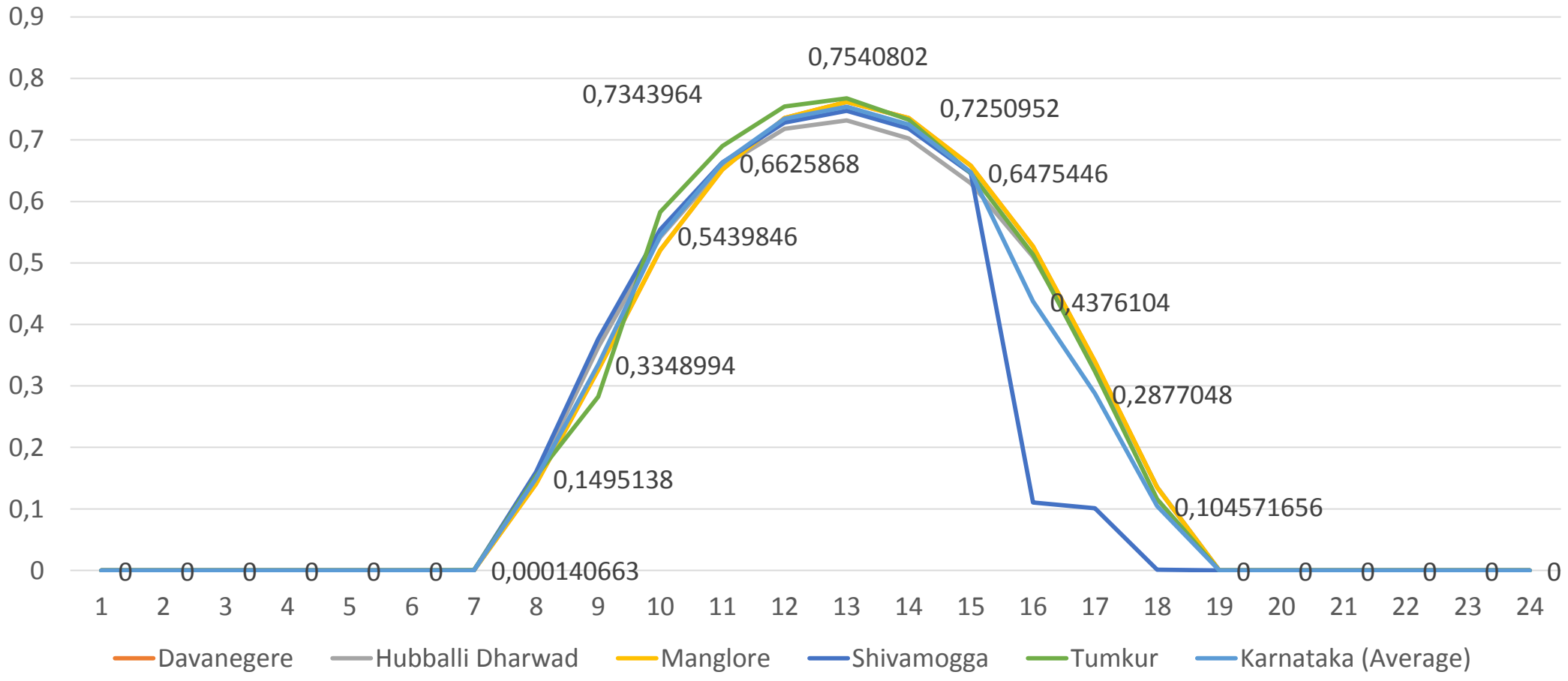
Normalised Solar Generation Profile of Rajasthan



