MINUTES OF ELEVENTHMEETING OF "TECHNICAL COMMITTEE FOR IMPLEMENTATION OF FRAMEWORK ON RENEWABLES AT THE STATE LEVEL"

Venue	:	Rajindra Hall, ITC Grand Chola Hotel, Chennai-600032l
Date	:	28-03-2017
List of Participants	:	At **Annexure –I (enclosed)**

The Eleventh meeting of Technical Committee on Implementation of Framework for Renewables at the State level was held under the Chairmanship of Shri A.S. Bakshi, Member, CERC on 28thMarch2017.Shri A.S. Bakshi, Chairman, Technical Committee extended a warm welcome to all Members of the Committee. He thanked the Chairperson, TNERC for hosting the meeting at Chennai. The Chairperson, TNERC also welcomed all the Members of the Committee and wished fruitful deliberations over the day.

2. Shri Bakshi expressed his opinion that Technical Committee has been constituted for a specific purpose and success of this Committee lies in demonstrating cases of successful implementation of the activities covered under the mandate namely, Implementation of SAMAST, Forecasting, Scheduling and Deviation Settlement Mechanism for RE, Interstate ABT/ DSM Framework at state level, Ancillary Services at state level and operationalization of web portal for RPO compliance monitoring. It has been more than a year this Committee has been constituted and tangible results in terms of implementation are seen only in couple of states. He urged the members to make sure that the activities detailed as part of the mandate for the Committee be at least implemented in the States that arerepresented in this Technical Committee.

Discussion

1. **Agenda No. 1: Status of Implementation of SAMAST Report**

TANTRANSCO/SLDC Tamil Nadu made a presentation (enclosed as **Annexure II**) on detailed status update on implementation of SAMAST recommendations in the State, including ABT meters, Automated Meter Reading (AMR) project, software requirements, etc. It was stated that Rs.11.98 Crores have been already sanctioned from PSDF for implementation of intra-state ABT, and PSDF funding may kindly be granted for the purchase orders placed before the date of sanction of PSDF by MoP. Additional funds for procuring forecasting tools shall be requested in due time.

APERC member informed that APTRANSCO has prepared the DPR with cost estimate, and has written to NLDC on 27th March 2017 seeking support from PSDF for the implementation of SAMAST. Revised estimate indicated in the letter is Rs.52.723 Crores.

Rajasthan and Karnataka members informed that SLDC/STU in their States is initiating action in this regard. Rajasthan member added that LoI has already been issued, and the tender document for implementation shall be finalized by September 2017. Additionally, the State will finalize the Forecasting & Scheduling (F&S) Regulations by June 2017.

Karnataka shall provide detailed updates at the next meeting, scheduled to be held in Bangalore in May 2017.

2. **Agenda No. 2: Status of Implementation of Regulations on Forecasting, Scheduling and Deviation Settlement**

TANTRANSCO/SLDC Tamil Nadu made a presentation (enclosed as **Annexure III**) on grid integration of wind and solar energy in the State, including constraints and associated costs. They underscored that forecasting helps to make renewable energy appear more like conventional power. Tamil Nadu highlighted that they have more than 10000 MW of installed

RE in its State and of which the contribution of wind is about 7700 MW (~76%) and about 1580 MW of Solar (~15%). Further they highlighted that the Central Generating Stations maintained PLF of about 80% but the State Generating stations have PLF of about 45%. Accommodation of wind during the high wind season results in high Deviation, Surrendering of CGS, Backing down of power purchased from LTA/MTOA Generator, purchase of high cost power from IPPs, backing down of State run thermal stations. As a result, TANGEDCO has to accommodate wind generation by losing commercially to the tune of about Rs. 622 Cr. and is seeking support from MNRE.

To improve the spinning reserves, TN has about 3000MW of pumped storage in pipeline (in addition to Kadamparai)

TNERC presented on the issues and challenges arising in drafting F&S Regulations for Tamil Nadu (presentation enclosed as **Annexure IV**). Shri Akshaya Kumar, Chairperson TNERC, acknowledged that draft F&S and DSM regulations initiated by TNERC need to be revamped in light of learnings from deliberations of the Technical Committee. Considering large penetration of RE generation at embedded/distribution level, need to review separate treatment for balancing and OA transactions may also be explored. TNERC Chairperson sought support of a Consultant from the Technical Committee in the matter.

The Committee noted the request and discussed various options and agreed that the feasibility for extending support to TNERC as extension of ongoing support & compensation thereof will be explored, upon due process and approvals.

3. **<u>Agenda No. 3:</u> Update on Web Portal for RPO Compliance Monitoring**

The Consultant informed the Technical Committee about completion of security audit and hosting of RPO Webtool on RRECL website for Rajasthan. The Consultant also gave presentation on status update on development of Generic RPO webtool Beta version. It was informed that upon testing of Generic RPO Webtool, the same can be hosted on FOR website

and modalities for the same can be discussed separately with concerned web hosting team of FOR. Further, it was informed that discussions for roll out in Gujarat with concerned agencies GERC/GEDA have been scheduled in early April 2017.

4. **<u>Agenda No. 4:</u> Study on Grid Integration of RE conducted under Indo-US Greening the Grid (GTG) Project**

ShriS.R. Narsimhan,AGM, POSOCO, made presentation (enclosed as **Annexure V**) giving overview of the GTG project, comprehensive analysis using PLEXOS model and key findings of the study were discussed. Impact of 175 GW RE penetration into Indian Grid under different scenarios and its implications on Grid operations and potential strategies to operate thermal/hydel generating stations and resultant outcomes in terms of costs/savings etc. were discussed. The study involved participation by the SLDCs of six RE rich states, CEA, CTU and POSOCO from Indiaand NREL, LBNL and USAID from US.

POSOCO stated that these draft results were shared in a meeting taken by Secretary Power on 15th Feb 2017, by Chairperson CEA on 28th Feb 2017 and by Secretary MNRE on 28th Feb 2017. The suggestions received in these meetings have been taken note of. The final report would also incorporate the increase in Heat Rates on account of part loading of coal fired plants to 55%.

ShriSen observed that the study should also cover the impact of increase in power purchase cost for Utilities, increase in cost on account of technical performance (part load of thermal) and additional maintenance costs.

The needfor factoring in reactive compensation requirement of the transmission grid with high RE penetration and backing down of thermal generating stations at various nodes was also reiterated.

ShriSoonee clarified that this is the first time such a comprehensive modeling exercise covering multiple states/control areas have been undertaken. Underthr next stage of study, further detailed exercise addressing above observations can be undertaken.

Members appreciated the studies and felt that fixed costs also need to be factored in either in this or as a separate study. Chairperson WBERC remarked that instead of retiring old thermal units, efforts could be made to modify the same to provide additional flexibility. POSOCO emphasized the need for using tools such as PLEXOS (used in the current study) for further studies such as optimal capacity expansion, transmission planning studies as well as for areas like hydro scheduling etc. at the state and regional level.

5. **<u>Agenda no. 5:</u>Introduction of 5 Minute Time Block – Rationale, Preparedness and Costs (towards metering and related infrastructure) and Benefits, and way forward**

A copy of the presentation made by POSOCO is enclosed at **Annexure- VI**. The presentation covered the need for implementing a 5-minute scheduling and settlement at the Inter State Transmission System (ISTS) level considering the variability of load (particularly at the hourly boundary) and the high Renewable Energy (RE) penetration in the coming years. The issue of 15-minute scheduling and settlement at the ISTS level was settled way back in January 2000 with the landmark Availability Based Tariff (ABT) order by CERC. Subsequently w.e.f. 1st April 2012, the Power Exchangesalso moved to a 15-minute price discovery in the Day Ahead Market (DAM) instead of hourly which was a significant shift.

Worldwide, it has been recognized that 5-minute scheduling and settlement offered alot of advantages, particularly in terms of reduction of requirement of reserves, price discovery and bringing out the value of flexibility. Currently, tertiary reserves ancillary services have been implemented at the ISTS level where actions at the power plant happen 16-30 minutes after the same is advised by NLDC. Secondary regulation services through Automatic Generation Control (AGC) are soon expected to be introduced with a pilot project for NTPC, DadriStage-

II project scheduled to roll out in May 2017. This would necessitate moving to at least 5-minute settlement for the plants providing secondary regulation through AGC.

It was emphasized that the decision for 5-minute scheduling and settlement at the ISTS level need not come in the way of SAMAST implementation at the intra state level. All that is required is that the states implementing SAMAST at the intra state level factor the 5-minute periodicity in the metering as well as software being procured for scheduling and settlement. Discussions are also on at CEA level for amending the CEA Metering Regulations to this effect.

Members appreciated the need to move to 5-minute scheduling and settlement. For working out the modus operandi, it was decided that a sub-group would be constituted comprising CEA, CTU, RPCs, POSOCO and CERC Staff which would examine these issues in further detail and submit its report to the FOR Technical Committee.

6. <u>Agenda No. 6:</u> Development of Model RPO Regulations for SERCs

Proposed draft for amendment in RPO regulations, as deliberated during the 10th Meeting was tabled. There was general consensus on the proposed draft (the same was circulated under background note for 11th Meeting). It was felt that respective SERCs should incorporate suitable amendments in their RPO Regulations to this effect.

7. <u>Agenda No. 7:</u> Framework for Co-operation among States for Optimum Utilization of their Generation Resources

The issue was discussed amongst the members. However, it was felt that to operationalise such a framework, it is necessary to ensure political support. The same had been raised in the Southern Zonal Council meeting chaired by the Hon'ble Union Home Minister held on 28th Dec 2016 at Thiruvananthapuram. Subsequently, Joint Secretary, Transmission, Union Ministry of Power had taken a meeting on 10th Feb 2017.

After discussion, it was decided that sub-groups could be constituted in the Northern Region, Western Region and Southern Region (the three RE rich regions) headed by the Member Secretaries of the respective Regional Power Committees (RPCs). The Sub-groups should examine the feasibility and modality of co-operation among States in the respective region for ensuring optimum utilization of generation resources with least cost options for balancing across the region. The Sub-groups are to submit their findings before the Technical Committee.

8. <u>Agenda No. 8:</u> Presentation by NIWE on Wind Forecasting initiatives in Tamil Nadu

Shri A.G Rangarajan presented on the Wind Power Forecasting Technology (enclosed as **Annexure–VII**). Various approaches and their associated uncertainties for wind power forecasting were discussed. NIWE's indigenous Forecast Model was also discussed during the presentation. The Committee made a note of the presentation by NIWE.

The meeting ended with a vote of thanks to the Chair.

Annexure-I

LIST OF PARTICIPANTS ATTENDED THE ELEVENTHMEETING OF THE TECHNICAL COMMITTEE FOR "IMPLEMENTATION OF FRAMEWORK ON RENEWABLES AT THE STATE LEVEL"HELD ON 28.03.2017 AT THE ITC GRAND CHOLA HOTEL, CHENNAI

1	Shri. A. S.Bakshi, Member	CERC
2	ShriS. Akshayakumar, Chairperson	TNERC
3	Dr. M.K Iyer,Member	CERC
4	ShriT.M. Manoharan, Chairperson	KSERC
5	ShriIsmail Ali Khan, Chairperson	TSERC
6	ShriRabindraNathSen, Chairperson	WBERC
7	ShriD.B. ManivalRaju, Member	KERC
8	ShriP. Rama Mohan, Member	APSERC
9	ShriP.J. Thakkar, Member	GERC
10	ShriR.P Barwar, Member	RERC
11	Shri S.C. Shrivastava, Chief (Engg.)	CERC
12	DrSushanta K. Chatterjee, JC(RA)	CERC
13	Shri S. K.Soonee, Advisor	POSOCO
14	ShriS R Narasimhan, AGM	POSOCO
15	ShriAjitPandit, Director	Consultant

MINUTES OF ELEVENTH MEETING OF "TECHNICAL COMMITTEE FOR IMPLEMENTATION OF FRAMEWORK ON RENEWABLES AT THE STATE LEVEL"

CORRIGENDUM

Para 3 of '**Agenda No. 1: Status of Implementation of SAMAST Report'** under Discussion section shall read as under:

Rajasthan and Karnataka members informed that SLDC/STU in their States is initiating action in this regard. Rajasthan member added that LoI has already been issued, and the implementation will be achieved by September 2017. Additionally, the State will finalize the Forecasting & Scheduling (F&S) Regulations by June 2017.

Presentation to FOR Technical Committee

SLDC, TANTRANSCO

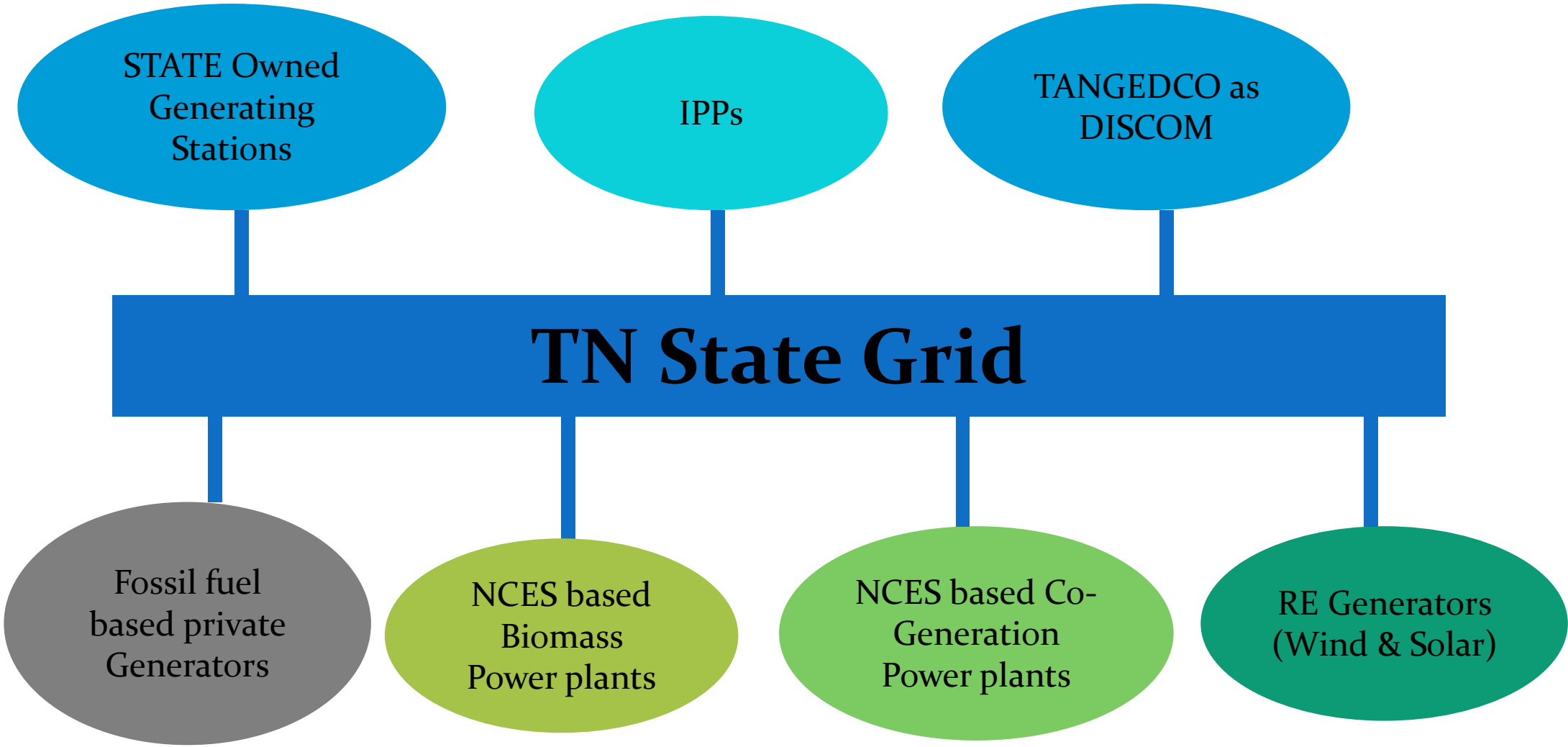
SAMAST

Scheduling, Accounting, Metering and Settlement of Transactions in electricity

SAMAST RECOMMENDATIONS

1. Identification of Intra State Entities and Demarcation of Interface boundary

INTRASTATE ENTITIES

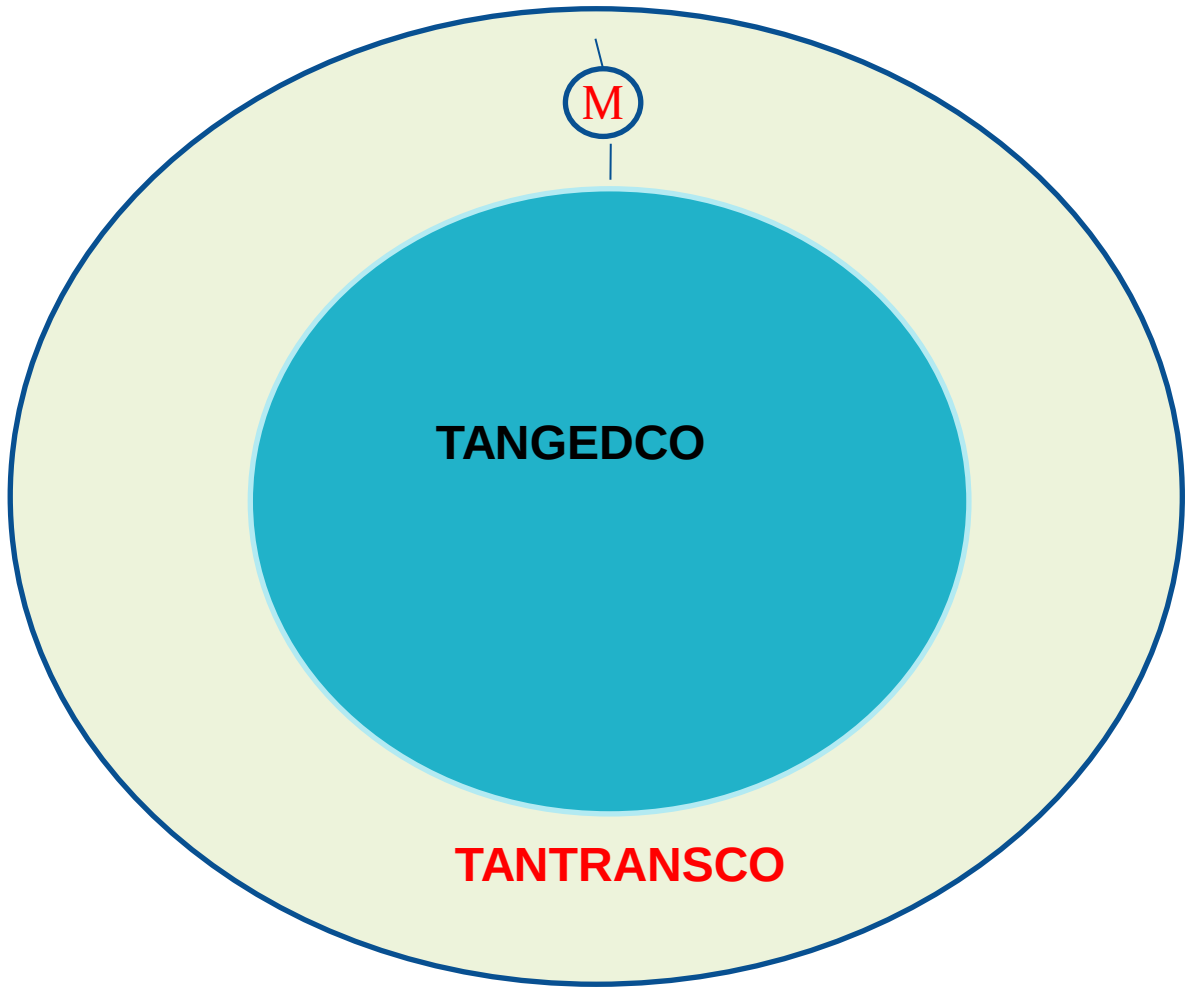


Identified Intrastate entities in Tamil Nadu

- TANGEDCO as a DISCOM
- State owned Generating Stations
- Fossil fuel based private generators
- NCES based Co-generation power plants
- Biomass power plants
- IPPs
- RE Generators (Wind and Solar)

2. Assessment of Meters

Control Area Demarcation



M = 1153 Nos. Of ABT meters at 110KV/230KV interfacing grid feeders & 3032 Nos. of ABT meters at 110KV GC & LV

Total Meters = 4185 Nos.