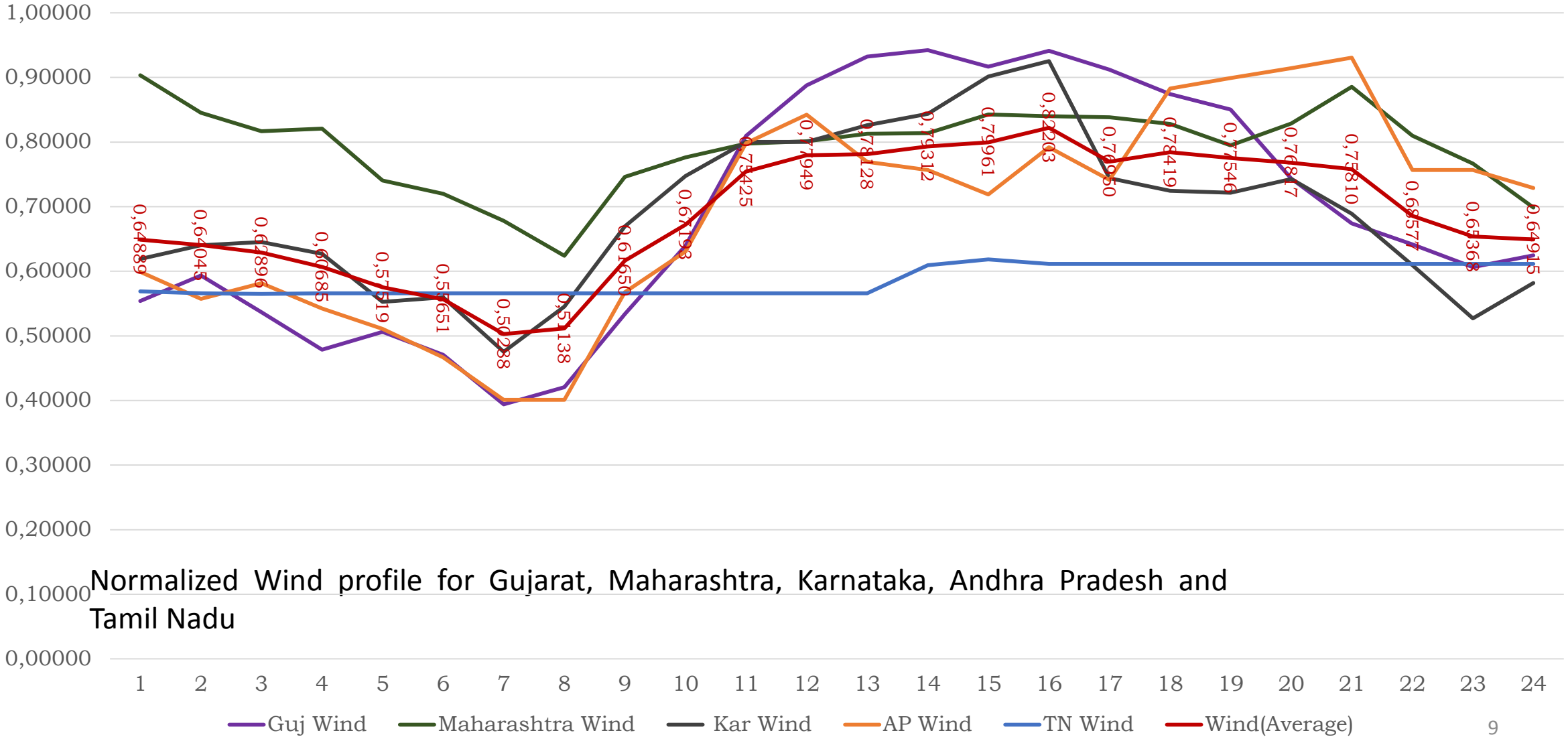
Normalised Solar Profile of Gujrat



Normalised Solar Profile of Karnataka

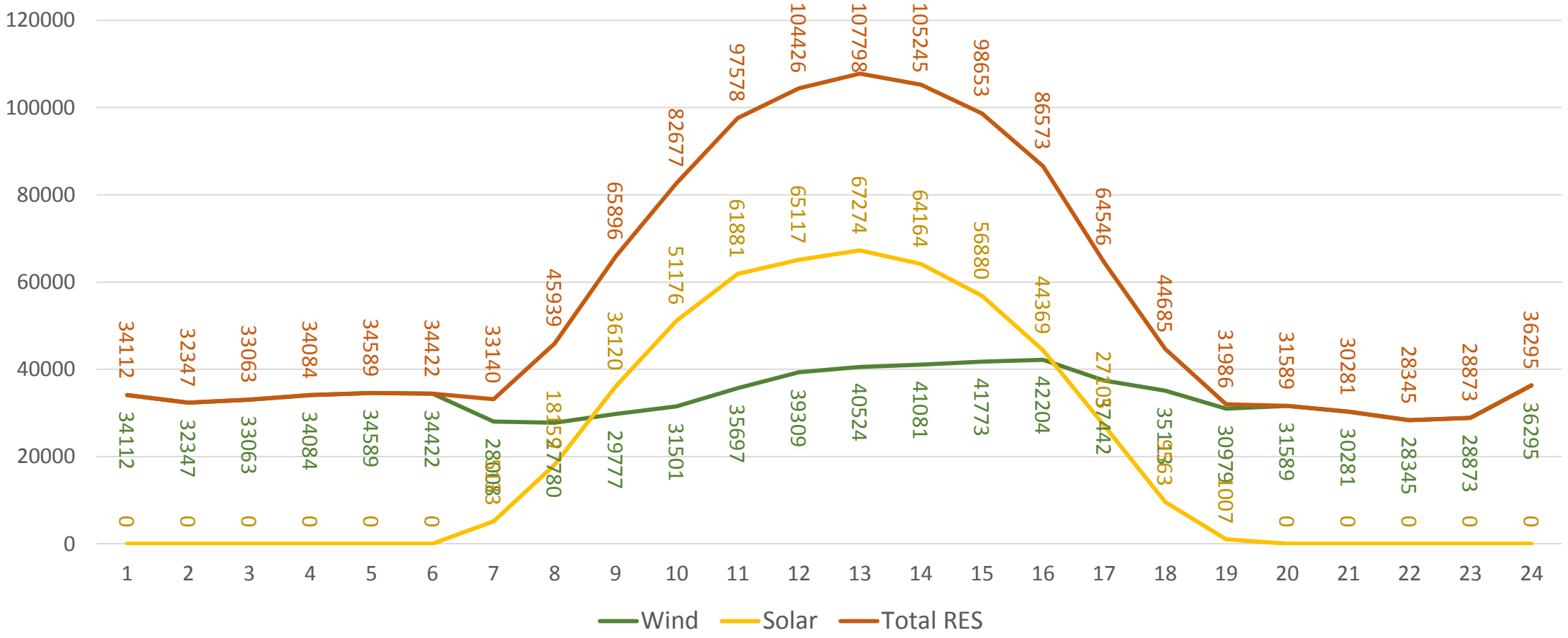


Normalised Wind Generation profile

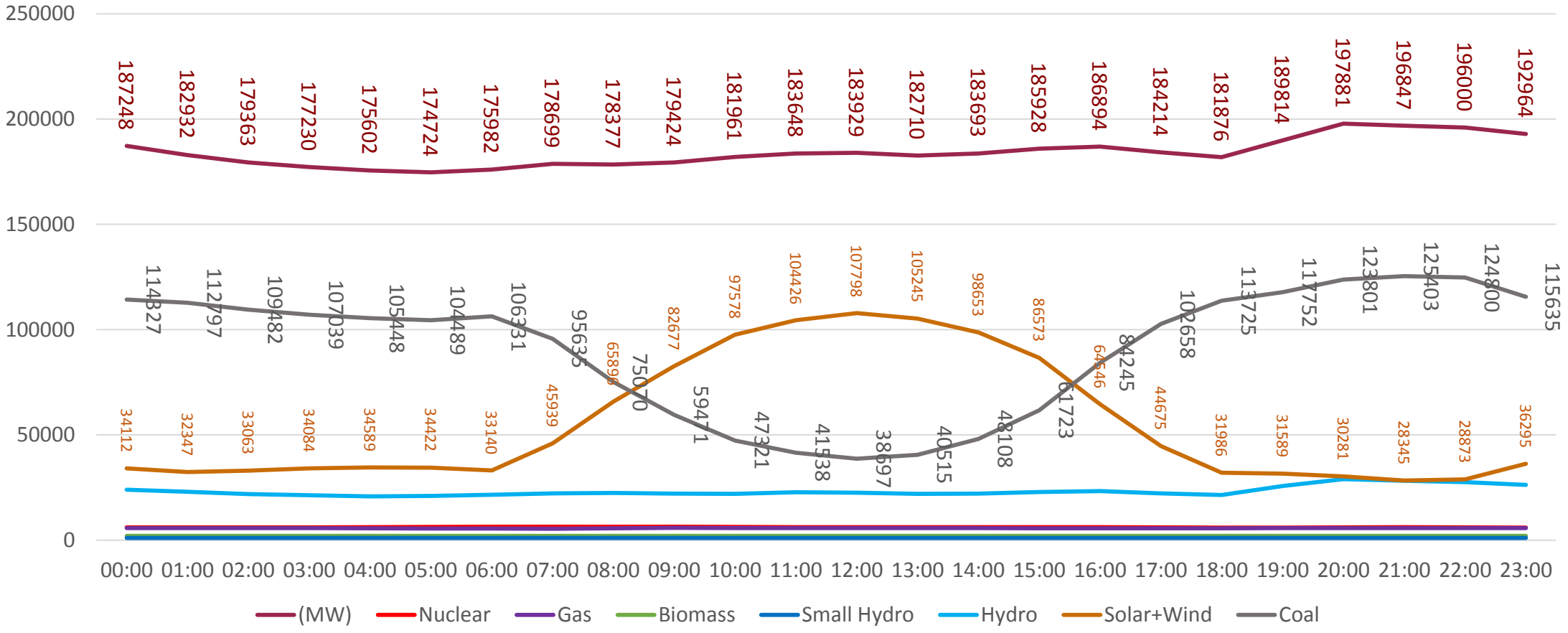


Normalized Wind profile for Gujarat, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu

Maximum Solar & Wind generation predicted on 25th June,2021



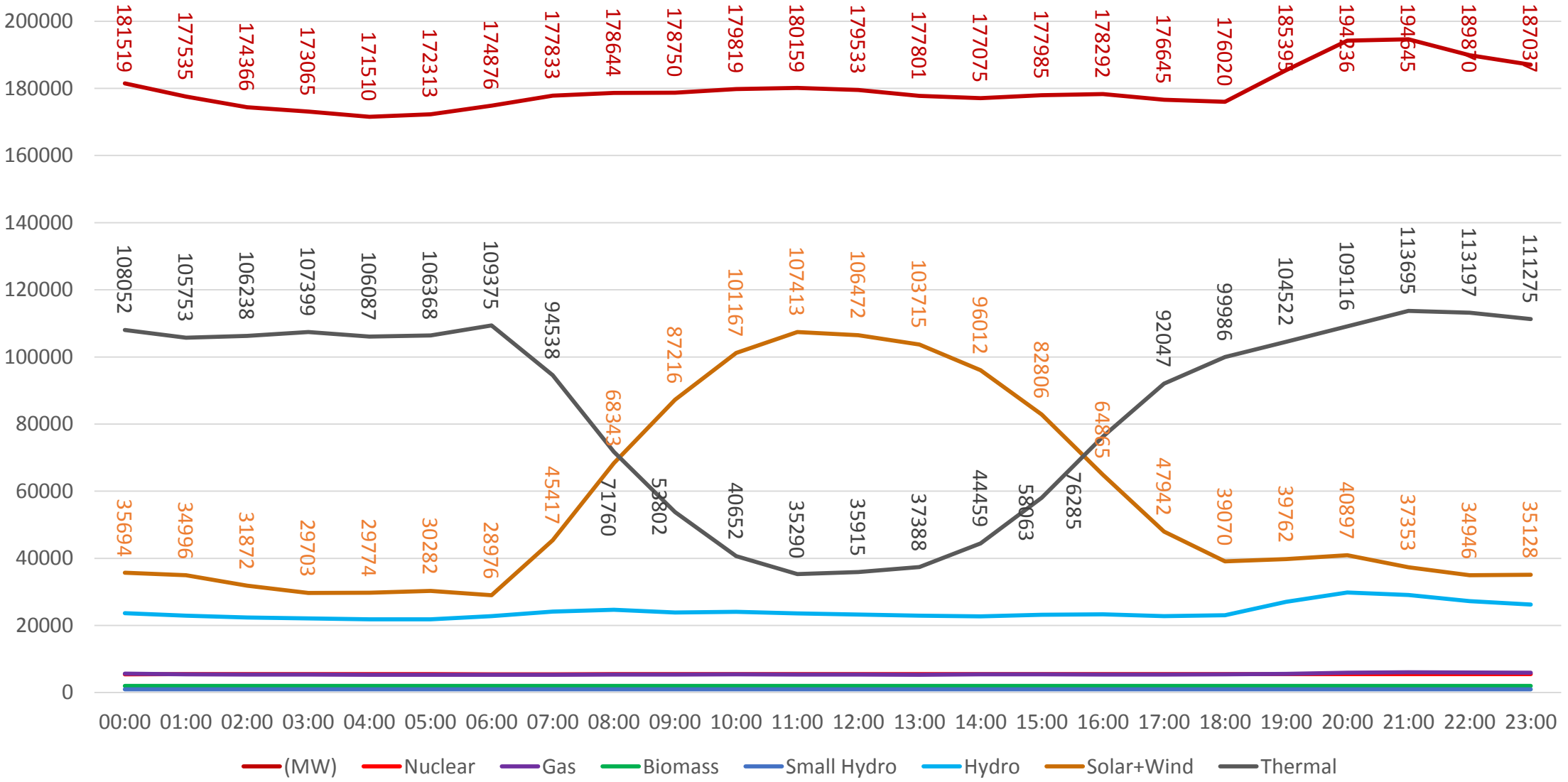
Demand & Generation on the day 25th June,2021



Demand & Generation on the day 25th June,2021

		Demand	Generation (MW)							Thermal capacity	Ramp Rate	Min. Load
Month/Day	Hour	(MW)	Nuclear	Gas	Biomass	Small Hydro	Hydro	Solar+Wind	Coal	(MW)	Mw/min.	Operation (%)
25-Jun	00:00	187248	6090	5710	2000	1000	24008	34112	114327			
25-Jun	01:00	182932	6092	5713	2000	1000	22984	32347	112797		-26	
25-Jun	02:00	179363	6103	5778	2000	1000	21938	33063	109482		-55	
25-Jun	03:00	177230	6121	5699	2000	1000	21287	34084	107039		-41	
25-Jun	04:00	175602	6134	5609	2000	1000	20823	34589	105448		-27	
25-Jun	05:00	174724	6288	5550	2000	1000	20975	34422	104489		-16	
25-Jun	06:00	175982	6437	5517	2000	1000	21557	33140	106331		31	
25-Jun	07:00	178699	6445	5466	2000	1000	22213	45939	95635		-178	
25-Jun	08:00	178377	6435	5585	2000	1000	22390	65896	75070		-343	
25-Jun	09:00	179424	6394	5819	2000	1000	22062	82677	59471		-260	
25-Jun	10:00	181961	6324	5774	2000	1000	21964	97578	47321		-203	
25-Jun	11:00	183648	6179	5730	2000	1000	22774	104426	41538		-96	
25-Jun	12:00	183929	6131	5764	2000	1000	22539	107798	38697		-47	
25-Jun	13:00	182710	6135	5778	2000	1000	22037	105245	40515		30	
25-Jun	14:00	183693	6147	5728	2000	1000	22058	98653	48108		127	
25-Jun	15:00	185928	6144	5615	2000	1000	22874	86573	61723		227	
25-Jun	16:00	186894	6151	5645	2000	1000	23307	64546	84245		375	
25-Jun	17:00	184214	6031	5659	2000	1000	22190	44675	102658		307	
25-Jun	18:00	181876	5997	5678	2000	1000	21489	31986	113725		184	
25-Jun	19:00	189814	6005	5718	2000	1000	25750	31589	117752		67	
25-Jun	20:00	197881	6050	5773	2000	1000	28975	30281	123801		101	
25-Jun	21:00	196847	6192	5744	2000	1000	28164	28345	125403	149824	27	
25-Jun	22:00	196000	6045	5773	2000	1000	27509	28873	124800		-10	
25-Jun	23:00	192964	5995	5785	2000	1000	26254	36295	115635		-153	
Maximum		**197881**	**6445**	**5819**	**2000**	**1000**	**28975**		**125403**	**149824**	**375**	
Minimum		**174724**	**5995**	**5466**	**2000**	**1000**	**20823**		**38697**		**-343**	28.38
Average		**184081**	**6169**	**5692**	**2000**	**1000**	**23255**		**90667**			