Present status of Provision of ABT meters

Sl.No	Category	Name of the Generators			Status
		Total	ABT meters provided	Balance to be provided	
1	Fossil fuel based private generators	50	50	-	Completed
2	NCES based Co-Gen generators	29	14	15	Under Installation
3	NCES based Biomass generators	31	27	4	Under Installation
4	IPPs	4	4	-	Completed
5	Wind Energy generators	9319	7713	1606	Under Installation
6	WEG Pooling Station feeders	710	656	54	Under Installation

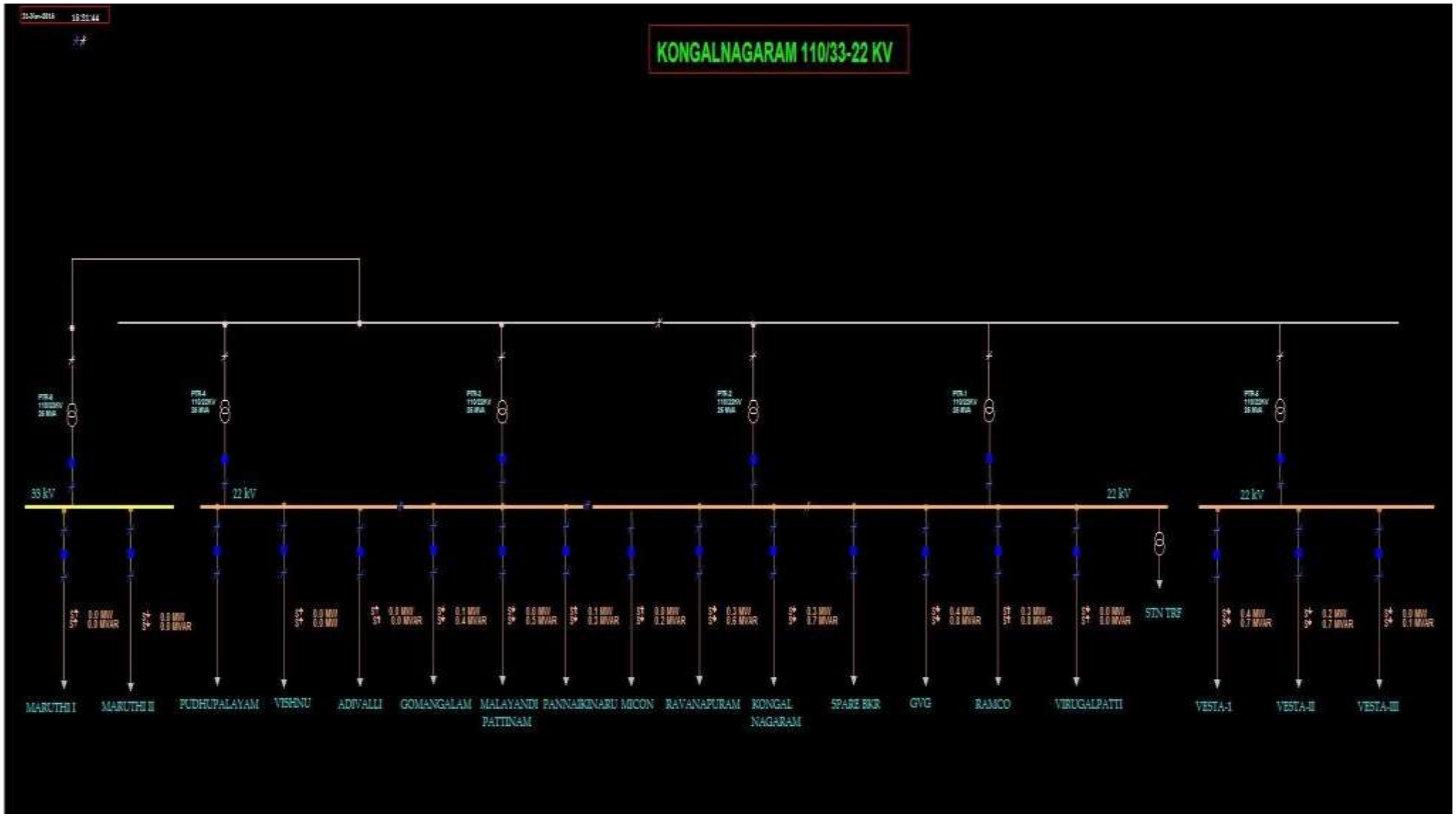
Present status of Provision of ABT meters

Sl. No	Category	Name of the Generators			Status
		Total	ABT meters provided	Balance to be provided	
7	Solar Developers	101	101	-	Completed
8	230 and 110 KV grid feeders	1153	100	1053	Under installation
9	GC and LV of 110KV radial SS	3032	-	3032	Procurement under process
10	State owned generating station evacuation feeders	190	-	190	Procurement under process

Status of Online Monitoring

Sl. No.	Category	Name of the Generators		
		Total	On line data received at SLDC	Online data Under process
1	Fossil fuel based private generators	50	19	31
2	NCES based Co-Gen generators	29	6	23
3	NCES based Biomass generators	31	1	30
4	IPPs	4	4	0
5	WEG Pooling Station**(Data from Kongalnagaram pooling station is received at SLDC)**	117	1	116
6	Solar Developers	101	1	100
7	State owned generating stations	45	45	0

Data received from Kongalnagaram SS



3. Assessment of Automatic Meter Reading logistics Requirement (AMR)

STATUS OF AMR PROJECT

- **P.O. ISSUED**
  - Procurement of servers & Network accessories : Date 22.11.2016.
  - Procurement of Software for Open Access Energy adjustment & Accounting (AMR): Date 01.11.2016
  - Procurement of MODEM & DCU: Date 01.07.2016

  Delivery period is 6 to 12 months

- **Billing Software is under development.**
- **Proof of concept for data transfer from 15 Nos. Wind Energy generators and 2 Nos. Wind SS has been programmed in first week of April 2017**
- **The AMR servers have been supplied and erection work is under progress and entire project will be completed by Dec-2017.**

4. Assessment of IT infrastructure (Hardware and Software) requirement

Status of Software for DSM

Administrative approval has been obtained for procurement of software for the implementation of Deviation settlement mechanism(DSM). Specification prepared. Put up to BLTC.

5. Application for funding from Central Government/PSDF

Power System Development Fund (PSDF)

- A grant of Rs.11.98 Crores from PSDF has been sanctioned by Ministry of Power towards establishment of IT infrastructure and cost of CT and PT for implementation of Intrastate ABT in Tamil Nadu vide their letter dt.2.01.2017.
- As per the guide lines /procedures for funding from PSDF a Tripartite Agreement has to be signed by the Nodal agency of PSDF (NLDC), Government of Tamil Nadu & Utility. The draft agreement has been vetted by NLDC and will be signed shortly.

Intrastate ABT Regulations

- **TNERC has notified the following draft regulations on 13.01.2016**

  a. Intra State Availability Based Tariff Regulations.

  b. Forecasting, Scheduling, Deviation Settlement and Related Matters of Wind and Solar Generation Sources Regulations, 2016

- **Model DSM Regulations**

  Model Deviation Settlement Mechanism (DSM) and related matters Regulations at State level has been framed by FOR in November 2016 and March 2017.

TIME LINE

Sl. No.	Description	Probable period of Completion
1	Provision of ABT meters	December-17
2	Online Monitoring	December-17
3	AMR installation	December-17
4	DSM Software	March -18

SUBMISSION TO TECHNICAL COMMITTEE

1. Request PSDF for AMR PO

The procurement process of Automatic Meter Reading requirement which is prerequisite for implementation of intrastate ABT has been initiated only after the recommendation of appraisal committee meeting held on 06.09.2016. and P.O. has been issued on 1.11.2016 for software and 22.11.2016 for server anticipating earlier sanction whereas MOP approval is on 2.1.2017.

Request:

- Since the procurement process has been speeded up to complete the AMR project with in the stipulated time frame , **PSDF funding may kindly be granted for the above purchase orders placed before the date of sanction of PSDF by MOP.**
- Additional amount from PSDF may kindly be sanctioned for our future developmental activities.

2. Suggestions on Model DSM Regulations

DSM Regulations needs to be modified to suit for the specific requirement of the state. Since High Renewable Energy Generators and more number of open access consumers are in Tamil Nadu.

3. MOCK IMPLEMENTATION OF INTRA STATE ABT

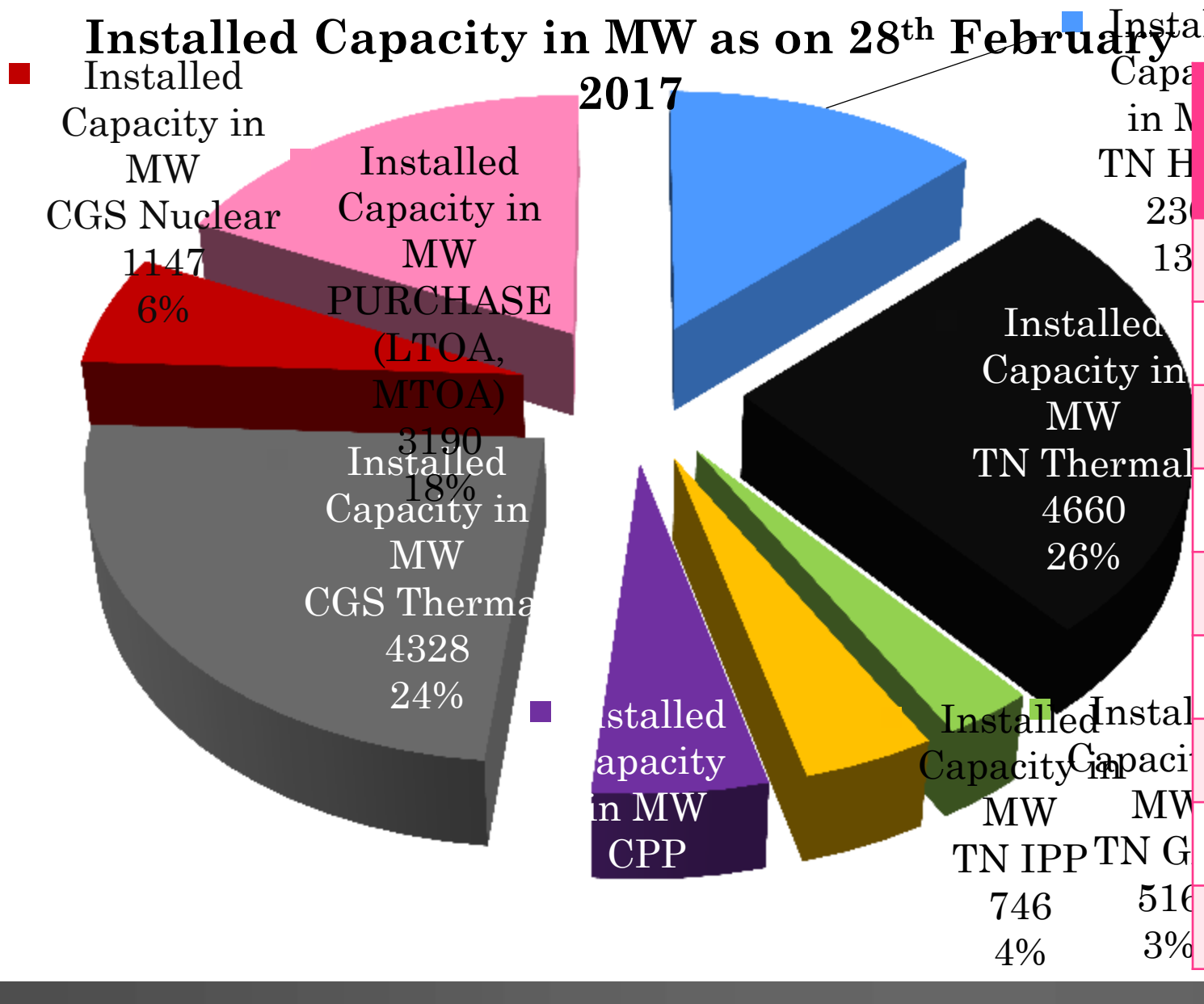
After notification of Intra State ABT Regulation by Hon'ble TNERC, Mock exercise has to be carried at least for a period of one year before commencing Commercial Operation.

Presentation to FOR Technical Committee

SLDC, TANTRANSCO

Tamil Nadu – Conventional Generation Mix

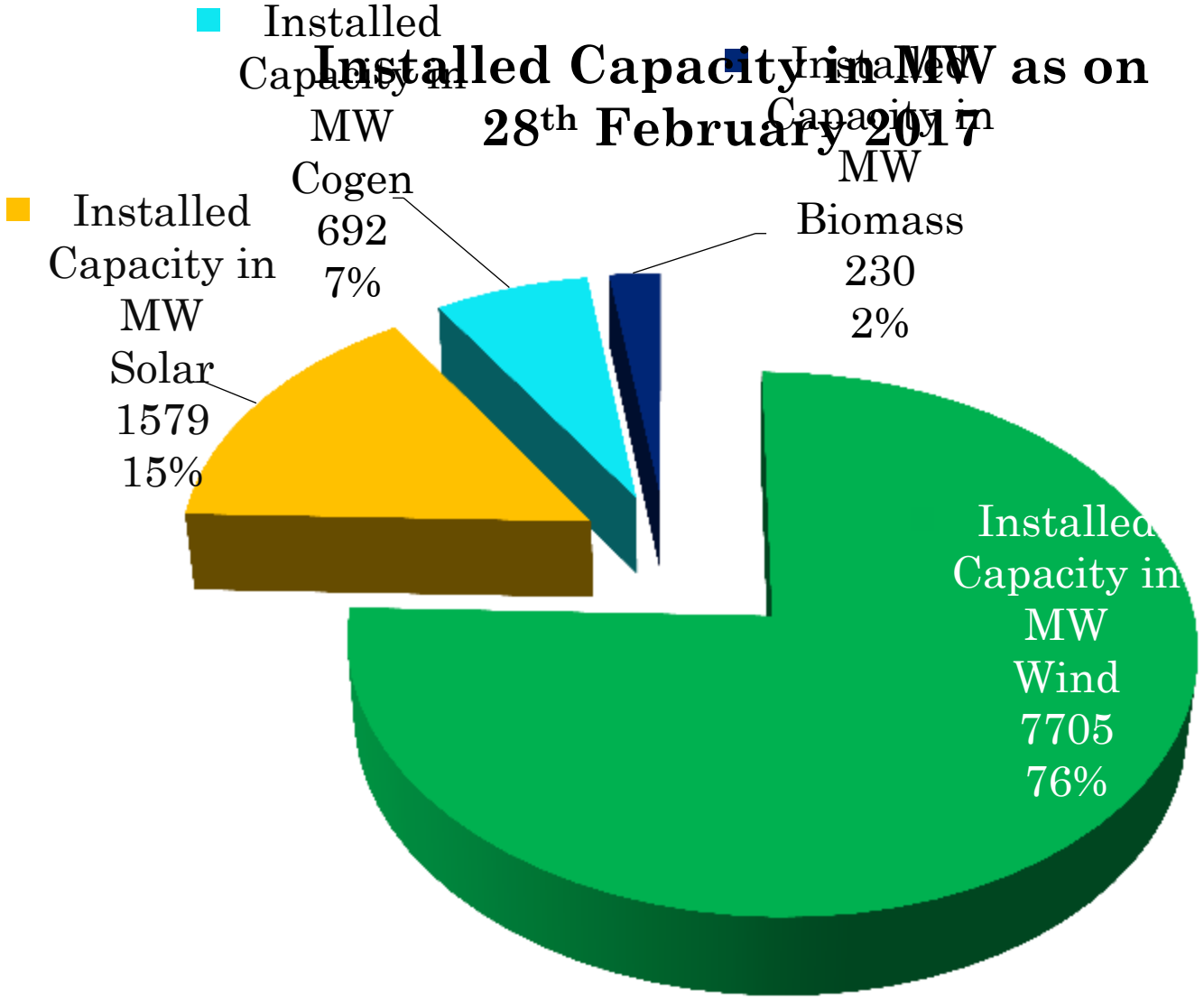
Installed Capacity in MW as on 28th February 2017



Conventional Generator	Installed Capacity in MW
TN Hydro	2308
TN Thermal	4660
TN Gas	516
TN IPP	746
CGS Thermal	4328
CGS Nuclear	1147
Purchase	3190
CPP	986
Total	17881

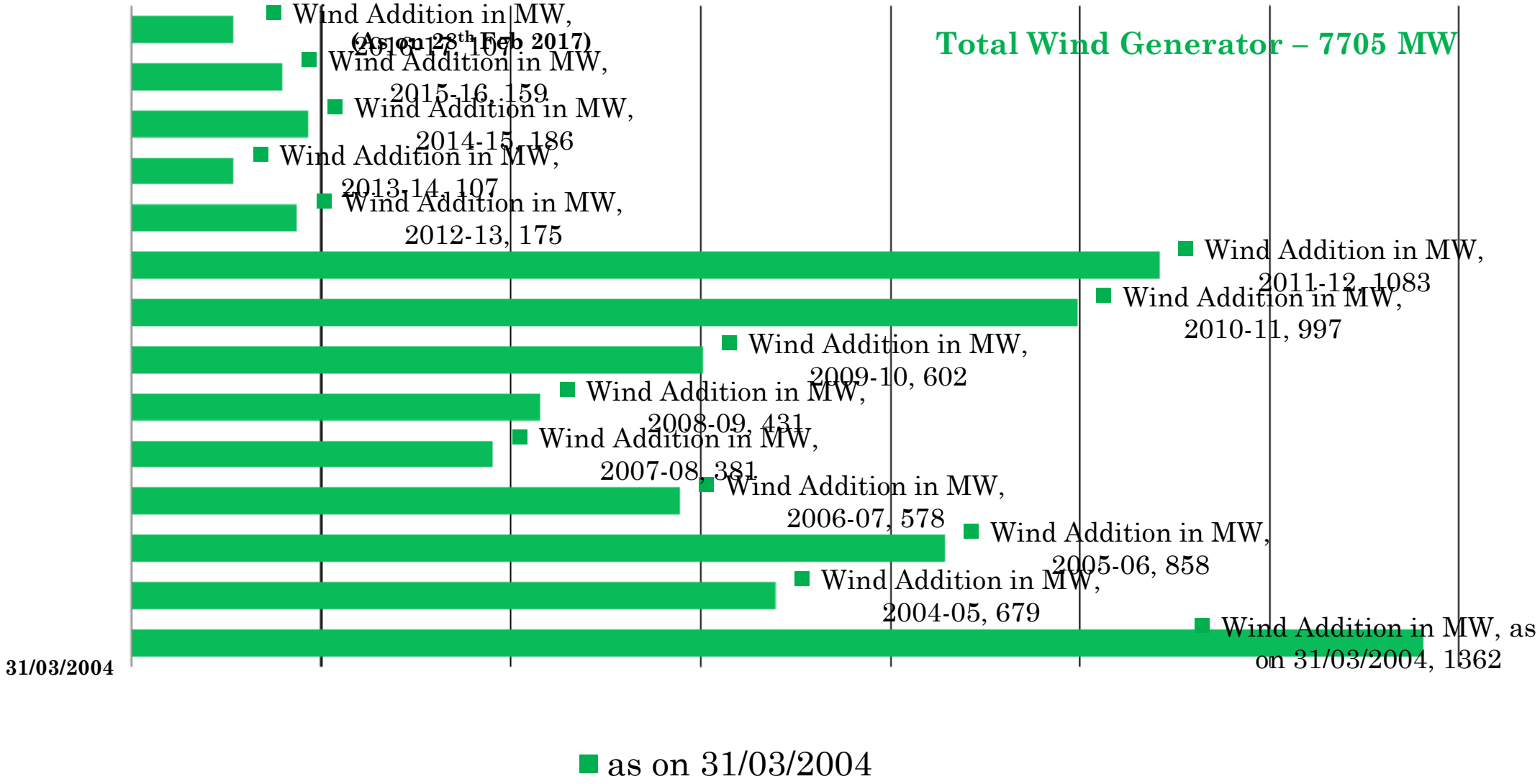
Tamil Nadu – Renewable Energy Generation Mix

Installed Capacity in MW as on 28th February 2017



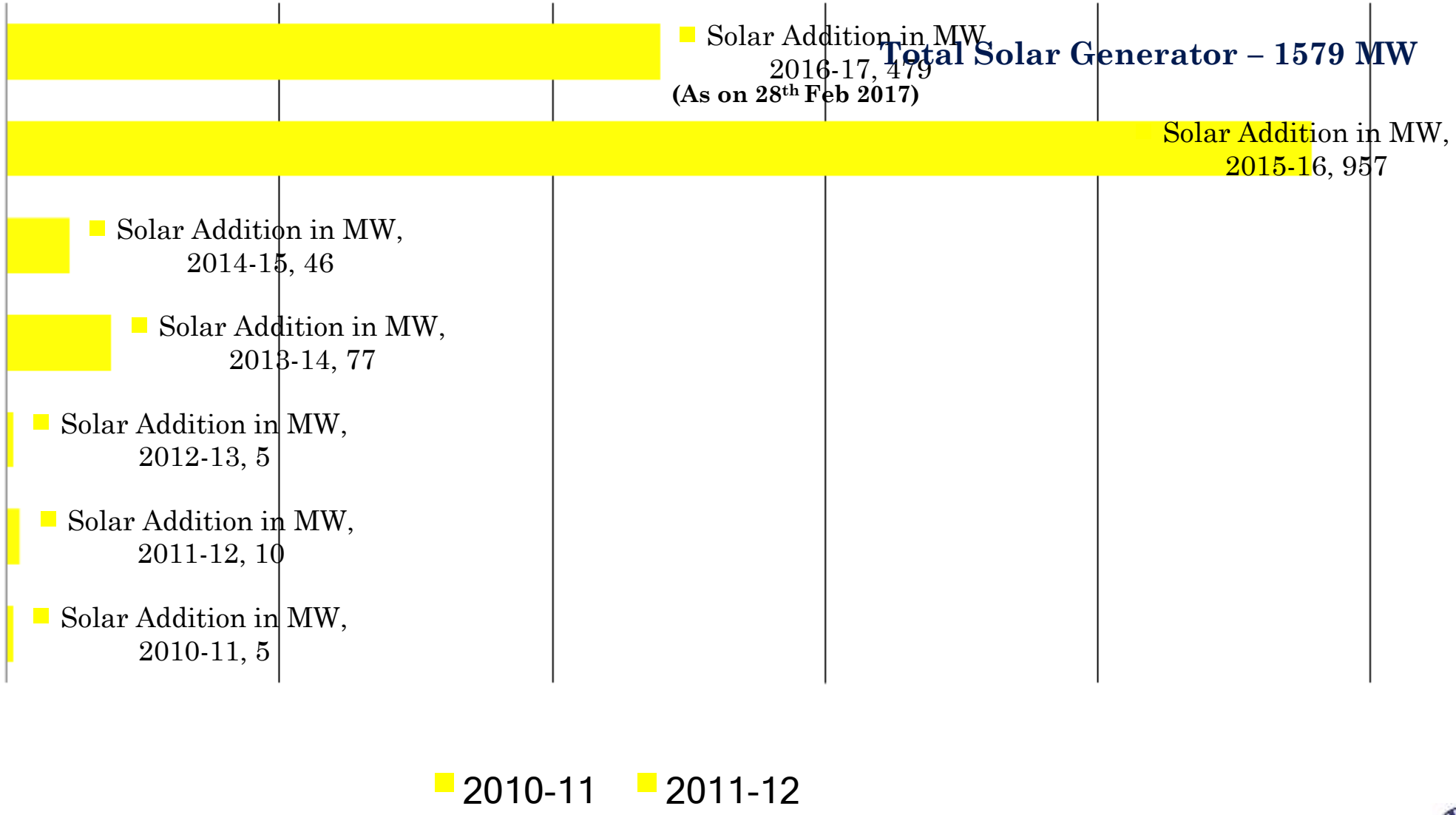
Renewable Energy Generator	Installed Capacity in MW
Wind	7705
Solar	1579
Cogen	690
Biomass	230
Total	10206