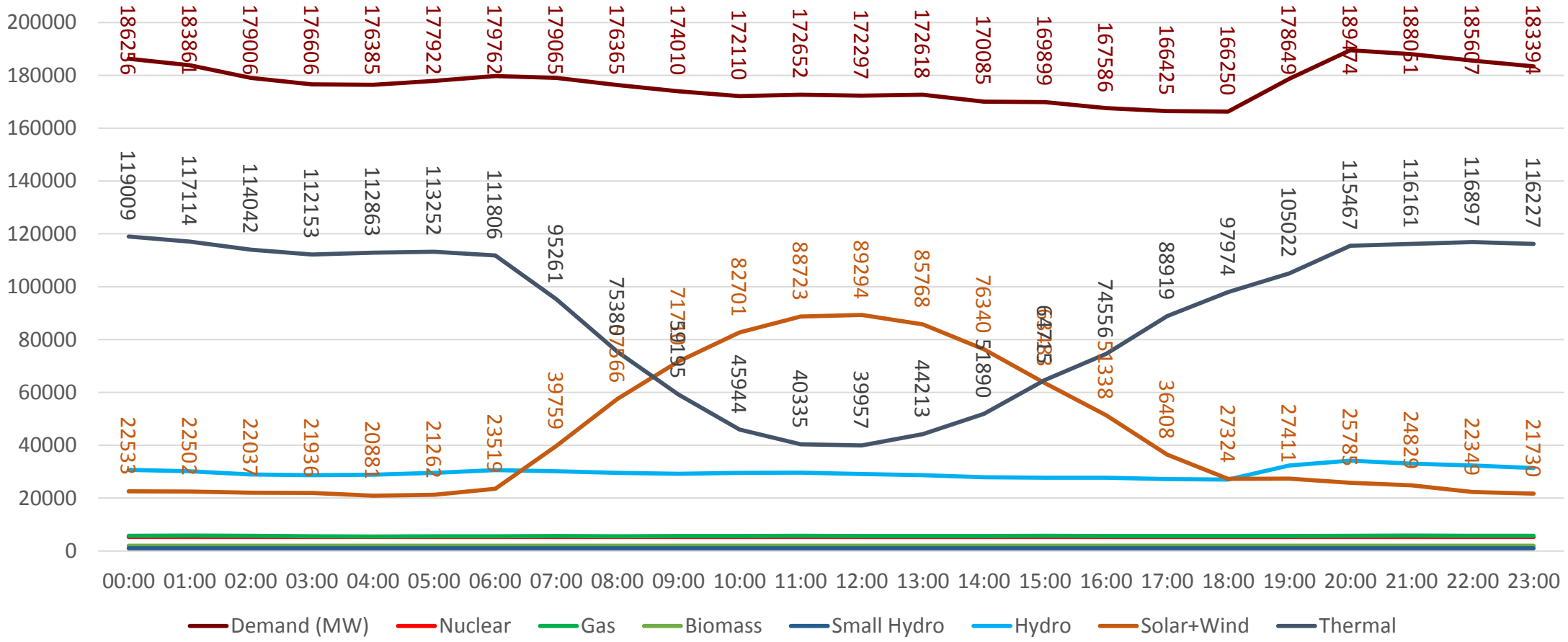
Demand & Generation on the day 19th July,2021



Demand & Generation on the day 19th July,2021

Month/Day	Hour	Demand (MW)	Generation (MW)							Thermal Capacity (MW)	Ramp Rate MW/min.	Min. Load Operation(%)
			Nuclear	Gas	Biomass	Small Hydro	Hydro	Solar+Wind	Thermal			
19-Jul	00:00	181519	5472	5625	2000	1000	23677	35694	108052			
19-Jul	01:00	177535	5478	5420	2000	1000	22888	34996	105753		-38	
19-Jul	02:00	174366	5485	5402	2000	1000	22368	31872	106238		8	
19-Jul	03:00	173065	5488	5359	2000	1000	22116	29703	107399		19	
19-Jul	04:00	171510	5491	5301	2000	1000	21857	29774	106087		-22	
19-Jul	05:00	172313	5490	5329	2000	1000	21844	30282	106368		5	
19-Jul	06:00	174876	5473	5311	2000	1000	22741	28976	109375		50	
19-Jul	07:00	177833	5471	5276	2000	1000	24131	45417	94538		-247	
19-Jul	08:00	178644	5480	5357	2000	1000	24703	68343	71760		-380	
19-Jul	09:00	178750	5485	5388	2000	1000	23859	87216	53802		-299	
19-Jul	10:00	179819	5475	5463	2000	1000	24061	101167	40652		-219	
19-Jul	11:00	180159	5483	5392	2000	1000	23582	107413	35290		-89	
19-Jul	12:00	179533	5486	5391	2000	1000	23269	106472	35915		10	
19-Jul	13:00	177801	5479	5330	2000	1000	22889	103715	37388		25	
19-Jul	14:00	177075	5488	5407	2000	1000	22709	96012	44459		118	
19-Jul	15:00	177985	5481	5466	2000	1000	23169	82806	58063		227	
19-Jul	16:00	178292	5477	5378	2000	1000	23286	64865	76285		304	
19-Jul	17:00	176645	5475	5392	2000	1000	22788	47942	92047		263	
19-Jul	18:00	176020	5478	5435	2000	1000	23051	39070	99986		132	
19-Jul	19:00	185395	5480	5587	2000	1000	27044	39762	104522		76	
19-Jul	20:00	194236	5477	5911	2000	1000	29836	40897	109116		77	
19-Jul	21:00	194645	5489	6051	2000	1000	29057	37353	113695	135836	76	
19-Jul	22:00	189870	5496	5961	2000	1000	27270	34946	113197		-8	
19-Jul	23:00	187037	5509	5882	2000	1000	26243	35128	111275		-32	
Maximum		**194645**	**5509**	**6051**	**2000**	**1000**	**29836**		**113695**	**135836**	**304**	
Minimum		**171510**	**5471**	**5276**	**2000**	**1000**	**21844**		**35290**		**-380**	28.55
Average		**179788**	**5483**	**5492**	**2000**	**1000**	**24102**		**85053**		**2**	

Demand & Generation on the day 15th August,2021



Demand & Generation on the day 15th August,2021

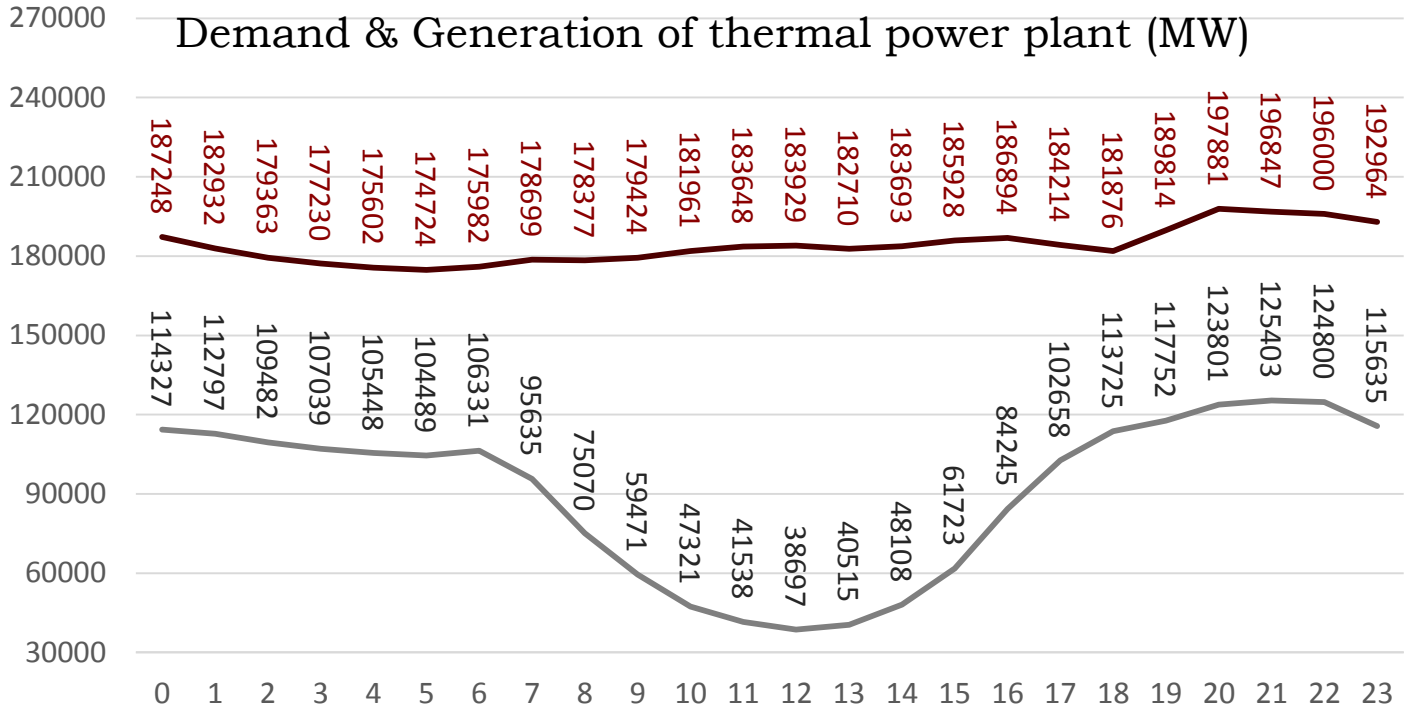
			Generation (MW)							Thermal capacity	Ramp Rate	Min. Load
Month/Day	Hour	Demand (MW)	Nuclear	Gas	Biomass	Small Hydro	Hydro	Solar+Wind	Thermal	(MW)	MW/min.	Operation (%)
15-Aug	00:00	186256	5265	5727	2000	1000	30722	22533	119009	142185		
15-Aug	01:00	183861	5261	5788	2000	1000	30197	22502	117114		-32	
15-Aug	02:00	179006	5271	5758	2000	1000	28898	22037	114042		-51	
15-Aug	03:00	176606	5273	5579	2000	1000	28664	21936	112153		-31	
15-Aug	04:00	176385	5274	5508	2000	1000	28858	20881	112863		12	
15-Aug	05:00	177922	5270	5547	2000	1000	29592	21262	113252		6	
15-Aug	06:00	179762	5273	5594	2000	1000	30571	23519	111806		-24	
15-Aug	07:00	179065	5279	5607	2000	1000	30160	39759	95261		-276	
15-Aug	08:00	176365	5283	5582	2000	1000	29554	57566	75380		-331	
15-Aug	09:00	174010	5277	5604	2000	1000	29225	71710	59195		-270	
15-Aug	10:00	172110	5279	5656	2000	1000	29530	82701	45944		-221	
15-Aug	11:00	172652	5275	5706	2000	1000	29613	88723	40335		-93	
15-Aug	12:00	172297	5270	5673	2000	1000	29103	89294	39957		-6	
15-Aug	13:00	172618	5270	5659	2000	1000	28708	85768	44213		71	
15-Aug	14:00	170085	5272	5657	2000	1000	27926	76340	51890		128	
15-Aug	15:00	169899	5270	5689	2000	1000	27741	63483	64715		214	
15-Aug	16:00	167586	5270	5680	2000	1000	27741	51338	74556		164	
15-Aug	17:00	166425	5269	5672	2000	1000	27157	36408	88919		239	
15-Aug	18:00	166250	5268	5654	2000	1000	27030	27324	97974		151	
15-Aug	19:00	178649	5263	5627	2000	1000	32326	27411	105022		117	
15-Aug	20:00	189474	5269	5762	2000	1000	34192	25785	115467		174	
15-Aug	21:00	188051	5269	5782	2000	1000	33010	24829	116161		12	
15-Aug	22:00	185607	5277	5751	2000	1000	32333	22349	116897		12	
15-Aug	23:00	183394	5279	5745	2000	1000	31414	21730	116227		-11	
Maximum		**189474**	**5283**	**5788**	**2000**	**1000**	**34192**		**119009**	**142185**	**239**	
Minimum		**166250**	**5261**	**5508**	**2000**	**1000**	**27030**		**39957**		**-331**	30.88
Average		**176847**	**5272**	**5667**	**2000**	**1000**	**29761**		**89515**		**-2**	