Wind Addition - Year Wise



All time high capacity addition of 1084 MW achieved during 2011-12

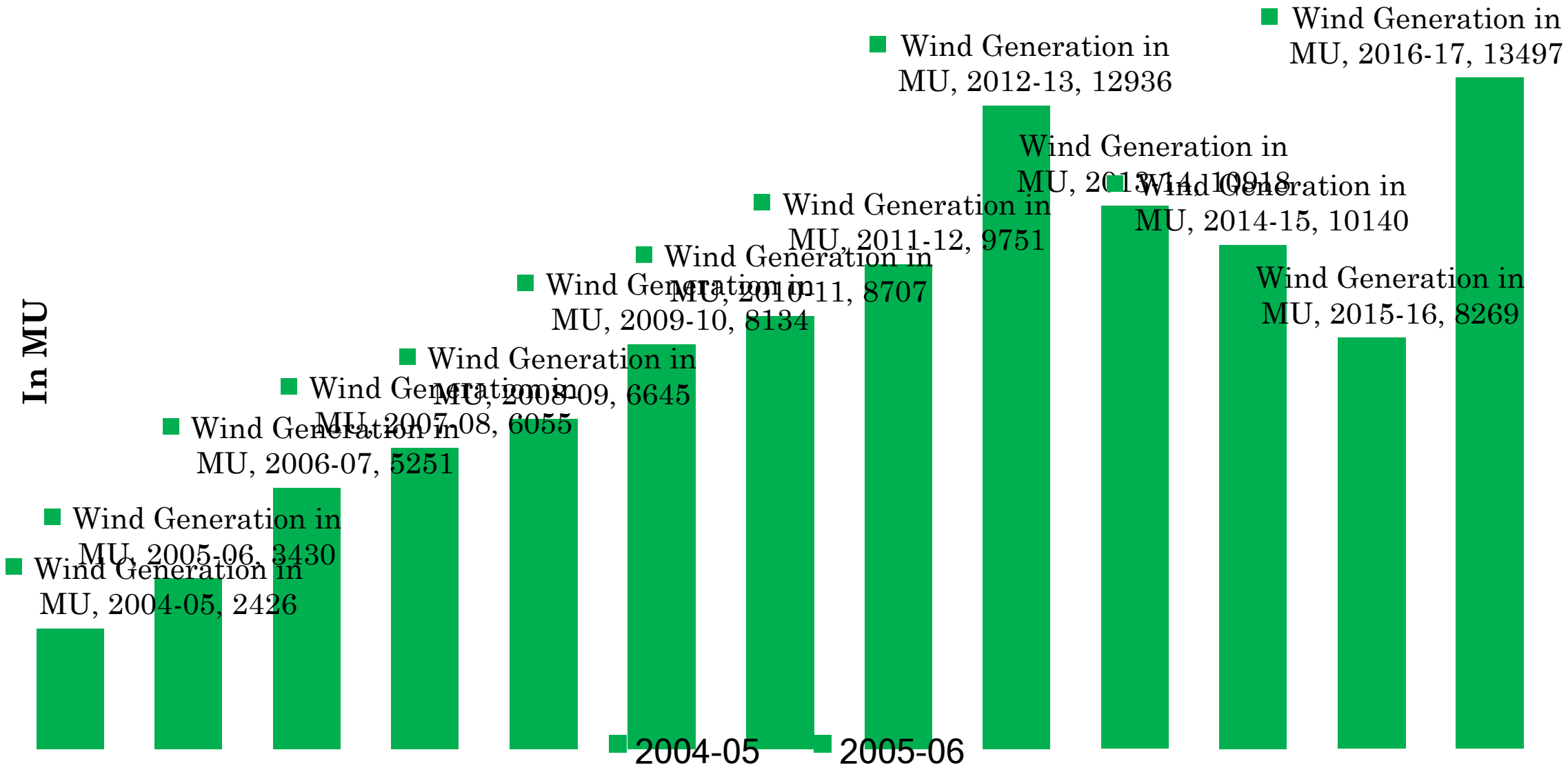
Solar Addition - Year Wise



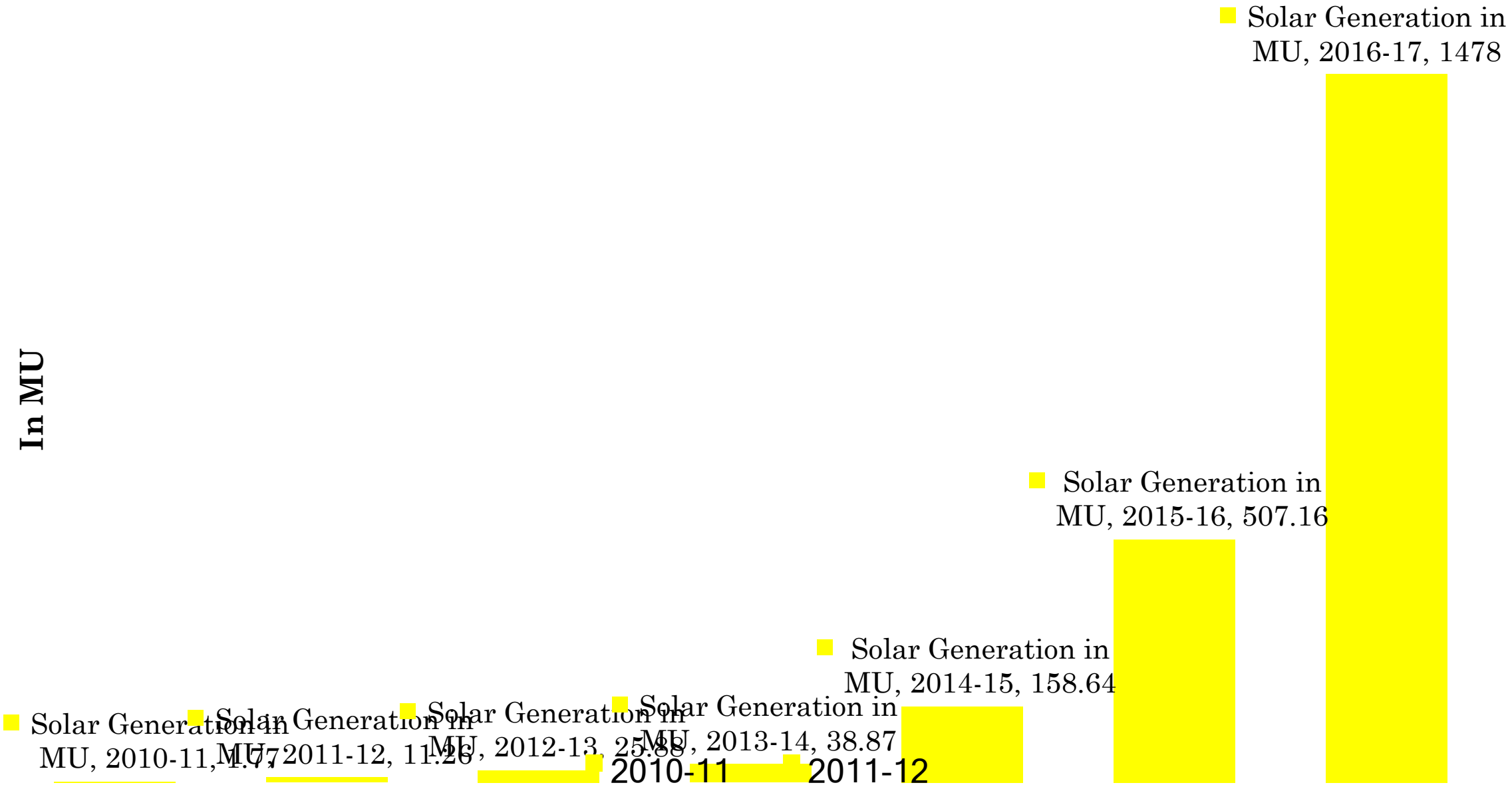
Total Solar Generator – 1579 MW

(As on 28th Feb 2017)

Tamil Nadu – Wind Generation in MU Year wise



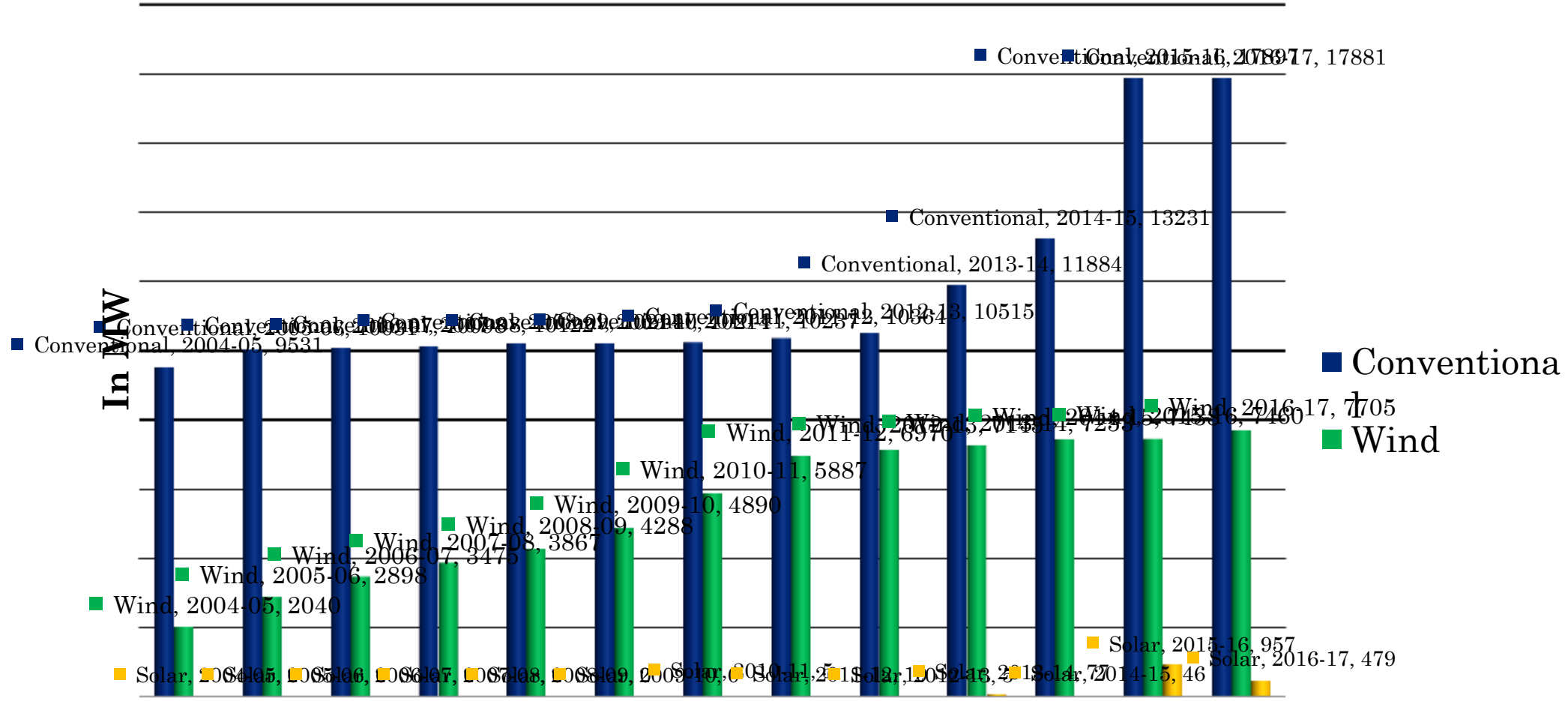
Tamil Nadu – Solar Generation in MU Year wise



Tamil Nadu High Energy Consumption Details Achieved in a Day

Details	Achieved	On
Consumption	345.617 MU	29th April 2016
Demand	15343 MW	29th April 2016
Wind Energy	97.351 MU	16th August 2016
Wind Generation	4906 MW	29th August 2016
Solar Energy	9.198 MU	23rd February 2017
Solar Generation	1443 MW	19th February 2017

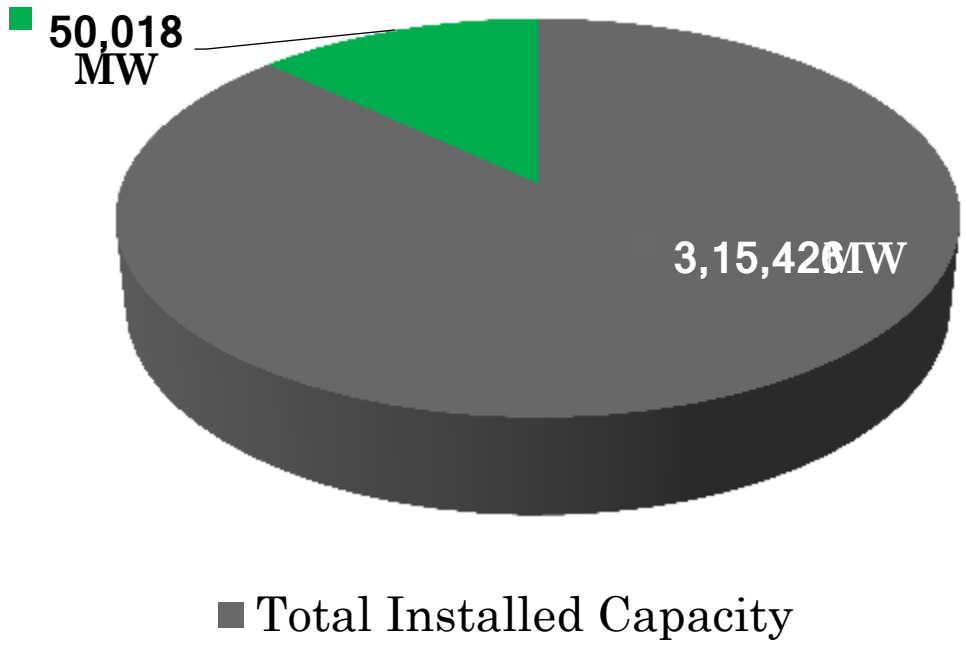
Installed Capacity – Renewable Vs Conventional



All India Installed Capacity Scenario

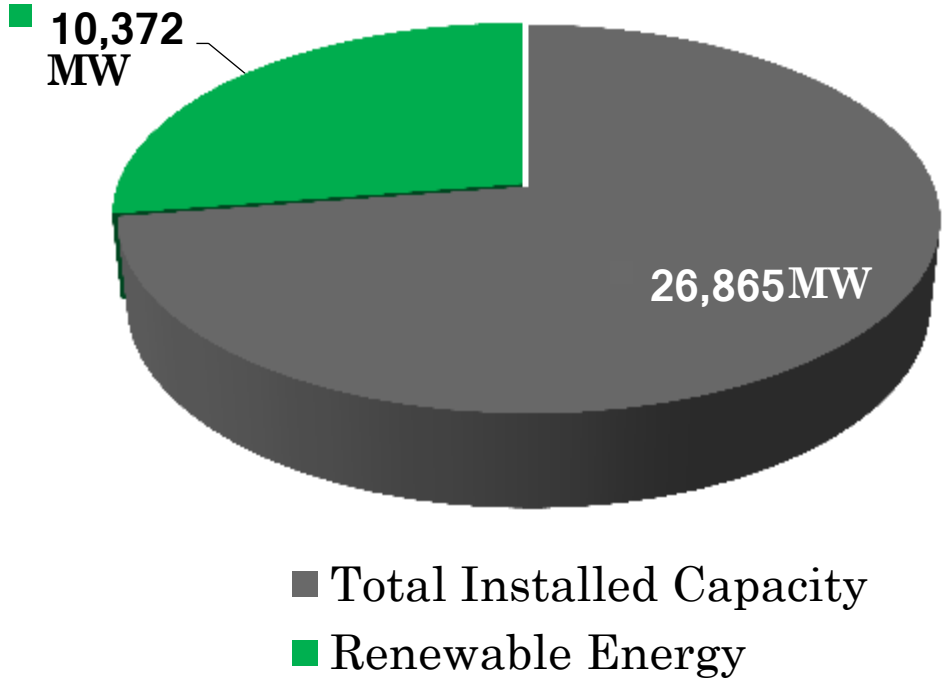
(as on 28th Feb 17 - source from CEA)