Integration of 107798 MW RES generation into grid

- The day, 25th June,2021, highest ever generation of 107798 MW from RES will be integrated into the grid at 12:00 hrs.
- Min. ex-bus thermal gen. of 38697 MW is required during peak RES generation.
- Max. ex-bus thermal gen. of 125403 MW is required during evening.
- Considering 10% reserved capacity in peak, 139336 MW coal capacity shall be on bar.
- Assuming 7% APC total thermal capacity of 149842 MW will be synchronised on the day.
- Min. thermal ex-bus generation of 38697 MW is required at 12:00 hrs. and considering 9% APC during low load the generation will be 42542 MW
- Thus 28.38% minimum load operation of thermal plant is required.

25th June,2021

Ramp Rate



Ramp Down Rate: Max. ramp down rate of 343 MW/min. is required at 8:00 am.

Ramp up Rate: Max. ramp up rate of 375 MW/min is required at 16:00 hrs.

* As RES generation data of 15 minutes' block is not available the analysis was conducted on hourly average generation data, the actual ramp rate may be higher than the predicted figure.

Ramp Rate

	Unit & Size	Capacity utilization	Capacity on Bar	Assumed Ramp	Ramp Rate
		%	MW	Rate (%)	(MW/Min.)
1	< 150 MW	57	5804	1%	57
2	200/210 MW	60	19368	1%	193
3	250 MW to -360 MW	60	23164	1%	231
4	500 MW	67	31219	1%	312
5	600 MW to 800 MW	67	70303	1%	703
	Total		149857		1498

Required ramp down rate: 343 MW/min.

Required ramp up rate: 375 MW/min.

Critical Period

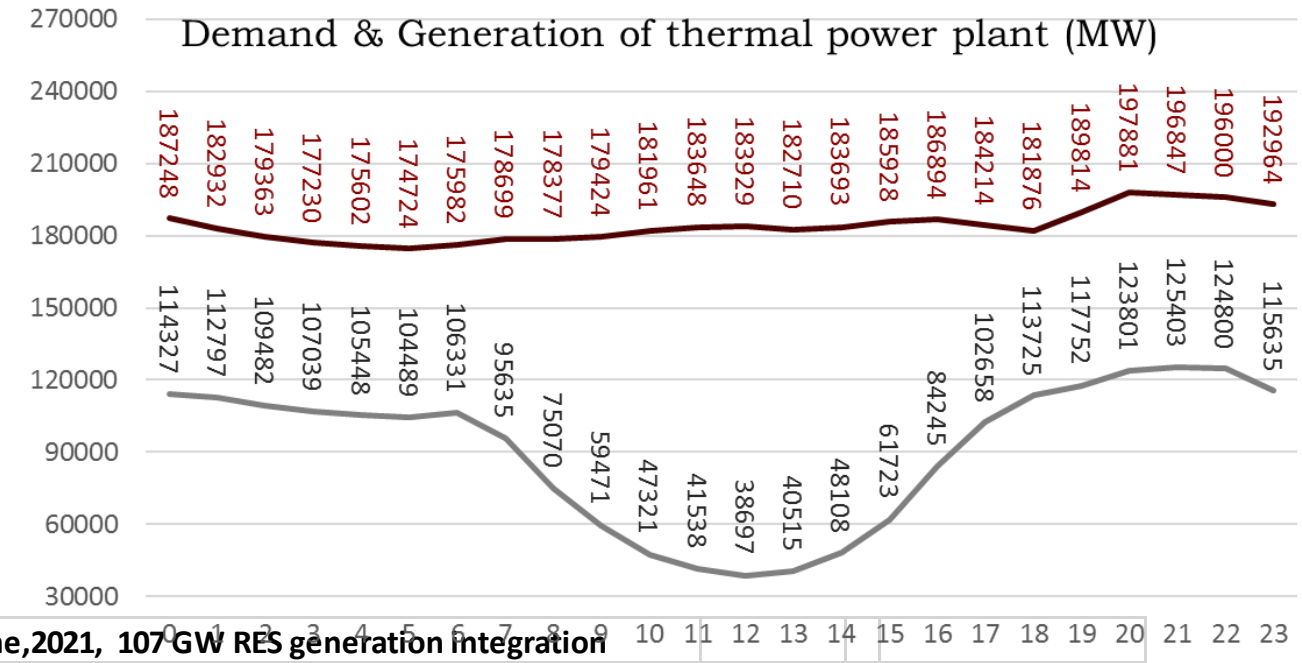
The most critical period is June, July & August,2021, specifically for operation of the thermal power plants and the grid as whole, due to the following reasons:

1. Continuous run of hydro plants due to abundant water supply during monsoon.
2. Quality of coal deteriorates in the monsoon which adversely affects the low load operation of thermal plant.
3. Maximum generation is available in June from Solar plant
4. High country peak demand during the period under review.
5 High Wind during monsoons produces maximum RES generation.

Hence, it may be concluded that if the Indian power system can accommodate full RES generation of 108 GW during the period and survive, it can potentially survive throughout the year.

Integration of 107798 MW RE generation on 25th June,2021

Scenario: 1



	A. 25th June,2021, 107 GW RES generation integration	Evening	Morning
1	Generation required from thermal power plant (MW)	125402	114327
2	Considering 10% reserve, thermal capacity (MW)	139336	127030
3	**Capacity on bar assuming 7% APC , MW**	**149823**	**136591**
4	Min. thermal gen.(MW) required on 25th june,2021	38697	38697
5	**Min. Generation assuming 9% APC at partial load, MW**	**42524**	**42524**
4	**Avg. min. load of running thermal unit (%)**	**28.38**	**31.13**

It is very difficult to operate thermal plant at 28.38% load with high ash contained Indian coal.