All India



RE penetration 15.85% of Total Installed Capacity

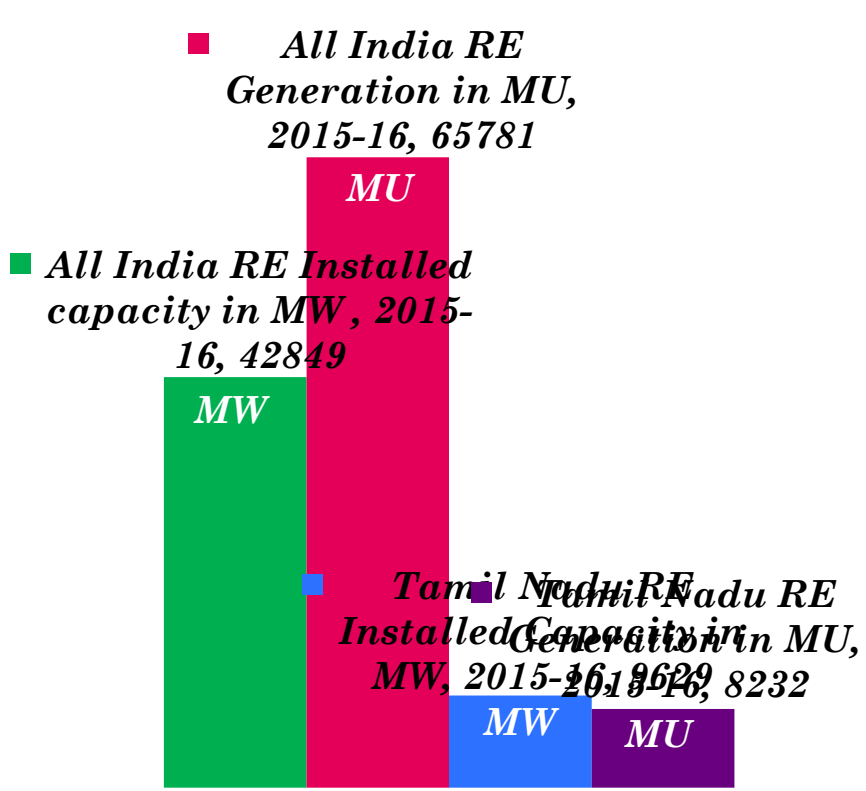
Tamil Nadu

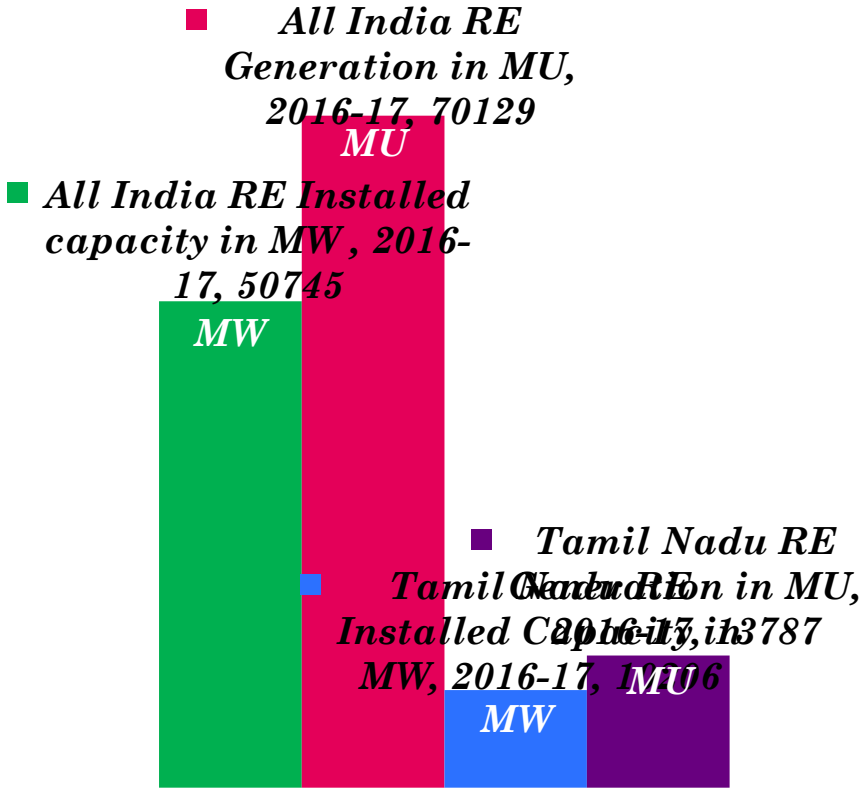


RE penetration 38.5% of Total Installed Capacity

TN Contributes to 21% of country's RE installed capacity

RE Installed Capacity Vs Generation

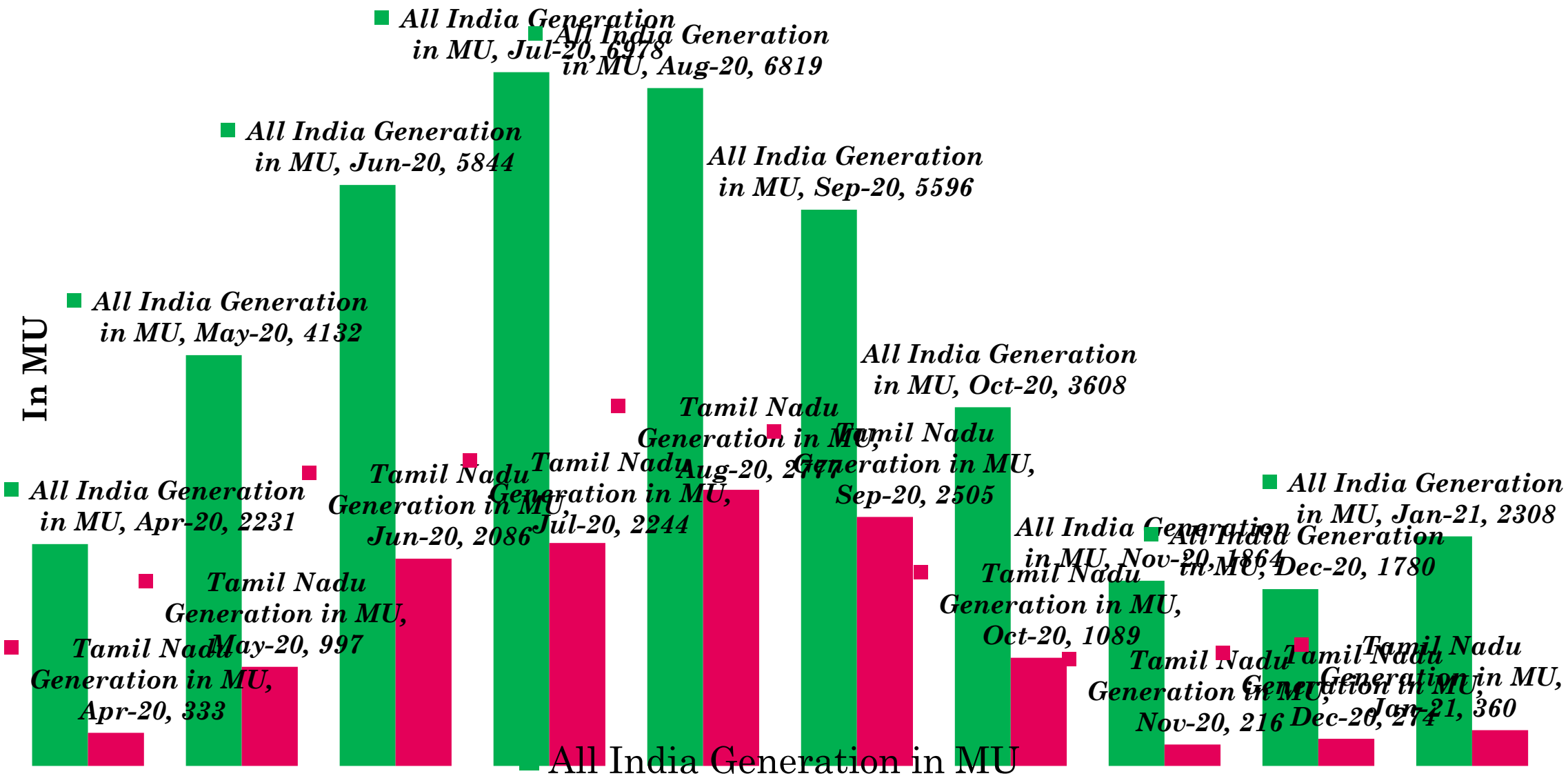




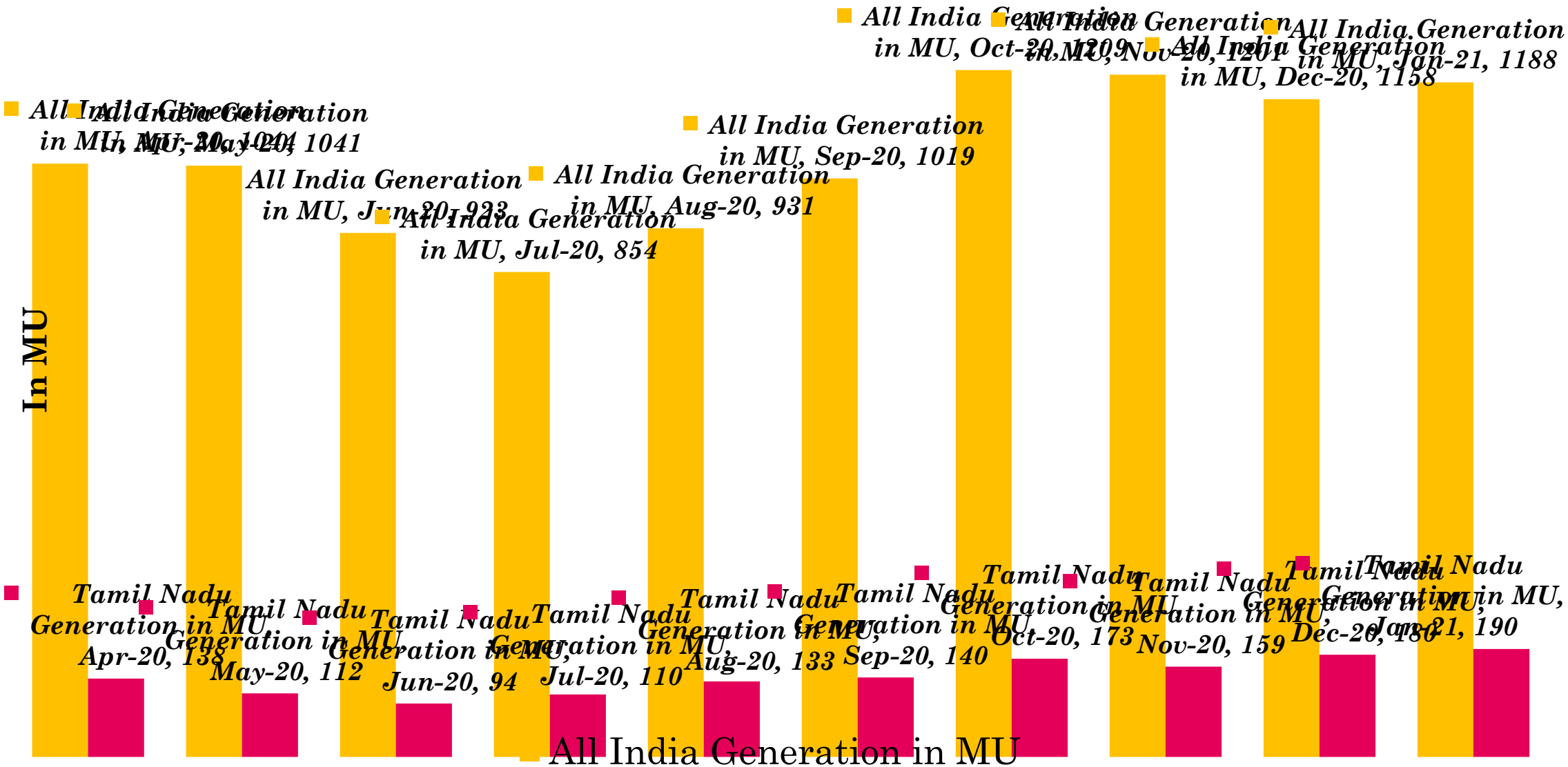
(Up to Jan 17)

- *All India RE Installed capacity in MW*
- *All India RE Generation in MU*
- *Tamil Nadu RE Installed Capacity in MW*

All India Vs Tamil Nadu – Wind Generation in MU



All India Vs Tamil Nadu – Solar Generation in MU

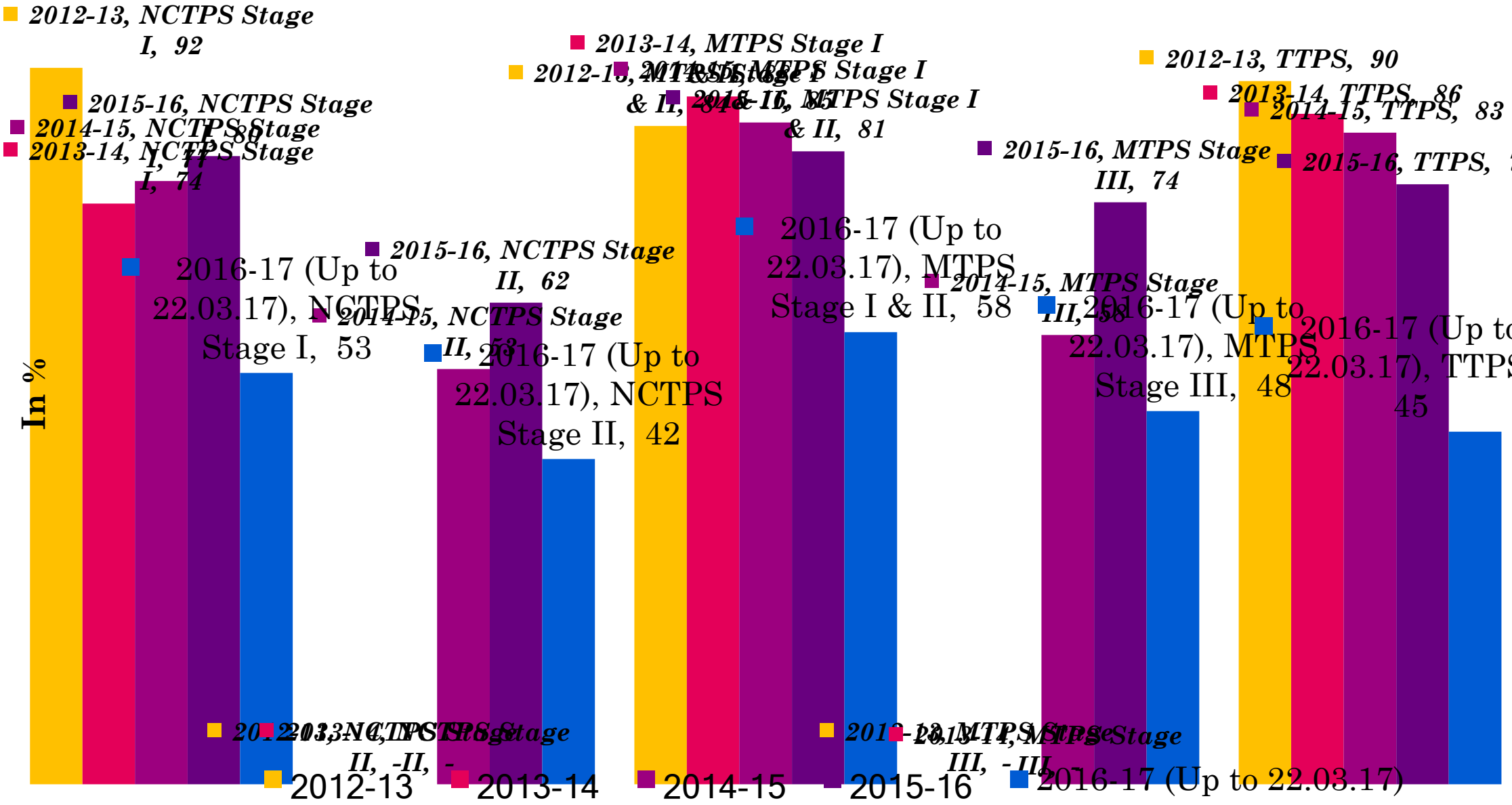


Action taken

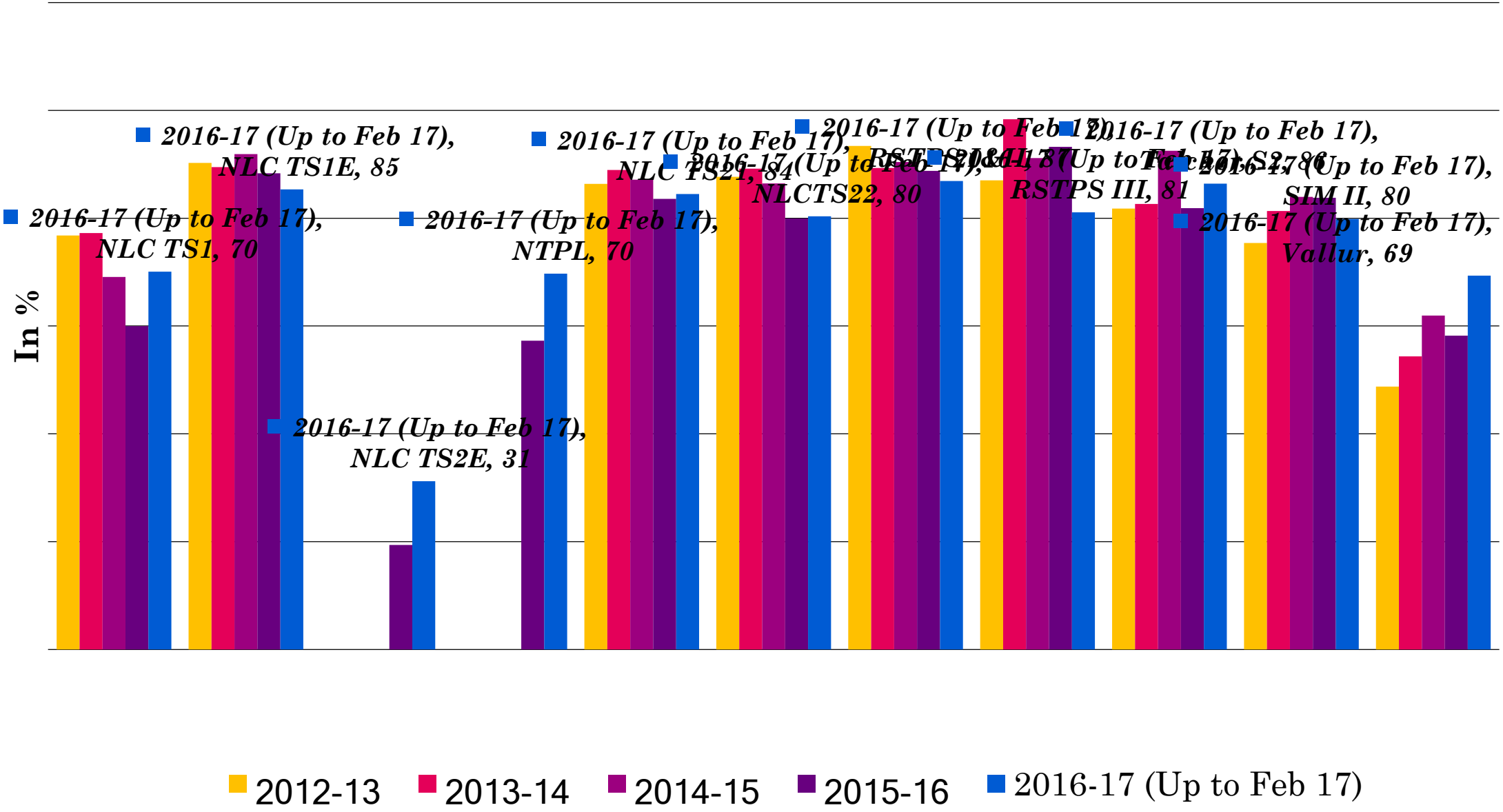
- **Load Shedding relaxed - 1st June 2014**
- **Restriction & Control measures relaxed - 5th June 2015**
- **AOH/COH for 2 to 3 TANGEDCO Thermal machines simultaneously- completed in June to September**
- **1 or 2 TANGEDCO Thermal Stations - Reserve Shut down**
- **AOH of CGS - Insisted in SRPC to complete in June to September.**
- **Sale of Power out the State - Resorted**

Thermal Stations PLF

TNEB Thermal Power Stations PLF

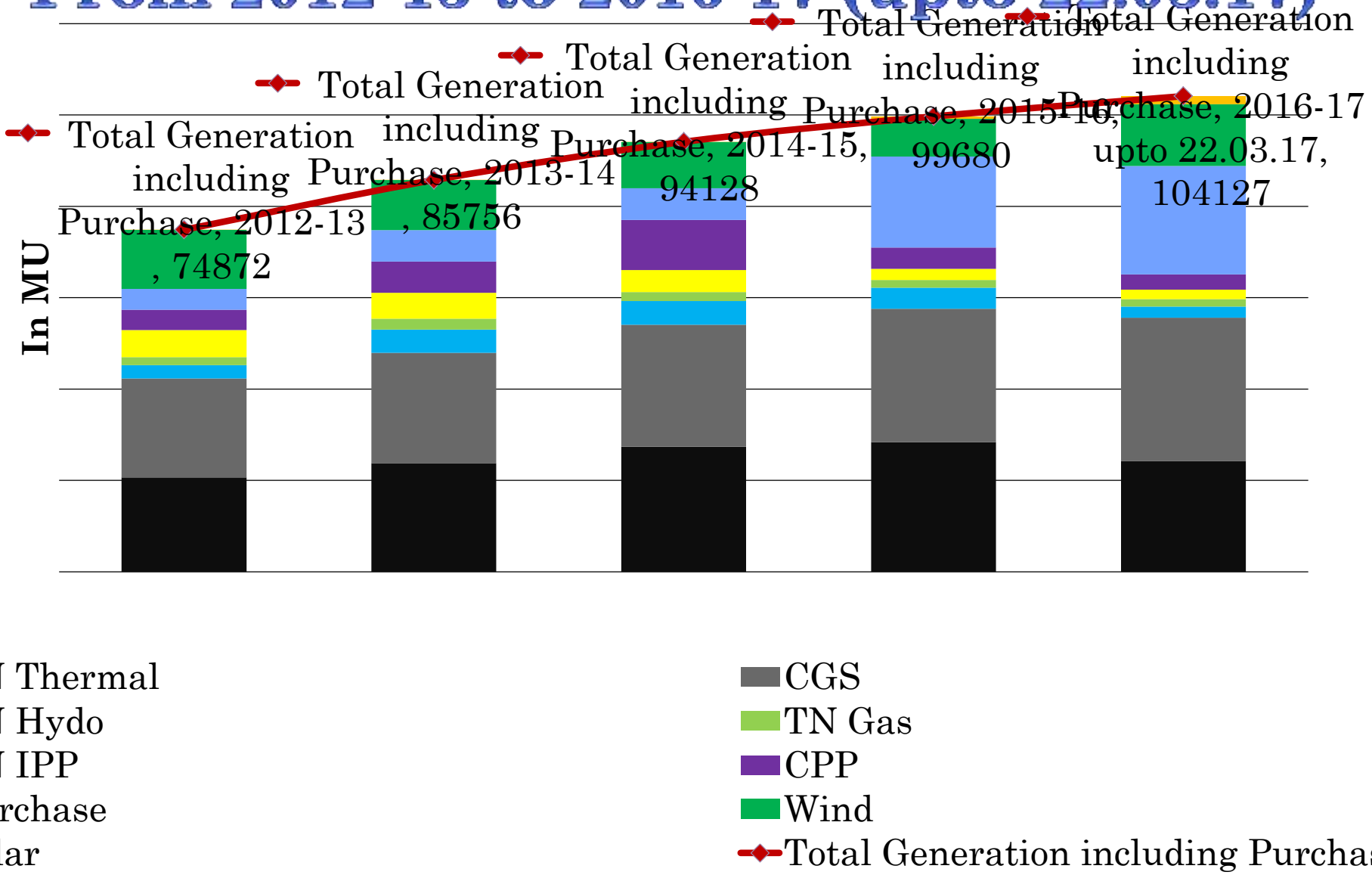


CGS Stations PLF

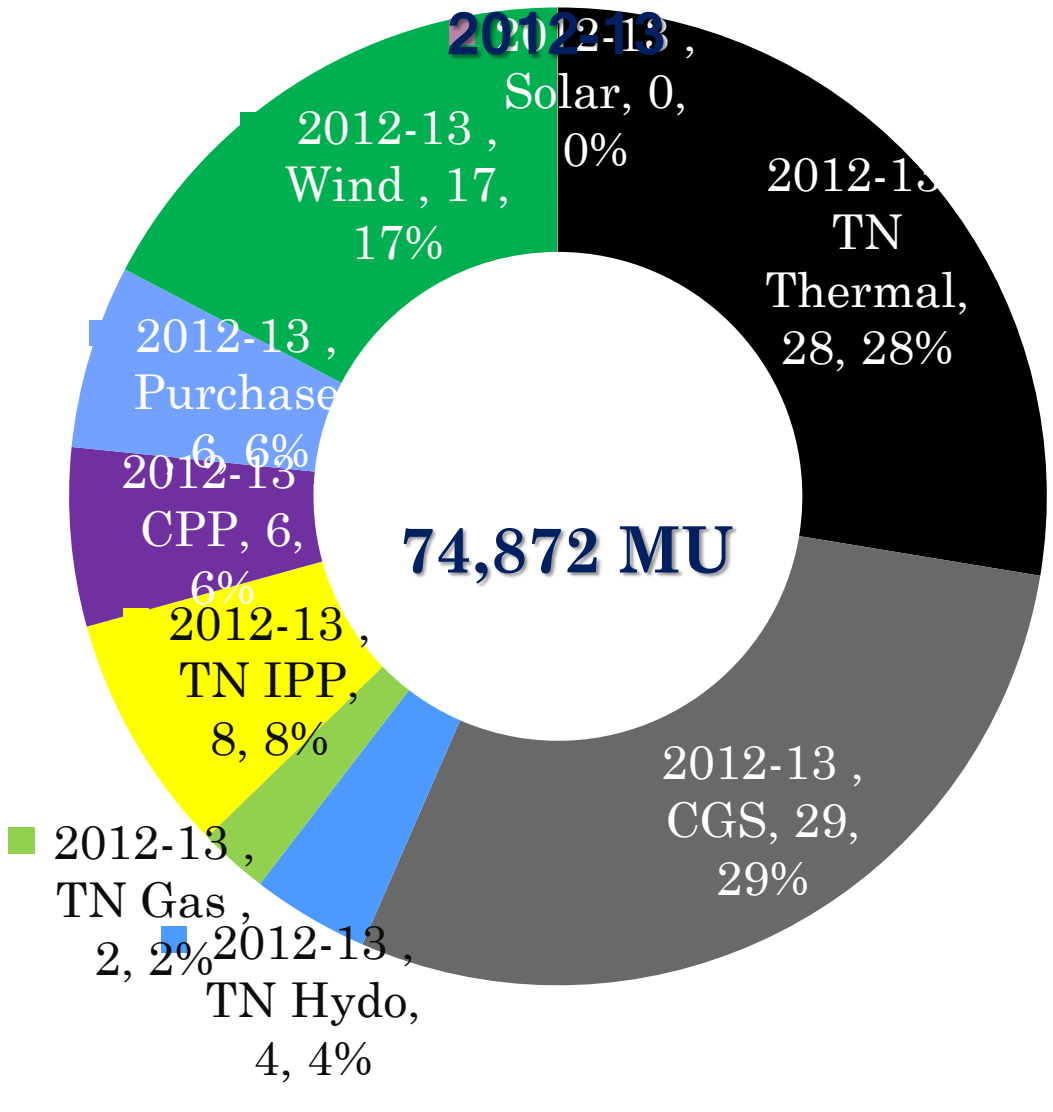


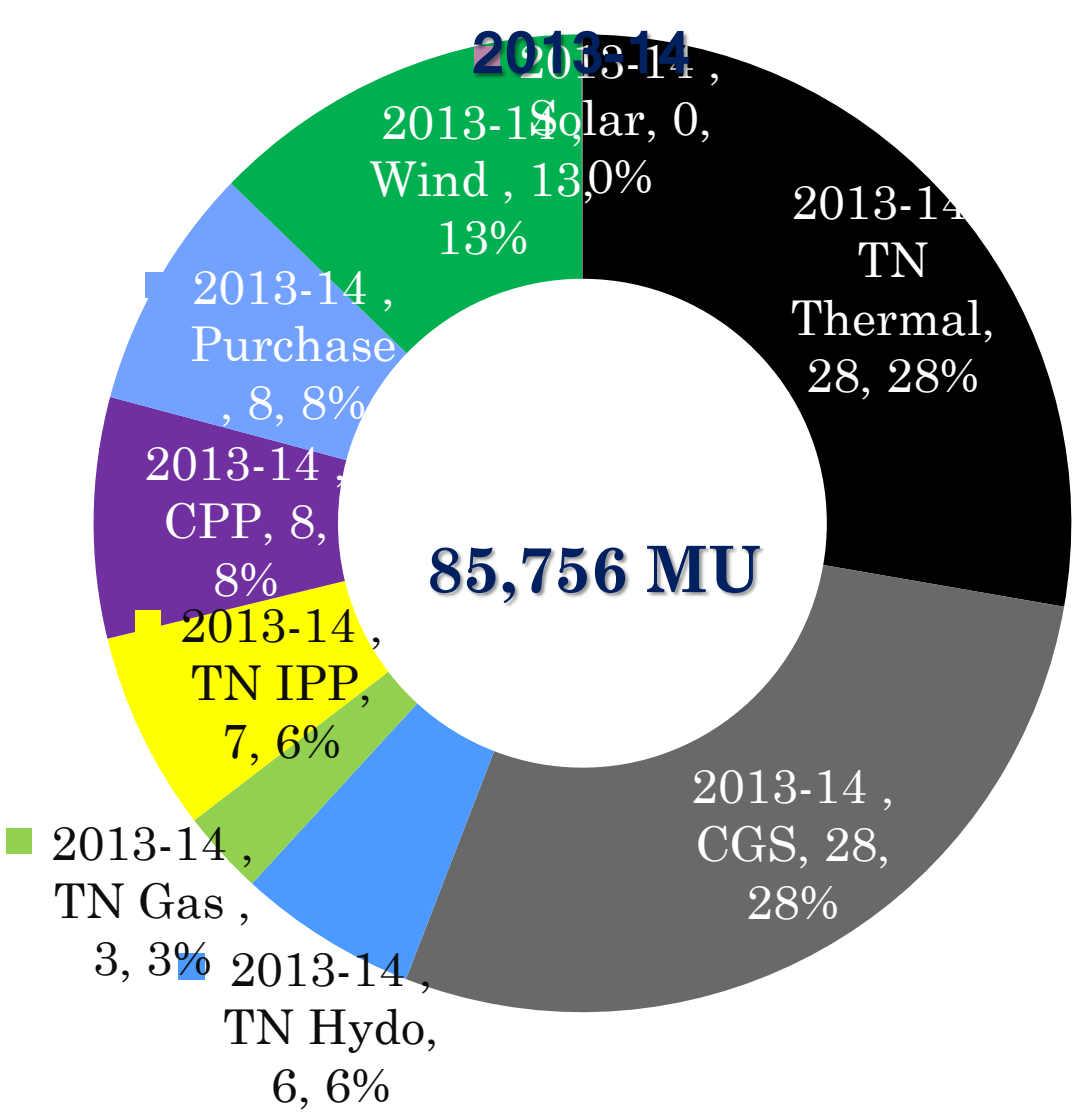
Total Generation from 2012-13 to 2016-17 (up to 22.03.17)