Scenario: 2

B	**25th June,2021, 107 GW RES generation integration**		
		Evening	**Morning**
1	Generation required from thermal power plant (MW)	125402	114327
2	10000 MW capacity (small & old unit) from 17:00 to 23:00 hrs.	10000	0
3	Balance generation required from thermal plant (1) - (2), MW	115402	114327
4	Considering 10% reserve, thermal capacity (MW)	128224	127030
5	**Capacity on bar assuming 7% APC , MW**	**137876**	**136591**
6	Min. thermal gen.(MW) required on 25th june,2021	38697	38697
7	**Min. Generation assuming 9% APC at partial load,MW**	**42524**	**42524**
8	Avg. min. load of running coal fired unit (%)	30.84	31.13

It is also very difficult to operate thermal plant at 30% load with high ash contained Indian coal.

Scenario: 3

C	**25th June,2021, 107 GW RES generation integration**		
		Evening	**Morning**
1	Generation required from thermal power plant during peak (MW)	125402	114327
2	10000 MW capacity (small & old unit) from 17:00 to 23:00 hrs.	10000	0
3	2-shift opn. of Gas plant - addl. 3000 MW peak support	3000	3000
4	Balance generation required from thermal power plant (1)-(2)-(3) MW	112402	111327
5	Considering 10% reserve, thermal capacity (MW)	124891	123697
6	**Capacity on bar assuming 7% APC , MW**	**134292**	**133007**
7	Min. thermal gen.(MW) required on 25th june,2021	38697	38697
8	Gas gen. is replaced by thermal generation, MW	3000	3000
9	Minimum coal gen.(MW) required on 25th june,2021 (7)+(8)	41697	41697
10	**Min. Generation assuming 9% APC at partial load, MW**	**45821**	**45821**
11	Avg. min. load of running coal fired unit (%)	34.12	34.45

Still it is difficult to operate thermal plant at 34.12% load with high ash contained Indian coal.

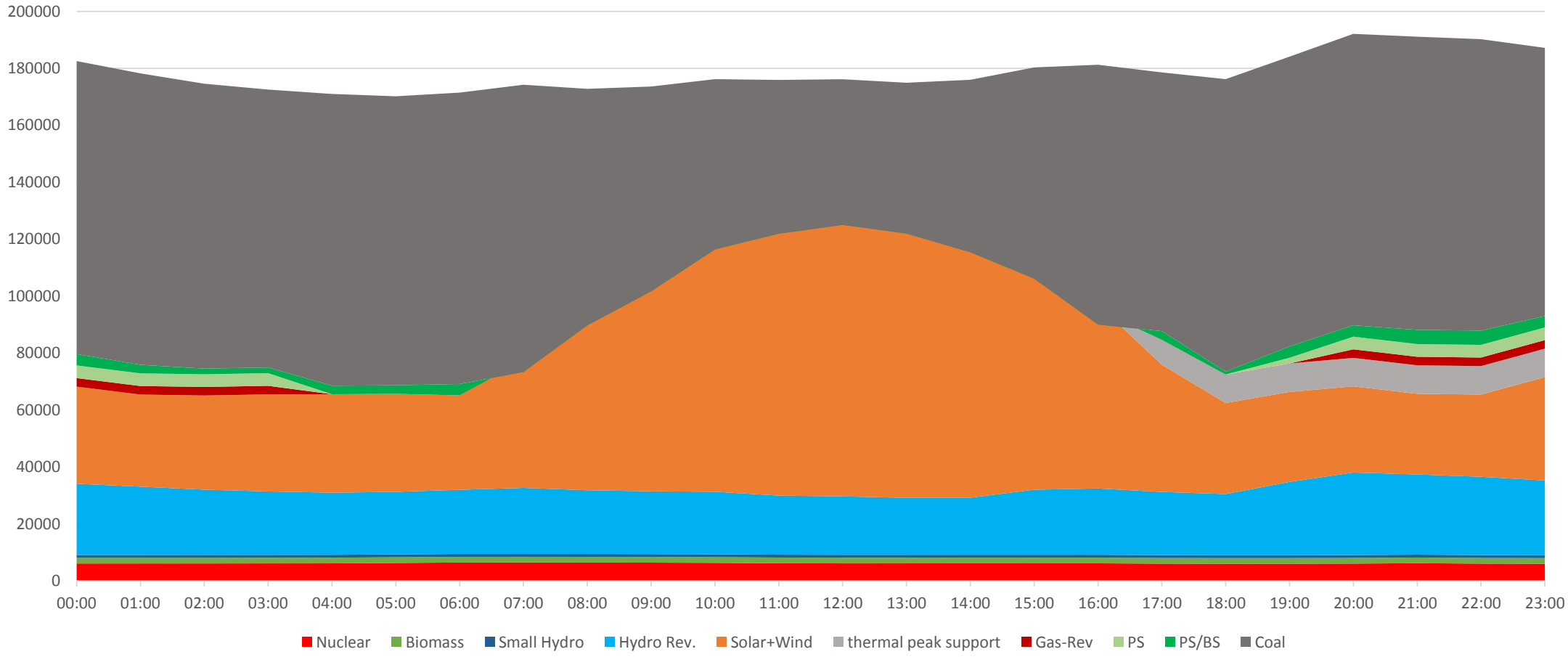
Scenario: 4

D	25th June,2021, 107 GW RES generation integration	Evening	Morning
1	Generation required from thermal power plant during peak MW	125402	114327
2	10000 MW capacity (small & old unit) from 17:00 to 23:00 hrs.	10000	0
3	2-shift opn. of Gas plant - addl. 3000 MW peak support	3000	3000
4	Peak support from running pump storage	2250	2250
5	Peak support from under construction pump storage	1200	1200
6	Re-allocation of hydro generation, MW	1000	1000
7	Balance generation required from thermal power plant (1)-(2)-(3)-(4)-(5)-(6) MW	107952	106877
8	Considering 10% reserve, thermal capacity (MW)	119947	118752
9	**Capacity on bar assuming 7% APC , MW**	**128975**	**127691**
10	Min. thermal gen.(MW) required on 25th june,2021	38697	38697
11	Gas gen. is replaced by thermal generation during Solar gen., MW	3000	3000
12	Consumption of running pump storage, MW	2250	2250
13	Consumption of under construction pump storage, MW	1200	1200
14	Re-allocation of hydro generation increases thermal generation, MW	1000	1000
15	Minimum coal gen. required on 25th June,2021 (10)+(11)+(12)+(13)+(14)+(15) MW	46147	46147
16	**Min. Generation assuming 9% APC at partial load, MW**	**50711**	**50711**
17	Avg. min. load of running coal fired unit (%)	39.32	39.71

Scenario: 5

E	**25th June,2021, 107 GW RES generation integration**		
		Evening	**Morning**
1	Generation required from thermal power plant during peak MW	125402	114327
2	10000 MW capacity (small & old unit) from 17:00 to 23:00 hrs.	10000	0
3	2-shift opn. of Gas plant - addl. 3000 MW peak support	3000	3000
4	Peak support from running pump storage	2250	2250
5	Peak support from under construction pump storage	1200	1200
6	Re-allocation of hydro generation, MW	1000	1000
7	Addl. peak support from Battery or Pump storage system MW	5000	5000
8	Balance generation required from thermal power plant (1)-(2)-(3)-(4)-(5)-(6)-(7) MW	102952	101877
9	Considering 10% reserve, coal capacity (MW)	114391	113197
10	**Capacity on bar assuming 7% APC , MW**	**123001**	**121717**
11	Min. thermal gen.(MW) required on 25th june,2021	38697	38697
12	Gas gen. is replaced by thermal generation during Solar gen., MW	3000	3000
13	Consumption of under construction pump storage, MW	2250	2250
14	Consumption of runing pump storage, MW	1200	1200
15	Re-allocation of hydro generation increases thermal generation, MW	1000	1000
16	Addl. Consumption of BS/ PS, MW	5000	5000
17	Min. coal gen. required on 25th june,2021 (11)+(12)+(13)+(14)+(15)+(16), MW	51147	51147
18	**Min. Generation assuming 9% APC at partial load, MW**	**56205**	**56205**
19	Avg. min. load of running coal fired unit (%)	45.70	46.18

Demand & Generation on the day 25th June,2021 considering scenario-5



Demand & Generation on the day 25th June,2021 considering scenario-5

			Generation											Backing Down
Month/Day	Hour	Demand	Nuclear	Biomass	Small Hydro	Hydro Rev.	Solar+Wind	thermal peak sup	Gas-Rev	PS	PS/BS	Coal	Ramp Rate	(%)
25-Jun	00:00	187248	6090	2000	1000	25008	34112		3000	4450	4000	102877		
25-Jun	01:00	182932	6092	2000	1000	23984	32347		3000	4450	3000	102347	-9	
25-Jun	02:00	179363	6103	2000	1000	22938	33063		3000	4450	2000	100032	-39	
25-Jun	03:00	177230	6121	2000	1000	22287	34084		3000	4450	2000	97589	-41	
25-Jun	04:00	175602	6134	2000	1000	21823	34589				3000	102448	81	
25-Jun	05:00	174724	6288	2000	1000	21975	34422				3000	101489	-16	
25-Jun	06:00	175982	6437	2000	1000	22557	33140				4000	102331	14	
25-Jun	07:00	178699	6445	2000	1000	23213	45939			-1250	-4000	100885	-24	
25-Jun	08:00	178377	6435	2000	1000	22390	65896		-3000	-2000	-3000	83070	-297	
25-Jun	09:00	179424	6394	2000	1000	22062	82677		-3000	-4450	-5000	71921	-186	
25-Jun	10:00	181961	6324	2000	1000	21964	97578		-3000	-4450	-5000	59771	-203	
25-Jun	11:00	183648	6179	2000	1000	20774	104426		-3000	-4450	-5000	53988	-96	
25-Jun	12:00	183929	6131	2000	1000	20539	107798		-3000	-4450	-5000	51147	-47	
25-Jun	13:00	182710	6135	2000	1000	20037	105245		-3000	-4450	-5000	52965	30	
25-Jun	14:00	183693	6147	2000	1000	20058	98653		-3000	-4450	-5000	60558	127	
25-Jun	15:00	185928	6144	2000	1000	22874	86573		-3000	-4450	-5000	74173	227	
25-Jun	16:00	186894	6151	2000	1000	23307	64546			-2000	-5000	91245	285	
25-Jun	17:00	184214	6031	2000	1000	22190	44675	10000		-1200	3000	90858	-6	
25-Jun	18:00	181876	5997	2000	1000	21489	31986	10000			1000	102725	198	
25-Jun	19:00	189814	6005	2000	1000	25750	31589	10000		2000	4000	101752	-16	
25-Jun	20:00	197881	6050	2000	1000	28975	30281	10000	3000	4450	4000	102351	10	
25-Jun	21:00	196847	6192	2000	1000	28164	28345	10000	3000	4450	5000	102953	10	
25-Jun	22:00	196000	6045	2000	1000	27509	28873	10000	3000	4450	5000	102350	-10	
25-Jun	23:00	192964	5995	2000	1000	26254	36295	10000	3000	4450	4000	94185	-136	
Maximum		**197881**	**6445**	**2000**	**1000**							**102953**	**285**	**45.70**
Minimum		**174724**	**5995**	**2000**	**1000**				**0**	**0**	**0**	**51147**	**-297**	
Average		**184081**	**6169**	**2000**	**1000**							**87750**	**-6**	

Demand Side Management

- Supply of electricity to agriculture sector
- Charging of Electric vehicle

Curtailment of RE generation

Thermal Minimum Load operation (%)	Percentage RES Curtailed p.a. (%)	Annual RES Curtailed p.a. (MU)	Value of RES lost p.a. @ Rs2.5/kWh (Rs. Crore)
29%	0.00%	0	0
30%	0.01%	22	6
35%	0.09%	252	63
40%	0.38%	1035	259
45%	0.96%	2630	658
50%	2.02%	5541	1385
55%	3.99%	10945	2736
60%	7.56%	20736	5184

Recommendations:

- Peak support of 10000 MW generation from 17:00 hrs. to 23:00 hrs has been proposed from 200 MW & below size old, inefficient units.
- 3000 MW additional peak support is suggested by 2-shift operation of gas power plant. This will increase (about 3%) the minimum load of operation of thermal power plant.
- 5500 MW generation from running & under construction pump storage has been proposed to utilize efficiently for balancing the grid. All existing pump storage are proposed to utilize to optimize the total system instead of optimization of any subsystem. Incentives and other measures shall be explored in this direction.
- 1000 MW hydro generation has been re-allocated for balancing the system. Incentives for those hydro plants shall be explored. The participation of more hydro plant in balancing the grid, specially from state sector may be further explored by means of announcing incentives, implementing two-part tariff, revision of grid code if required.
- Pumped storage or battery storage system or combination of both of 5000 MW has been considered at suitable locations. This will create additional load of 5000 MW during high RES generation and generate power of 5000 MW during less RES generation.
- Demand side management
- Measures to be implemented for 45% load operation of selected thermal generating units.

Thank you