Total Energy Generated including Power Purchase From 2012-13 to 2016-17 (upto 22.03.17)

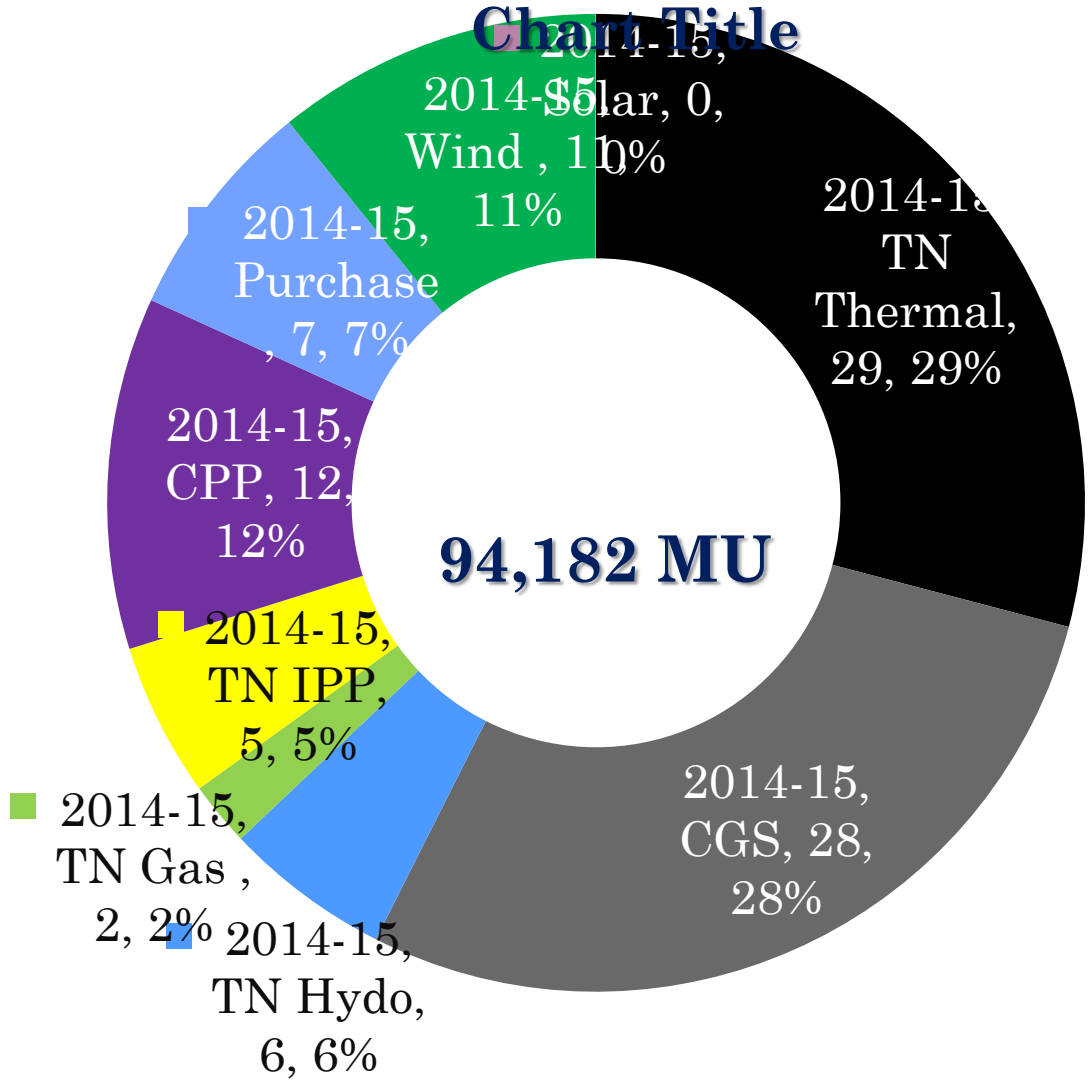


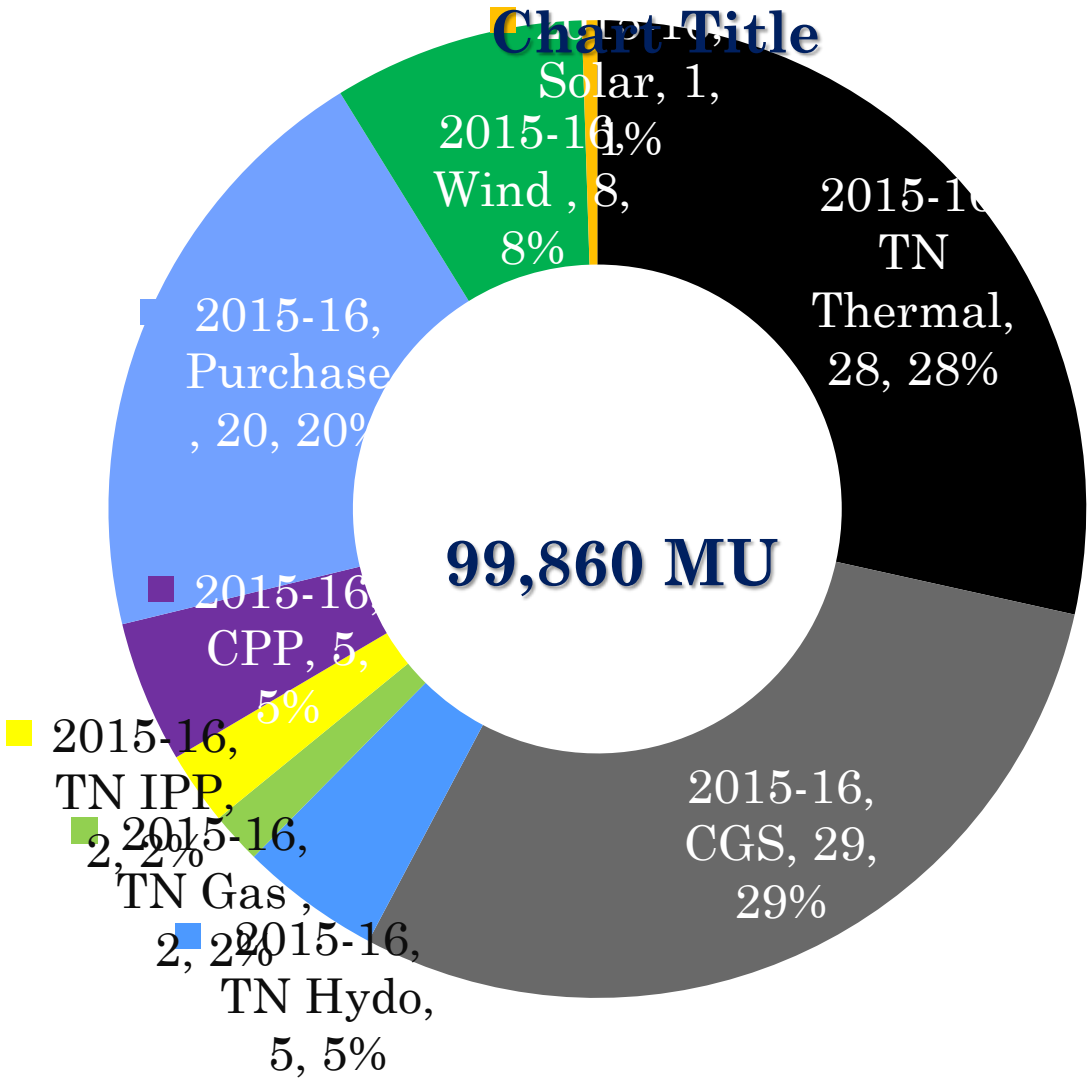
Year wise - % Contribution of Various Sources



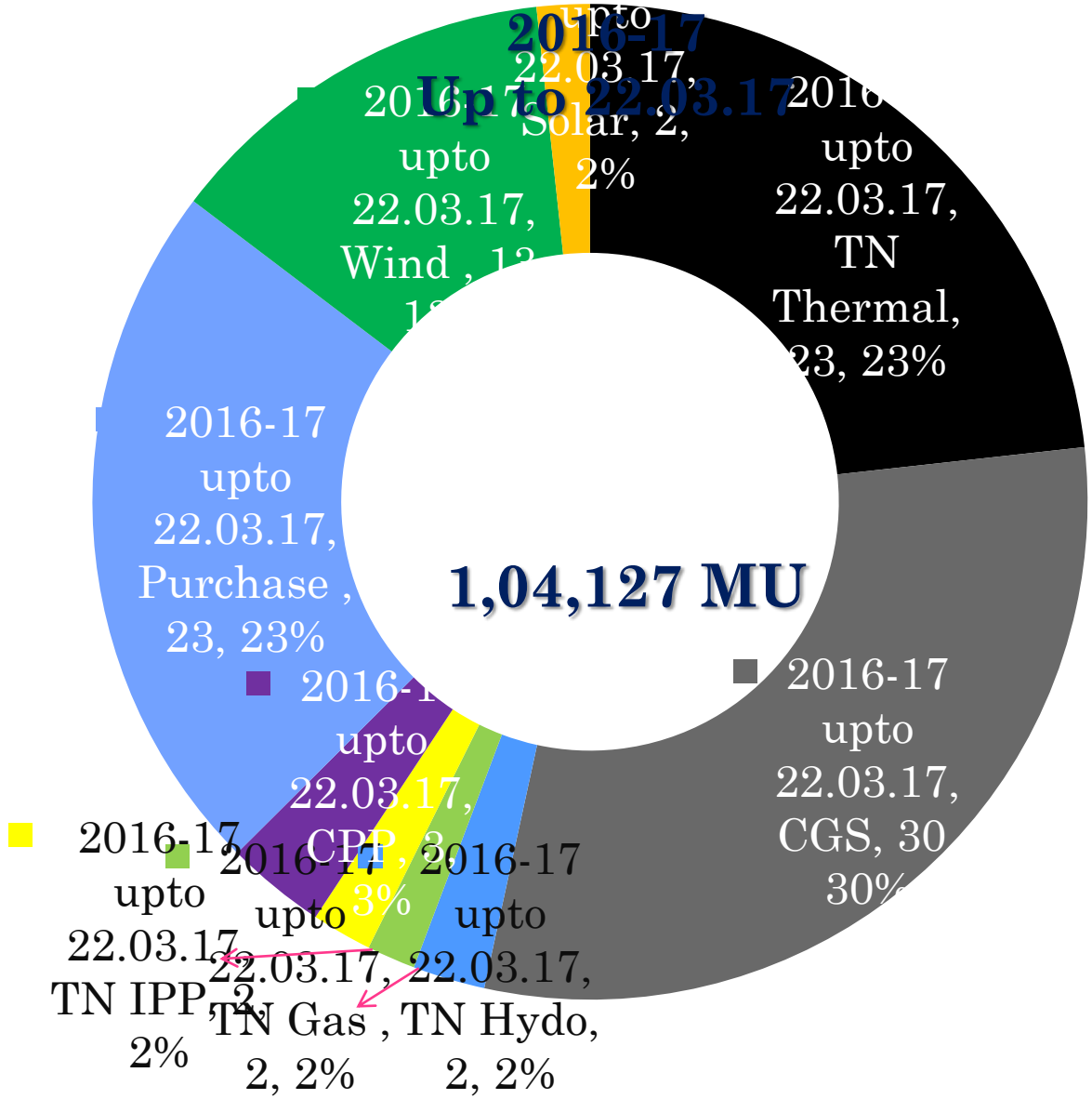


Year wise - % Contribution of Various Sources



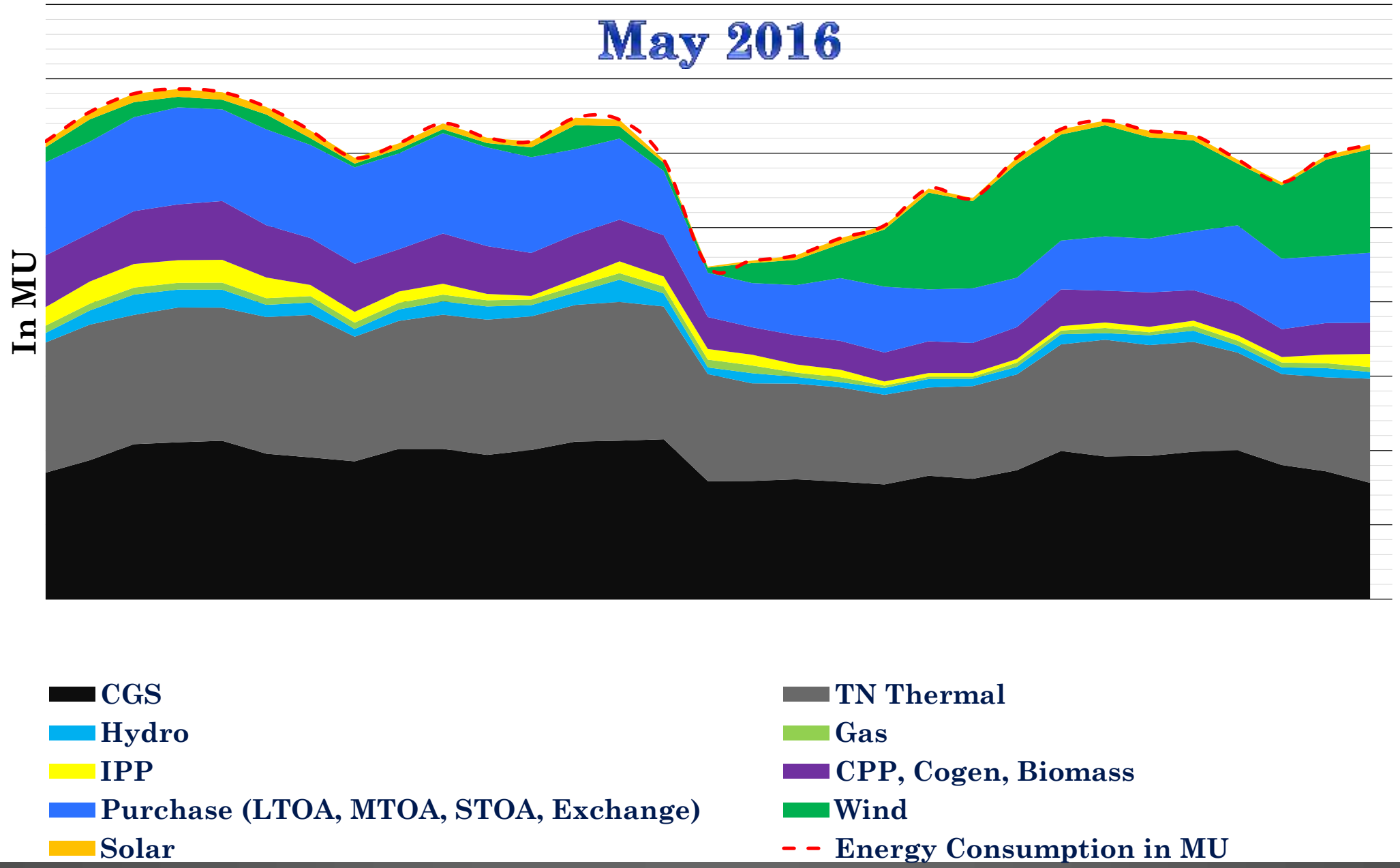


Year wise - % Contribution of Various Sources

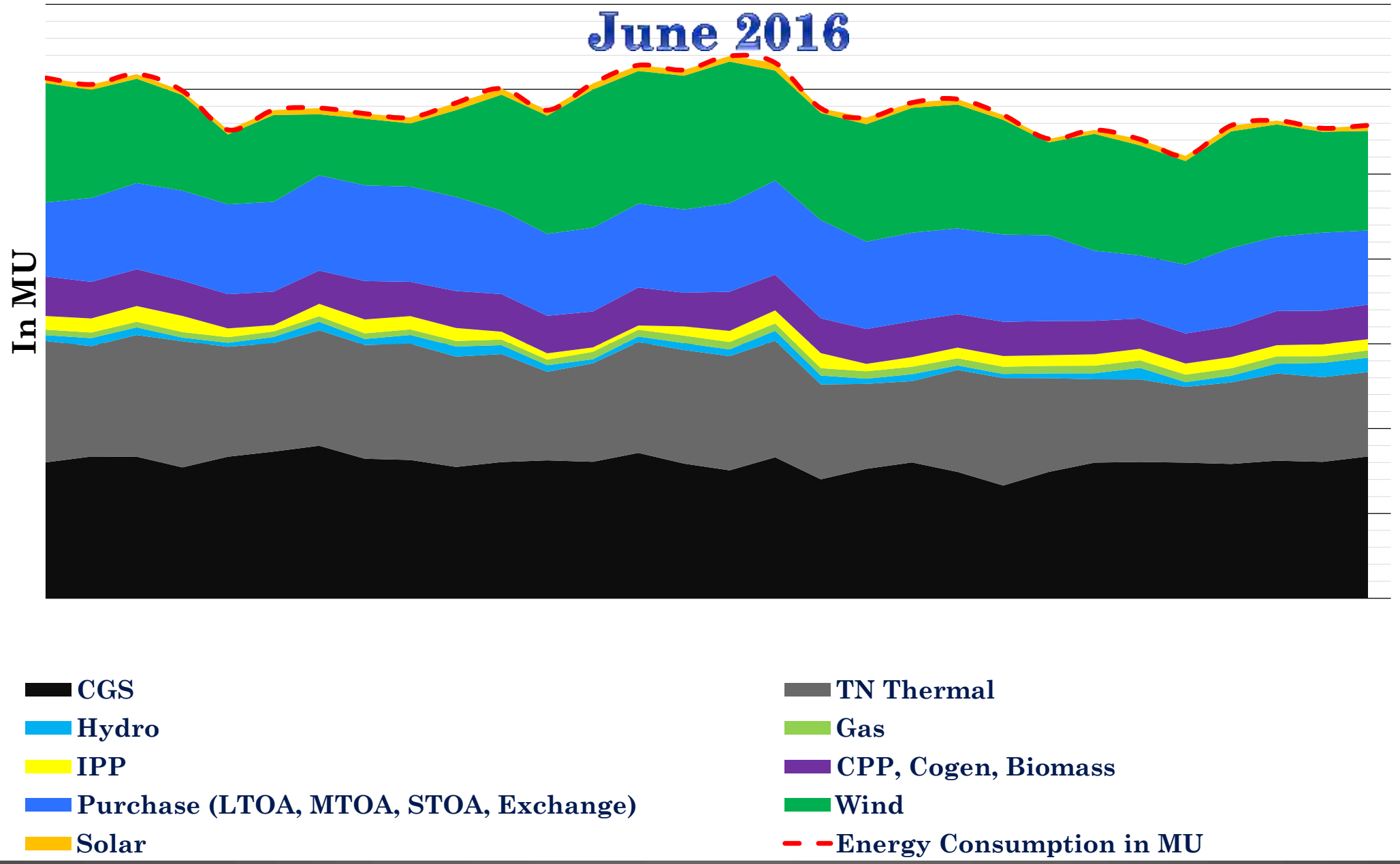


Wind Accommodation during 2016-17

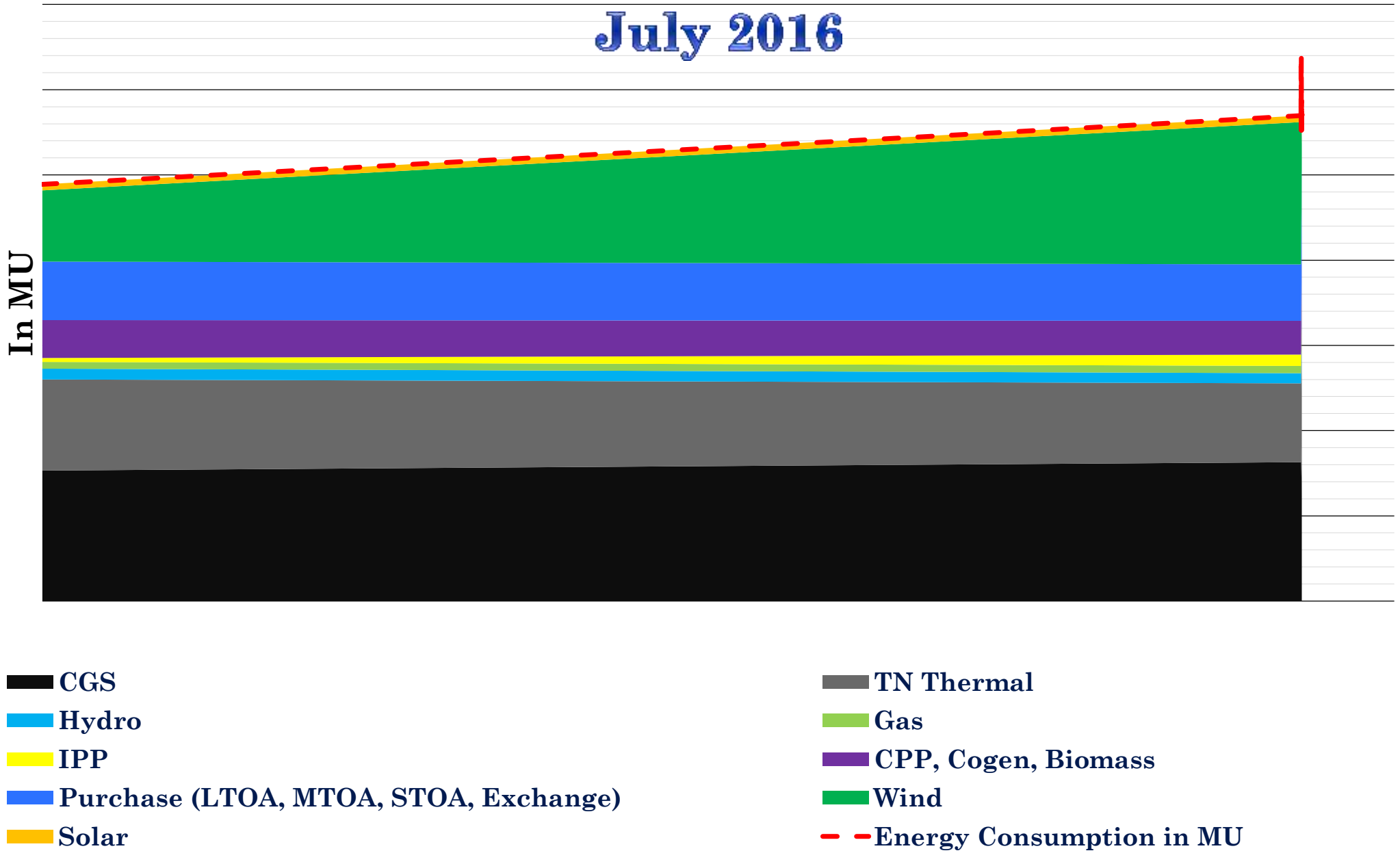
Energy Consumption Details and Category wise split up details



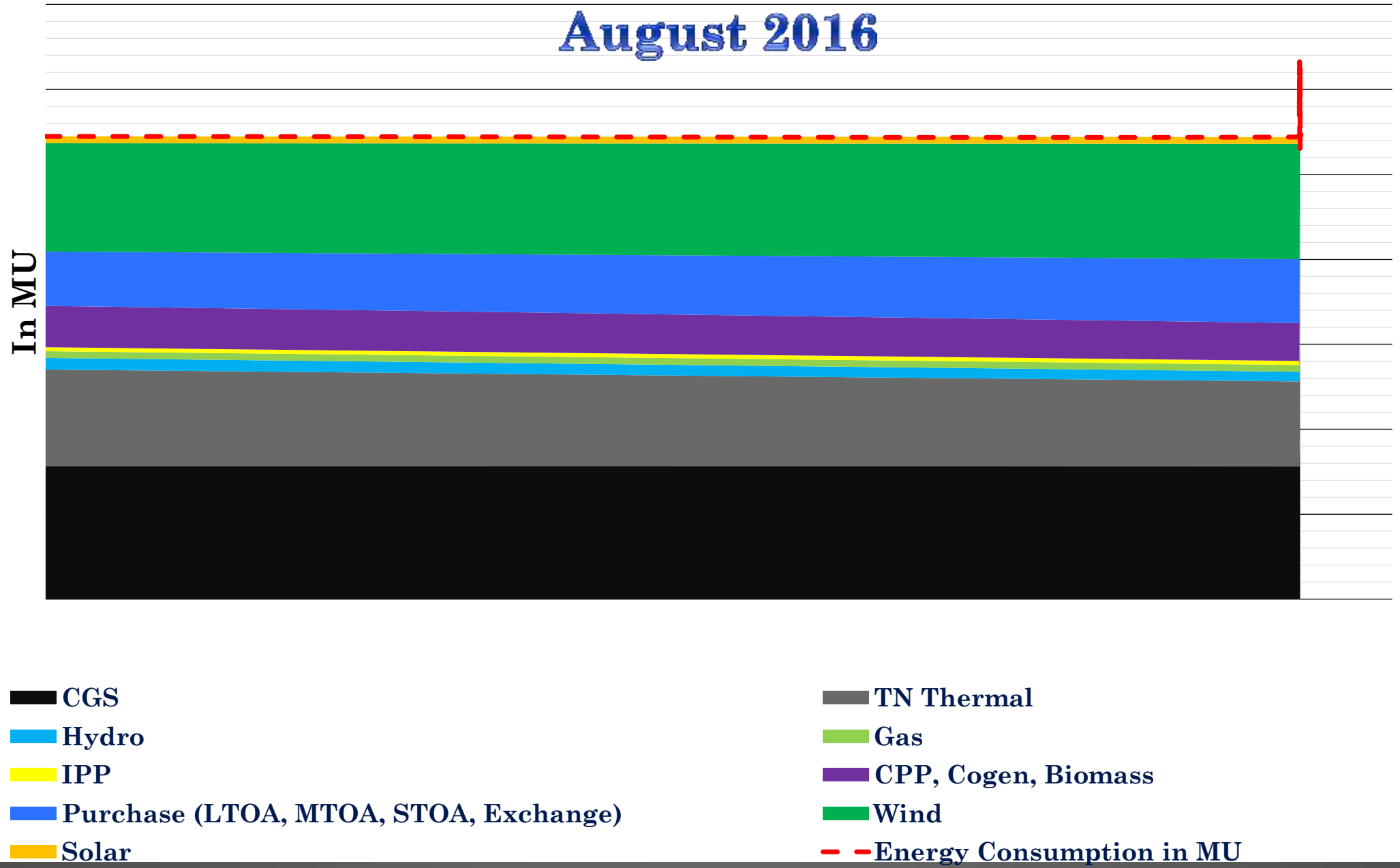
Energy Consumption Details and Category wise split up details



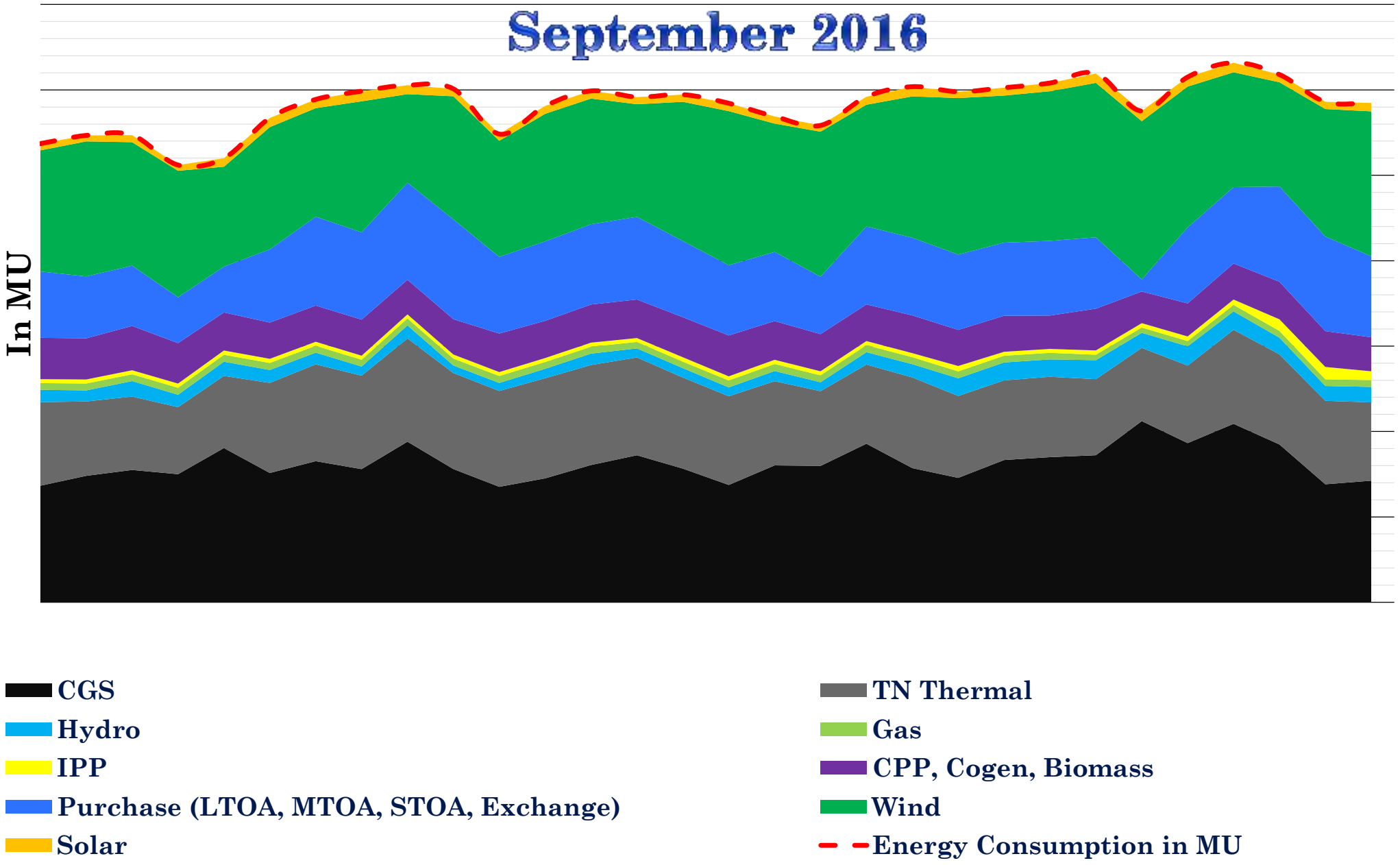
Energy Consumption Details and Category wise split up details



Energy Consumption Details and Category wise split up details

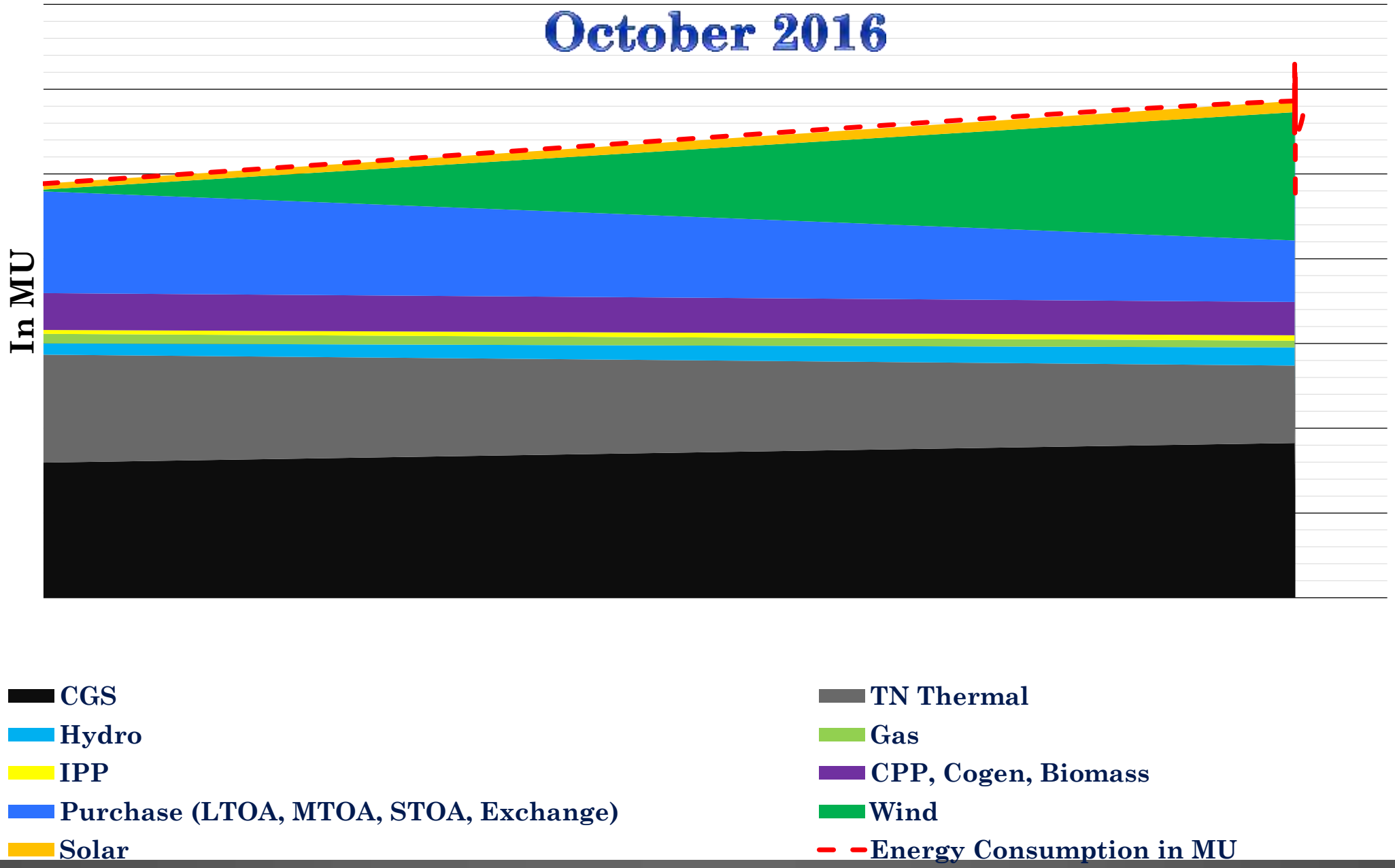


Energy Consumption Details and Category wise split up details



Energy Consumption Details and Category wise split up details

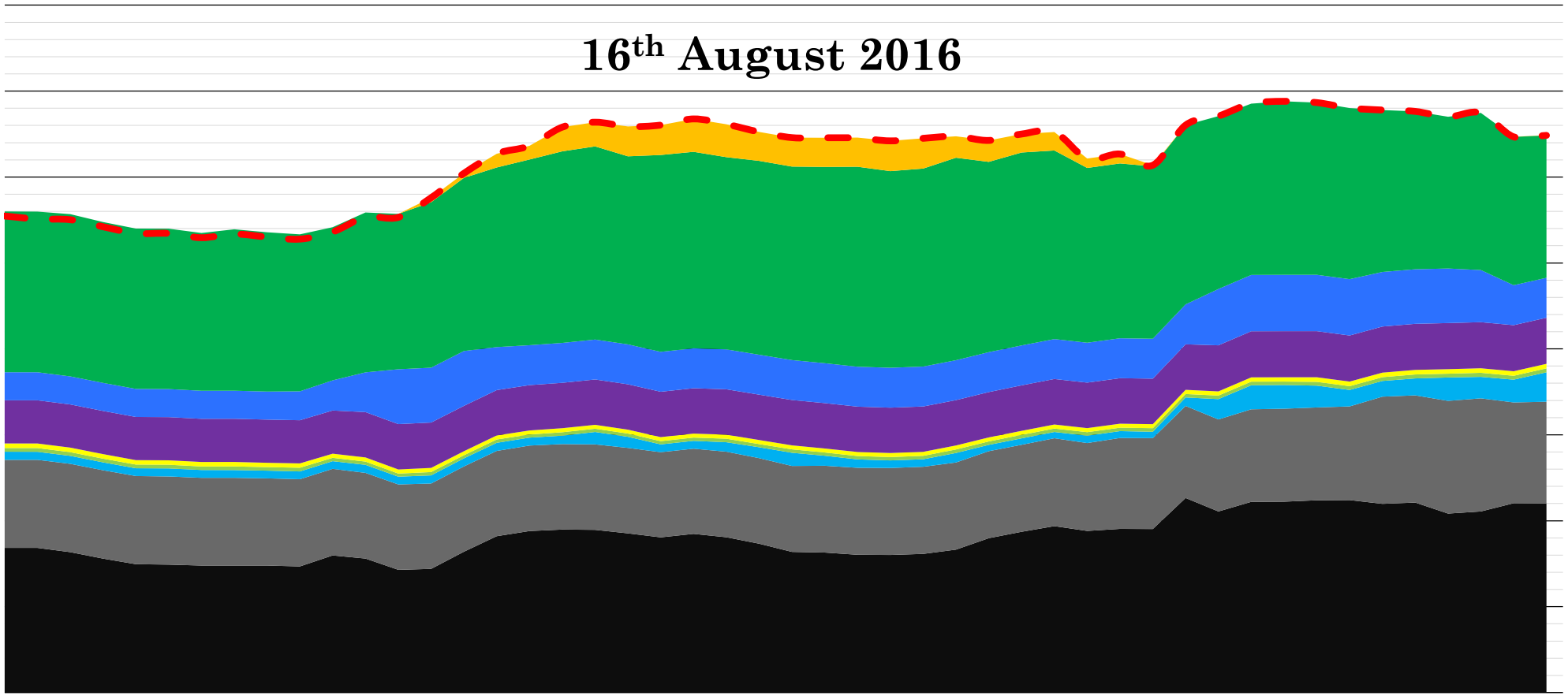
October 2016



Wind Accommodation – Effects on Other Sources of Generation in a day during

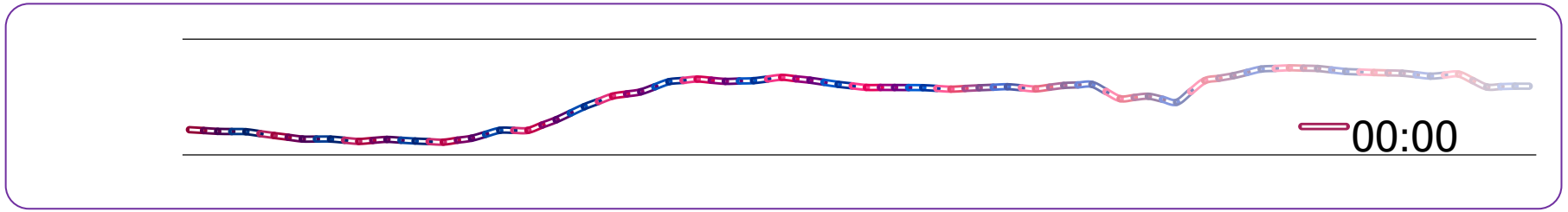
1. High Wind day – 16th August 2016
2. No/Low Wind day – 15th October 2016

Hourly Generation Split up – on High Wind Absorption day



CGS
Hydro
IPP
Purchase (LTOA, MTOA, STOA, Exchange)
Solar
TN Thermal
Gas
CPP, Cogen, Biomass
Wind
Demand

Day Consumption : 297.062 MU
Wind contribution : 97.351 MU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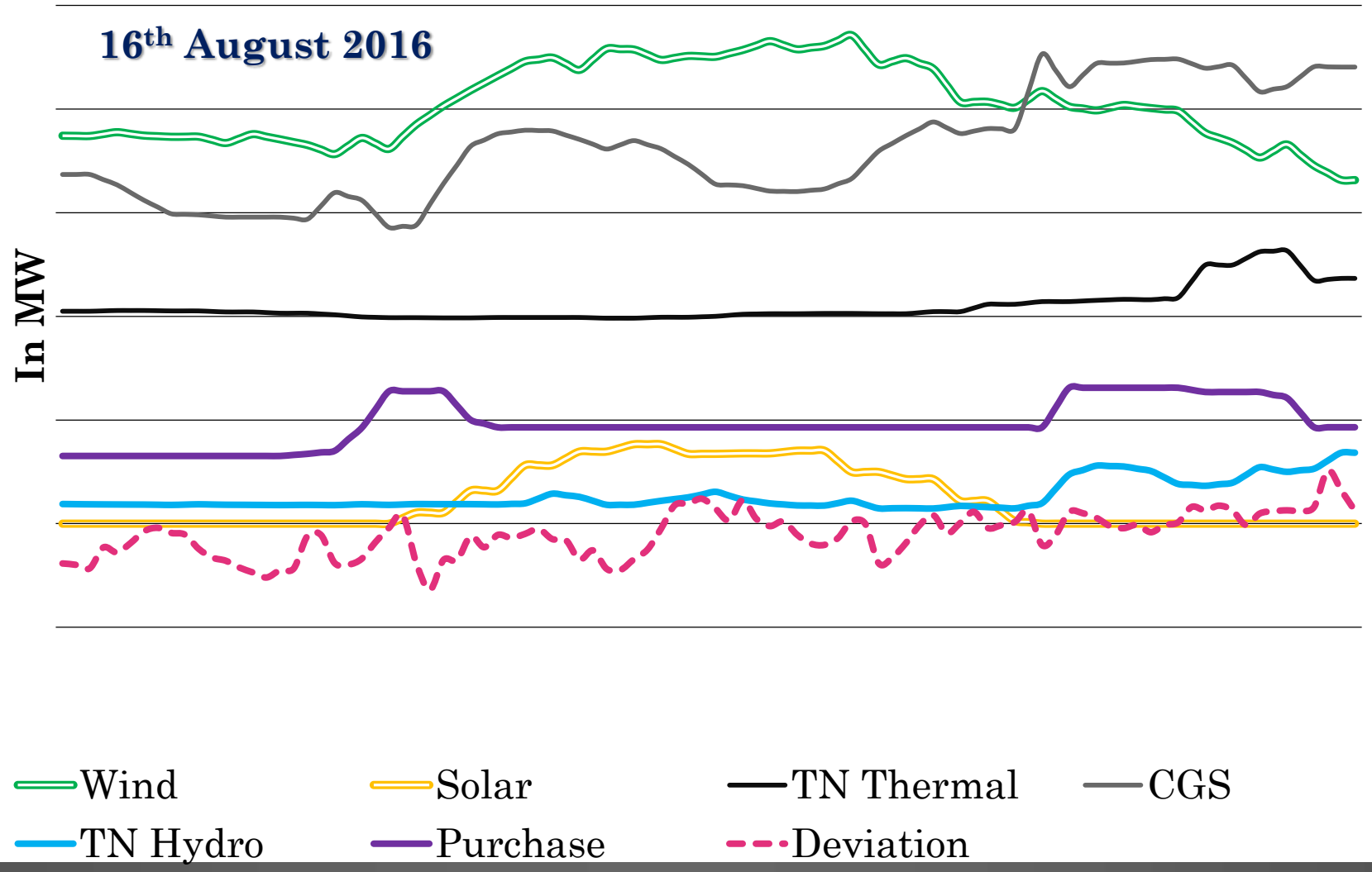
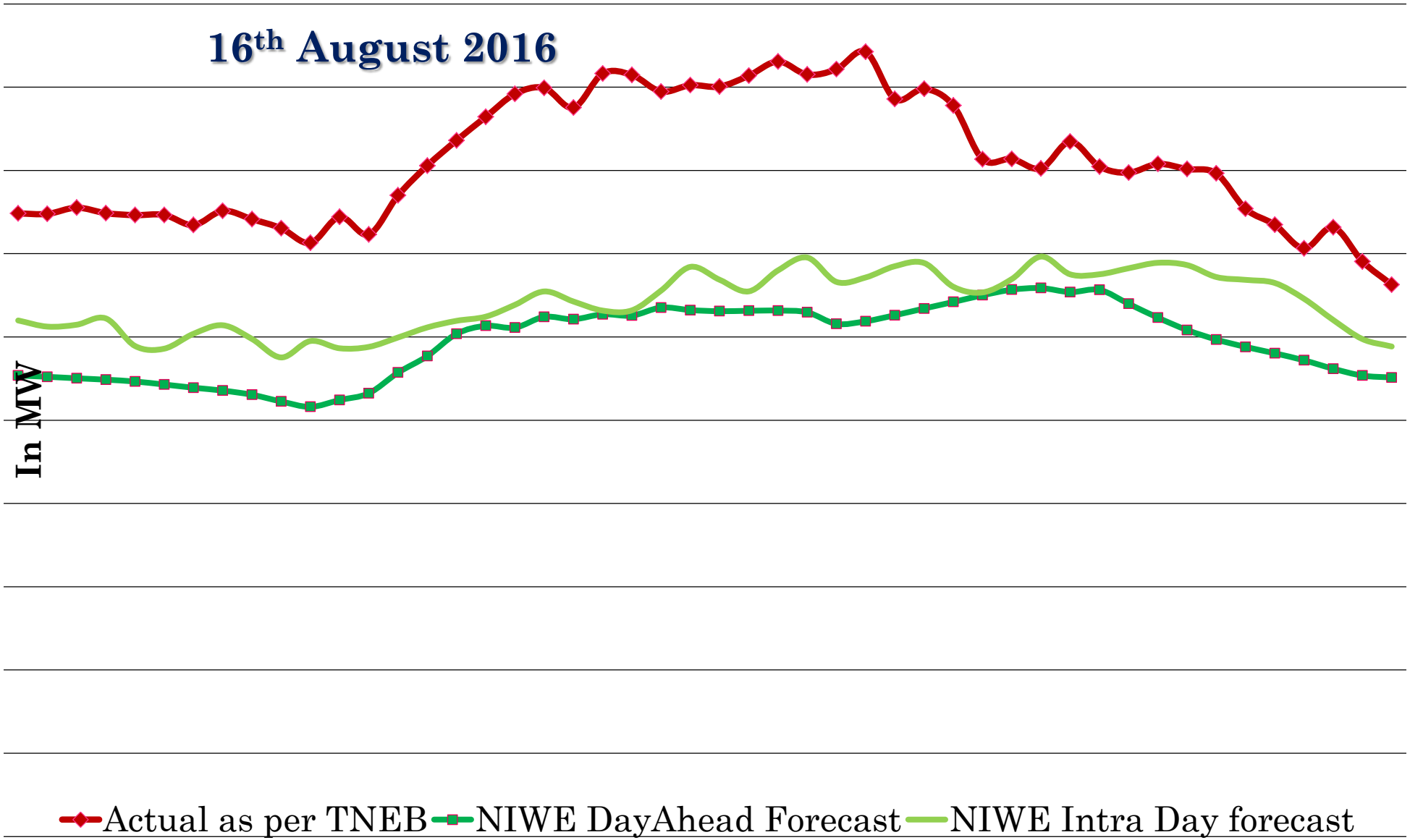
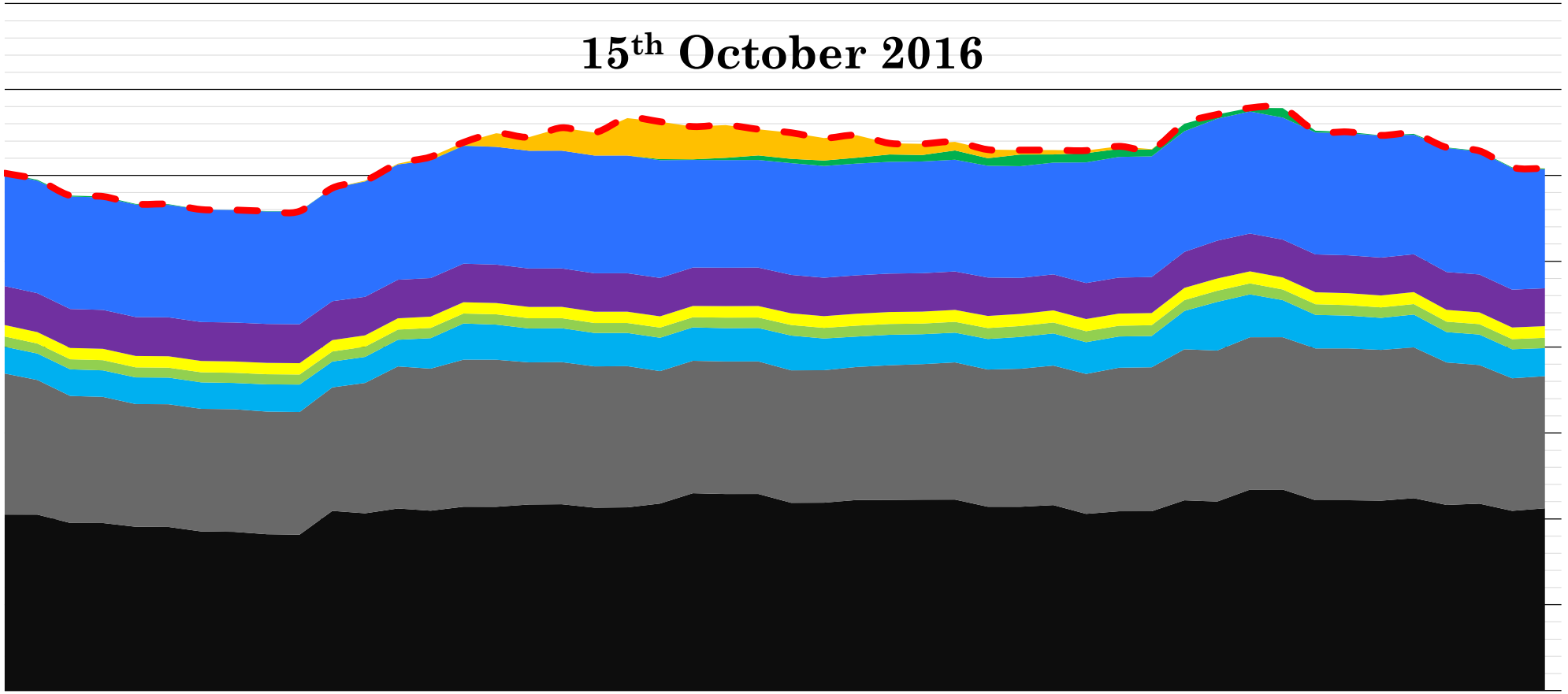
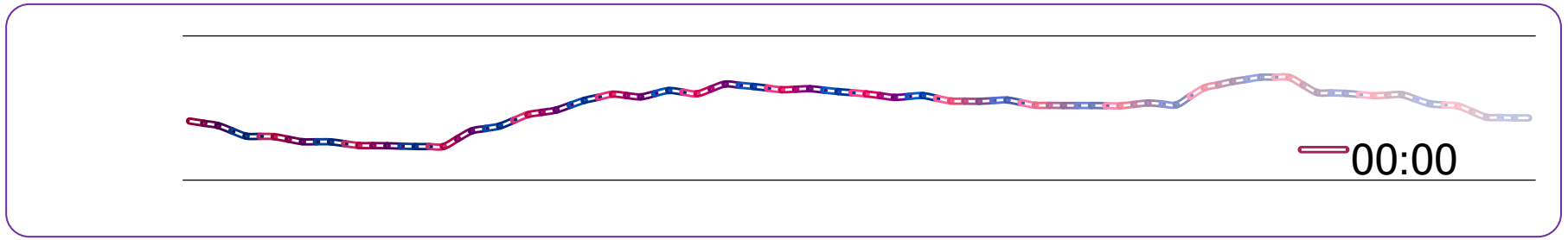

16th August 2016
In MW
Wind
Solar
TN Thermal
CGS
TN Hydro
Purchase
Deviation

NIWE Forecasting Vs Actuals During High Wind Season



Hourly Generation Split up – on Low Wind day

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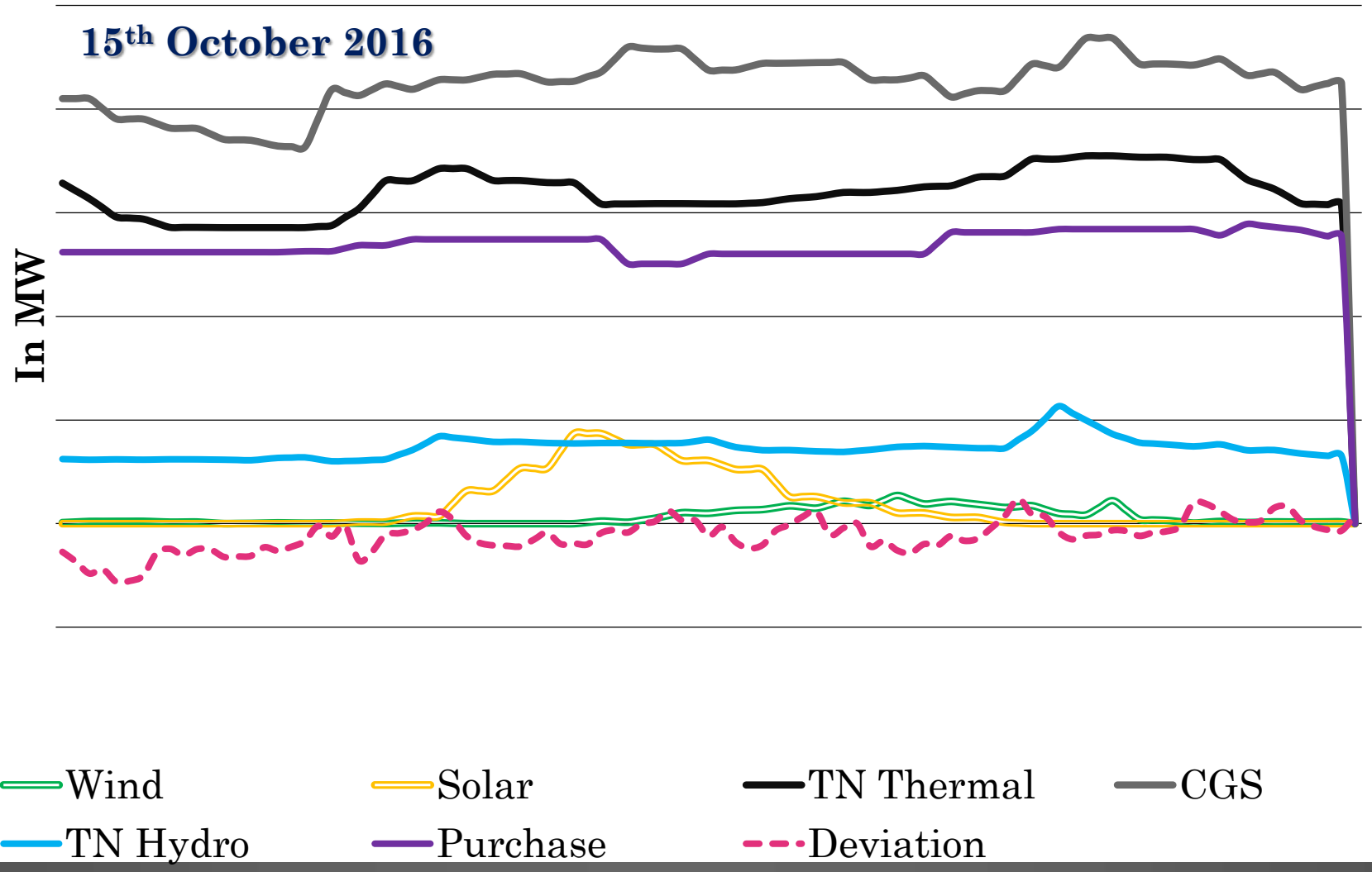
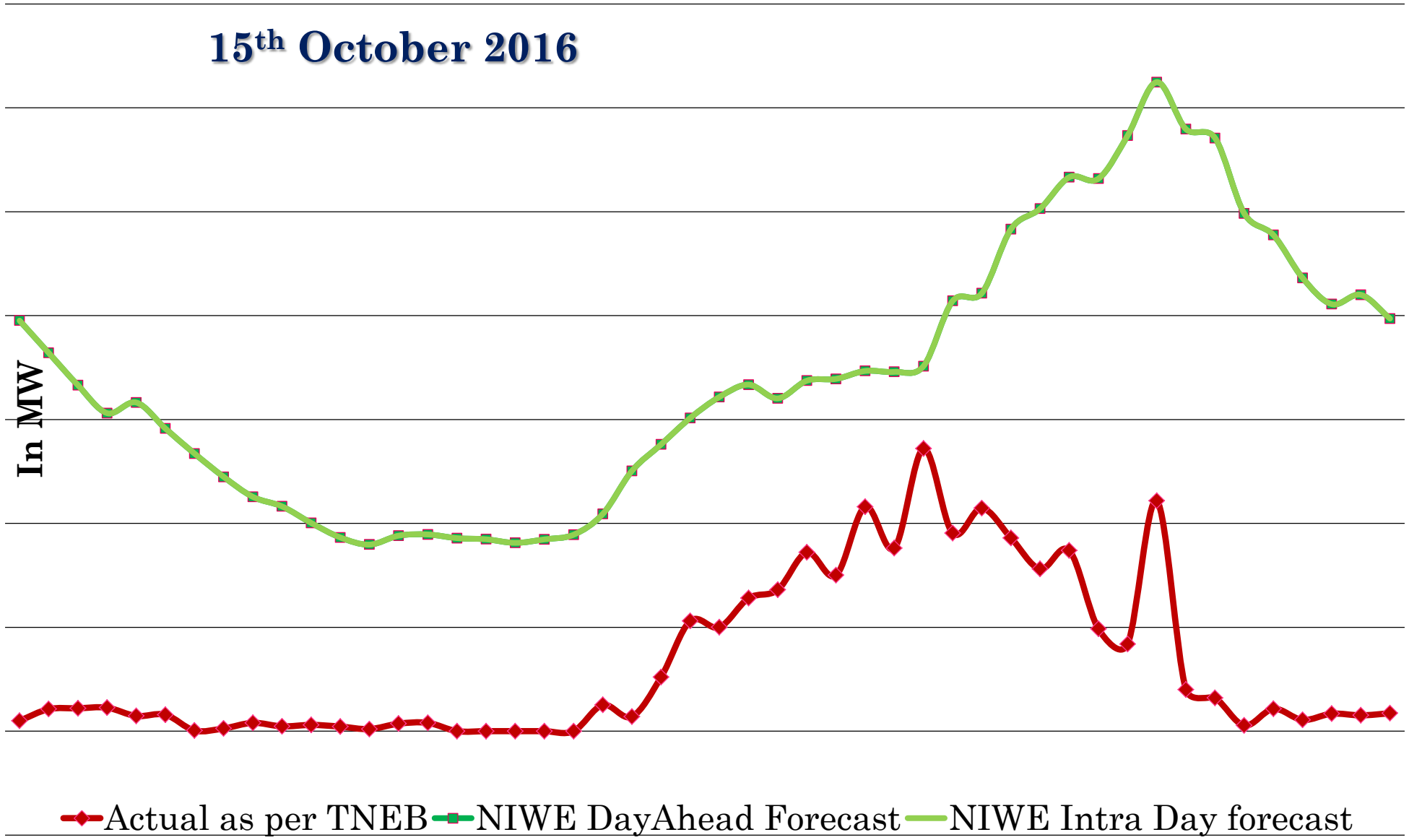

15th October 2016
In MW
Wind
Solar
TN Thermal
CGS
TN Hydro
Purchase
Deviation

NIWE Forecasting Vs Actuals During Low Wind Season



Energy Consumption Split up Details during

16th August 2016

Generator Details	Energy Consumption in MU	% of Contribution
TN Hydro	6.539	2.20
TN Thermal	50.398	16.97
TN Gas	1.963	0.66
TN IPP	2.365	0.80
CGS	85.263	28.70
Purchase	23.057	7.76
CPP	24.935	8.39
Wind	97.351	32.77
Solar	5.191	1.75
Total	297.062	

15th October 2016

Generator Details	Energy Consumption in MU	% of Contribution
TN Hydro	17.608	5.90
TN Thermal	76.832	25.74
TN Gas	5.820	1.95
TN IPP	6.516	2.18
CGS	101.599	34.04
Purchase	63.783	21.37
CPP	20.616	6.91
Wind	1.590	0.53
Solar	4.071	1.36
Total	298.435	

Developments in Transmission Corridor

- **TANTRANSCO developed the 400 KV Transmission corridors in order to accommodate the wind energy**

1. **Tamilnadu Backbone Network 1495 CKMS – *Rs.2186.15 crores***
2. **Tamilnadu Wind Power Corridor 846 CKMS – *Rs.1418.18 crores***
3. **Tamil Nadu Inter State transfer of Power 696 CKMS - *Rs. 993.43 crores***

Additional Financial Burden

Accommodation of maximum wind generation results

- ***Deviation Settlement Mechanism***
- ***Surrendering of Central Generating Stations power.***
- ***Backing down power purchase from LTA/MTOA Generators.***
- ***Purchase of high cost power from IPPs.***
- ***Intraday purchase during sudden withdrawal of wind generation***
- ***Backing down the TANGEDCO Thermal Stations.***

On account of Banking

- **The unutilised energy generated during wind seasons at low cost are banked and allowed to utilise the same throughout the year from 1st April to 31st March of the following year and adjusted during non-windy season.**
- **The adjustment of banked energy during non wind season will lead to revenue loss to TANGEDCO.**
- **The balance energy as on 31st March of every year may be encashed at the rate of 75% of the respective applicable wind energy tariff Or 75% of the pooled cost notified by TNERC in the case of REC.**

TANGEDCO to accommodate wind generation by losing commercially on various accounts indirectly

June to September 16

Sl. No.	Due to	Rs. In crores
1	On account of Deviation Settlement Mechanism as per CERC Regulations (for the period from 01/06/16 to 25/09/16)	68.17
2	On account of surrendering CGS power	181.30
3	On account of backing down the power from LTA/MTOA purchase	356.47
4	Generation from IPP utilized due to fall of Wind during the month	16.75
	Total amount	622.69

RE Forecasting

- **Forecast at present - National Institute of Wind Energy (NIWE), Chennai**

- **Separate wing has been formed for REMC (Renewable Energy Management Centre) to monitor the REMC project**

- **REMC - Forecast Service Providers (FSP) – 3 Nos**

Hydro – Pumped Storage Projects

To improve spinning reserve in Tamil Nadu control area, the following Hydro pumped storage projects are under pipeline.

- **Kundah – 500 MW (4 X 125 MW) – expected by 2020-21**
- **Sillahalla - 2000 MW (4 x 500 MW) – expected by 2021-22**
- **Mettur – 500 MW (4 X 125 MW)**

Constraints

- **Installed capacity of Renewable Energy in Tamilnadu control area is the highest in India.**
- **Balancing in Tamilnadu control area is not available**
- **Share from NPCIL 1147 MW – treated as infirm power**
- **To meet out the demand - Long term and medium term contracts**
- **Continuous variations – TANGEDCO Thermal Stations – Based on merit order – forced outages increased**

- **CGS power surrendered – LTA, MTOA generators not scheduled – Based on merit order.**
- **Some of the IPP not able to off take granted quantity of Fuel**
- **Intra State Generators are requested to back down their generation to technical minimum / shutdown resort legal action**
- **STOA Revision possible before 3 days**

Suggestions

1. **Forecasting and Balancing mechanism are an essential tools to aid the integration of the increasing amount of wind energy.**
2. **Forecasting helps us to make Renewable Energy appear more like a conventional power station.**
3. **Storage technology to store the renewable energy have to be cost effective.**
4. **Available Transfer Capability (ATC) margin between Regions to be revised practically**

5. **Compensation have to be considered by MNRE for accommodating Renewable Energy in Tamilnadu control area for the following items**
   - **for maintaining thermal units at low PLF**
   - **Commercial losses to TANGEDCO on various accounts indirectly**
   - **Expenditure made on to increase the Transmission corridor capability**
6. **Special Green Corridor to a quantum of 500 to 1000 MW immediately for SR to NR through WR & ER**


Thank
you

Tamil Nadu Electricity Regulatory Commission

Implementation of Forecasting, Scheduling and Deviation Settlement

Framing of regulations

First meeting of Technical Committee for implementation of framework on renewables at State level : 16.12.2015

Second meeting of Technical Committee : 08.01.2016

Commission's draft regulations floated :

- Intra State ABT Regulations ,2016 : 13.01.2016
- Forecasting, Scheduling , Deviation Settlement and Related matters of Wind and Solar Generation Sources, 2016 : 13.01.2016

Scope of regulations

Intra State Availability Based Tariff :

Applicability - i) All generating stations (except interstate, nuclear, hydro, merchant power plants),
ii) Distribution licensees, Trading licensees
iii) Open access consumers (energy accounting)

Settlement - Capacity and Energy charges mutually between buyers and sellers .

Deviation charges to be paid by Generating stations, Distribution licensee at the rates notified by the Central Electricity Regulatory Commission.

Open access consumers to pay to Distribution licensee as per Terms & Conditions of Supply

Scope of regulations - Intra State ABT -contd.

SLDC – To prepare monthly accounts and weekly statement of deviation charges;
Maintain state imbalance pool account and reactive energy account.

SPC - State Power Committee for verification of accounts

Constituents} - Representatives from SLDC, STU,
of SPC } Distribution licensee, Generators

Scope of regulations - contd.

Forecasting, Scheduling, Deviation Settlement and Related matters of Wind and Solar:

Applicability - To all wind and solar generators connected to the State grid, including those connected via pooling stations, and selling power within the State.

Forecasting,Scheduling – Wind, Solar generators connected to state grid or by Qualified Coordinating agencies (QCA); SLDC mandated to forecast;

Scope of regulations - Forecasting, Scheduling, Deviation Settlement and Related matters of Wind and Solar -contd.

- Schedules - Wind, Solar generators to submit schedules Day ahead, Week ahead as per own forecast or SLDCs forecast.

- Revisions - every one and half hours; maximum of 16 revisions.

- Commercial impact – Deviation from schedule to be borne by wind, solar generator or transacted through QCA
- QCA to undertake all commercial settlements including de-pooling

Deviation charges for wind generators

- For Under injection/Over injection by wind generators for sale of power within state

Sl.No.	Absolute Error in the 15-minute time block	Deviation Charges payable to State DSM Pool
1.	< = 10%	None
2.	>10% but <=20%	At Rs. 0.50 per unit for the shortfall or excess energy for absolute error beyond 10% and upto 20%.
3.	>20% but <=30%	At Rs. 0.50 per unit for the shortfall or excess energy beyond 10% and upto 20% + Rs. 1.0 per unit for balance energy beyond 20% and upto 30%
4.	> 30%	At Rs. 0.50 per unit for the shortfall or excess energy beyond 10% and upto 20% + Rs. 1.0 per unit for shortfall or excess energy beyond 20% and upto 30% + Rs. 1.50 per unit for balance energy beyond 30%.

Deviation charges for Solar generators

- For under or over injection by Solar generators for sale of power within the state:

Sl.No.	Absolute Error in the 15-minute time block	Deviation Charges payable to State DSM Pool
1.	< = 5%	None
2.	>5% but <=15%	At Rs. 0.50 per unit for the shortfall or excess energy for absolute error beyond 5% and upto 15%.
3.	>15% but <=25%	At Rs. 0.50 per unit for the shortfall or excess energy beyond 5% and upto 15% + Rs. 1.0 per unit for balance energy beyond 15% and upto 25%.
4.	> 25%	At Rs. 0.50 per unit for the shortfall or excess energy beyond 5% and upto 15% + Rs. 1.0 per unit for shortfall or excess energy beyond 15% and upto 25% + Rs. 1.50 per unit for balance energy beyond 25%.

Scope of regulations – Forecasting,Scheduling,Deviation Settlement and related matters of Wind and Solar - contd.

De-pooling by Qualified Coordinating Agencies(QCAs):

- Energy deviations and deviation charges to be de-pooled in proportion to

  Actual generated units in each time block

  or

  Available capacity of each generator

Issues raised by stakeholders

Intra State ABT:

- ABTs scope for short term single part tariff
- Fixing of technical minimum, exemption from merit order despatch
- Responsibility of procurement, installation of ABT meters
- To reveal SLDC's capability of handling data
- To conduct mock exercise and then notify regulations

Issues raised by stakeholders -contd.

Forecasting, Scheduling and DSM for Wind and Solar:

- Specify QCA selection criteria
- Empanelment of QCAs by SLDC
- Applicability to new projects ,projects of higher capacities - 50 MW and above
- Lenient view on existing generators
- Higher tolerance band required
- Sought for centralised forecasting
- To state on preparedness of SLDC to forecast
- Apprehensive of treatment of banked energy for wind
- Technical feasibility of old machines to provide real time data – generation and forecasting

Issues raised by stakeholders - contd.

- Consider error based on normalised actual and normalised scheduled generation
- Adequacy of telemetry, communication infrastructure
- Socialisation of burden of deviation within tolerance band
- To specify funds to meet deficits of pool account
- Unanimous request to postpone implementation by a year or two/when SLDC is ready to forecast.

Uniqueness of the State and status

- Renewable energy capacity - 10206 MW
- No. of wind Mills - 11906 Nos.
- Other Renewable energy generators - 161 Nos.
- Open access consumers - captive & 3rd party - 2307 Nos.
- No. of generators in EHT - 70 Nos.
- No. of generators at 33 kV and below - 9414 Nos.
- No. of captive users (Wind & Solar) - 1515 Nos.

Status of the State at the time of issue of draft regulations

- No ABT meters for TANTRANSCO boundaries
- No Forecasting/Scheduling
- IT infrastructure –Hardware, Software for Scheduling

Energy Accounting & DSM, Load forecasting - not in place

Commission's directives and compliance

- Orders issued to provide ABT meters to all open access consumers approving specification.
- Directed to furnish progress of implementation
- Utility reported compliance in all services of open access consumers.
- Plan of action sought from SLDC for implementing DSM in the state.

Additional requirements

- Installation of ABT meters

  - All generators, grid feeders, State owned generating station's evacuation feeders

- Procurement of hardware, software to handle large volumes of data and huge number of transactions

- AMR from old wind machines

Challenges

- Handling large quantity of wind energy with banking throughout the year
- Considerable (1409 MW) capacity of wind generation in Distribution feeders
- Segregation of distribution loads an important task to be undertaken
- Many 250 kW - 500 kW wind machines to total capacity of 1100 MW.
- Enormous data and large number of transactions due to captive use and third party open access

Issue of regulations afresh

Contemplates to issue a revised draft regulation

- a DSM regulation covering conventional and renewables as in the revised Model DSM regulations of Forum Of Regulators with state specific changes.

Issues before the Commission:

- To have separate regulations for Transmission network and Distribution network or combined
- To continue the lone distribution licensee model or multiple licensees model


THANK YOU

Renewable Energy Integration Studies

Forum of Regulators (FOR) Technical Committee Meeting

28th March 2017

Objective : To study the impact of large scale RE integration on the Indian Power System

Output:

Potential Grid Reliability Concerns

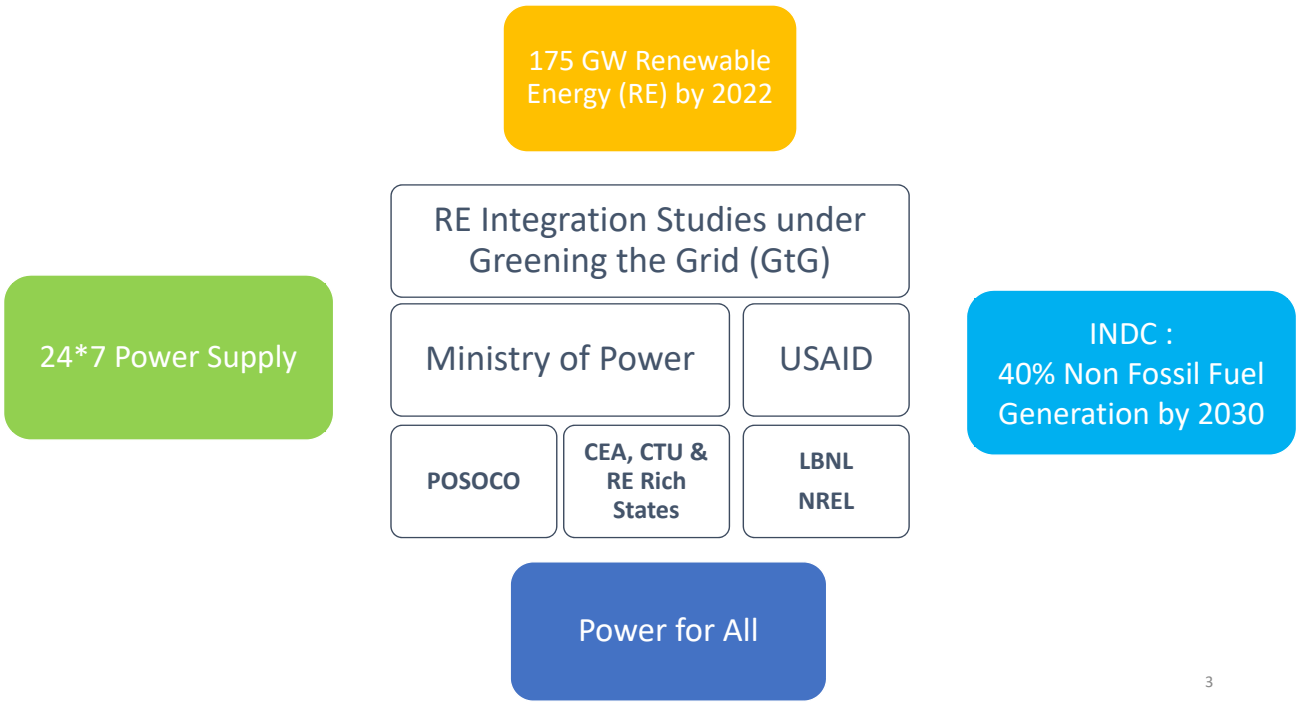
Policy and Regulatory measures for cost effective RE Integration

Methodology:

Production Cost Modelling using PLEXOS software

Minimization of production cost honoring physical, operational, and market constraints

Approximate modelling of decentralized mechanism



Problem Formulation

Objective Function

$$Min\ (Total\ Production\ Cost\ of\ all\ Generators\ on\ All\ India\ basis)$$

Subject to constraints:

Inter Regional Transfer Limits
Line Loading Limits
Generator Min Stable Level; Minimum up and down times
Generator Max Capacity
Generator Ramp Rate
Hydro Monthly Energy Constraint……

Optimization of dispatch for each 35040 time block (15min) in 2022

Stakeholder Participation : Modelling Team

- Modeling Team: Around 30 Engineers
  - POSOCO, CEA, CTU, RE Rich States, NREL, LBNL
- More than 20 webinars (more than 200 person-hours) between modeling team to discuss:
  - All India Power System Modeling in PLEXOS
  - Update on RE integration studies
  - Use of PLEXOS software

Stakeholder Participation : Capacity Building

- PLEXOS Software provided to:
  - CEA/CTU/NLDC/WRLDC/SRLDC/RE Rich States
- Basic-level training
  - 01-04 Sep 2015
  - More than 50 Participants (16 SLDC, 5 RLDCs, NLDC, CEA and CTU)
- Advanced-level training
  - 17-20 Jan 2017
  - 25 Participants (5 SLDC, 5 RLDCs, NLDC and CTU)

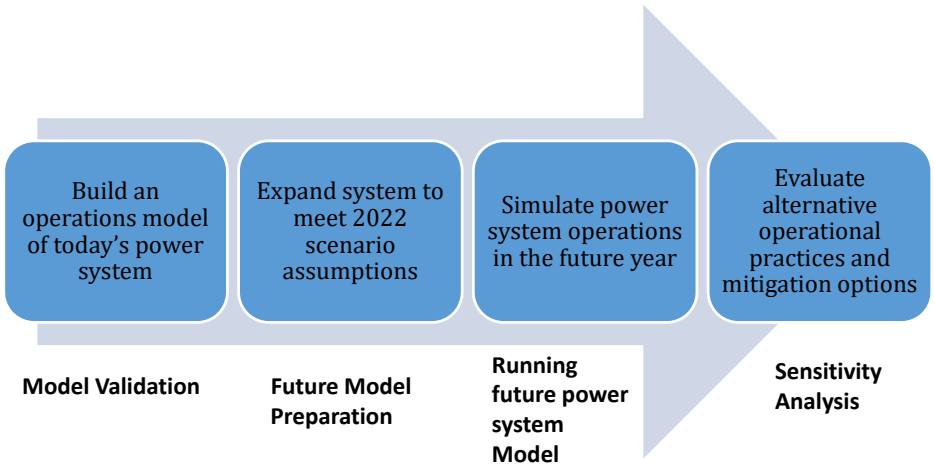
Stakeholder Participation : Study Review

- Grid Integration Review Committee (GIRC)
  - Peer Review and Guidance
  - Over 150 Experts
  - Three GIRC Meetings

	National (New Delhi)	Southern (Bengaluru)	Western (Mumbai)
1st GIRC	13/10/15	15/10/15	19/10/15
2nd GIRC	19/4/16	21/4/16	22/4/16
3rd GIRC	18/7/16	20/7/16	22/7/16
4th GIRC	17/2/17	20/2/17	22/2/17

More than 2000 person hours

Basic Philosophy of RE Integration Study



Data Intensive Modelling

- Generation
  - Maximum Capacity
  - Fuel type
  - Ramp rates
  - Heat rates at various loadings
  - Design Minimum generation limit
  - Forced Outage Rate and Maintenance Rate
  - Start Up and Shutdown cost
  - Min up time
  - Min down time
  - Variable Charges
- Hydro Generation
  - Energy Constraints (Daily/Weekly/Monthly)
- Transmission
  - Network Topology
  - Transmission Line Loading & Interface Limits

8760 hrs modelling of All India Power System

Major Assumptions

- Fixed Cost and Transmission Charges considered as sunk cost
- 2022 weather same as of 2014
  - RE generation profile based on 2014 weather model
  - Hydro generation based on actual generation in 2014
- 2022 load shape same as of 2014
  - Load scaled to meet energy projections as per draft 19th Electric Power Survey (EPS), CEA
  - Perfect Load Forecast
- 2022 Variable Charges of generators same as of 2014
- Contracts not modeled*
  - All plants, within their physical constraints, are available for scheduling if they are not on an outage
- Reserves as per CERC roadmap

*** sub-optimality factored through a wheeling charge or hurdle rate applied for inter state power exchanges**

Other Assumptions

- Generator Properties
  - Ramp Rate: 1% for coal & 3% for gas
  - 55% min generation level as per CERC regulation
  - New conventional generation capacity (plants built after 2015) is given similar parameters to existing capacity.
  - Variable costs of new plants assumed as 10th percentile of existing plants of the same technology within a region.
  - Minimum up time & Minimum down time (24 hrs for coal and 8 hrs for gas)
  - Outage Rates
  - Mean time to repair

Other Assumptions

- Hydro Generation Modelling
  - Run of the River: Same generation profile as in 2014
  - Pondage: Same daily energy and min generation as in 2014
  - Storage: Same monthly energy and min generation as in 2014
  - Zero Variable Cost for each hydro generator
- Transmission
  - Transmission Network data for 2022 scenario provided by CEA/CTU.
- RE Generation
  - 80 m hub height for all existing wind turbines, and a 100m hub height for all new installations
  - Solar PV project assumed to be a fixed-tilt system, with the tilt set at the latitude of the site location.
  - 15 min solar and wind data based on 2014 actual weather parameters

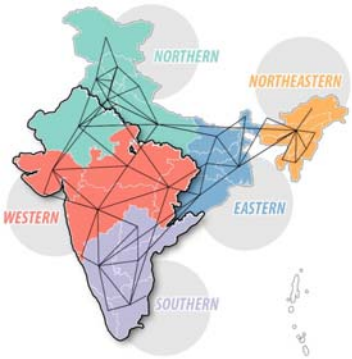
RE Site Selection

- Location of 175 GW RE still to be decided.
- Further State specific target for solar not available at the start of the study.

- Site Selection for New RE
  - Wind capacity additions **:** Additional capacity added to the sites with best potential in states with MNRE capacity targets for 2022.
  - Utility-scale solar capacity additions
    - Details of planned solar park provided by POWERGRID
    - Additional capacity added to the sites with best potential
    - Limit of 15% of the total national target for any state
  - Rooftop solar capacity additions
    - As per MNRE targets for each state
    - Addition only in smart cities

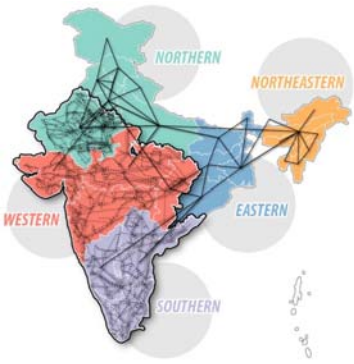
Transmission representation in the model

National Study



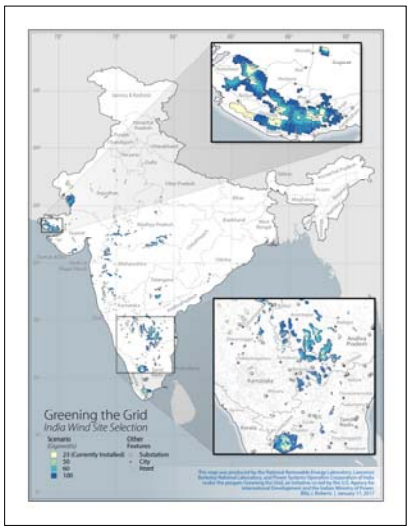
- All generation and transmission located on a single node per state plus union territories (36 nodes total)
- No enforced intrastate transmission constraints

Regional Study

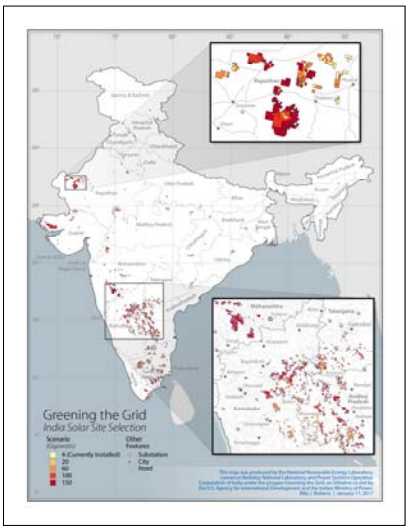


- Full, planned transmission system in Southern and Western Regions plus Rajasthan (3,280 nodes)
- Loading limits enforced on all relevant intrastate lines; congestion limits enforced on all high-volume intrastate lines (>400 kV)

Location of RE Sited



Locations of installed wind capacity for each scenario



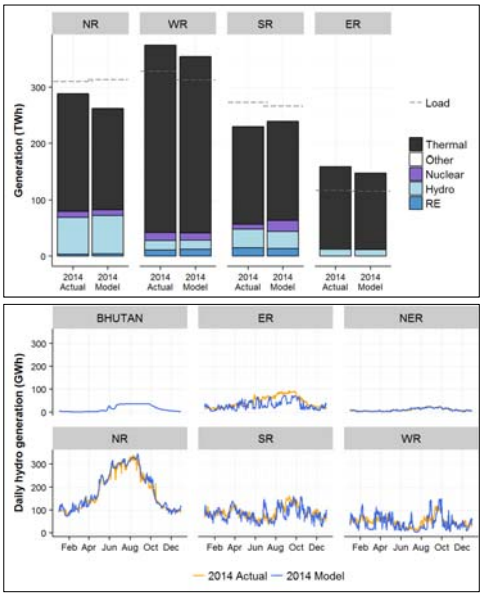
Locations of installed solar capacity for each scenario

Scenarios Studied

Scenario name	Solar (GW)	Wind (GW)	Description	Purpose
No New RE	5	23	Wind and solar capacities in 2014	Establish a baseline to measure impact of adding new RE to the system
20S-50W	20	50	Total installed capacity as targeted in Green Energy Corridors & National Solar Mission	Evaluate changes to power system planning and operations to meet near-term targets
100S-60W	100	60	Current government of India target for 2022	Evaluate changes to planning and operations to meet the official target of 175 GW RE
60S-100W	60	100	Solar and wind targets reversed in comparison to official target	Understand differential impacts of wind versus solar on need for system flexibility
150S-100W	150	100	Ambitious RE growth	Evaluate how needs for system flexibility would change under a higher wind and solar buildout

Model Validation

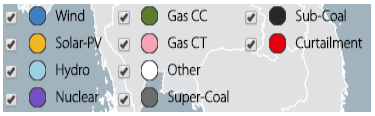
- 2014 Year Validation Model
- Two Phase Validation
- Tuning of model parameters to match simulation output with actuals
  - Inter Regional Flows
  - Generation Profile



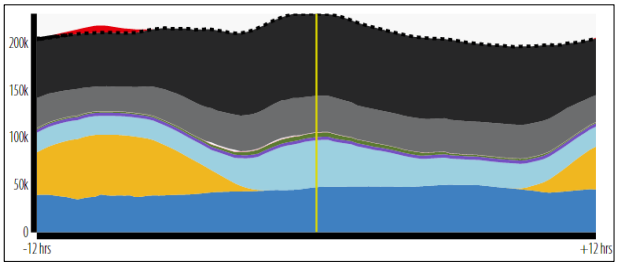
Dispatch Under Various Scenarios

Snapshot---→	Time	Value	Coal (GW)	Wind & Solar (GW)	Hydro (GW)	Gas (GW)	Other (GW)
Max load	6/30/2022 21:15	230 GW	125	48	49	5	3
Min load	2/28/2022 3:30	141 GW	105	19	7	3	7
Max RE	6/25/2022 11:30	113 GW	71	11	16	1	4
Min RE	11/29/2022 6:15	3 GW	148	3	21	10	8
Max net load	10/21/2022 19:00	215 GW	153	13	45	10	6
Min net load	9/6/2022 13:45	80 GW	60	84	15	2	4
Max RE penetration	6/23/2022 11:30	55 %	70	113	16	1	4
Min RE penetration	11/29/2022 6:15	2 %	148	3	21	10	8

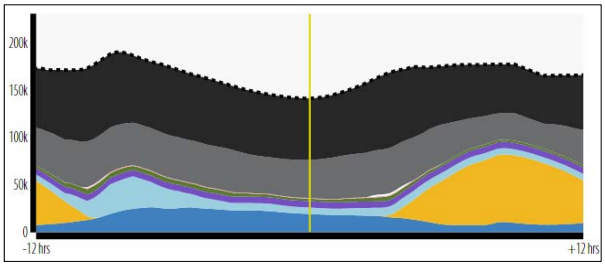
Dispatch Under Various Scenarios



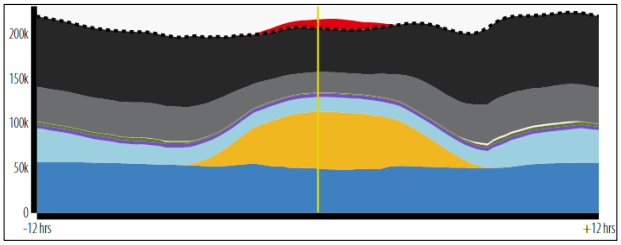
Max Load 30th June (230 GW) 2022 21:15



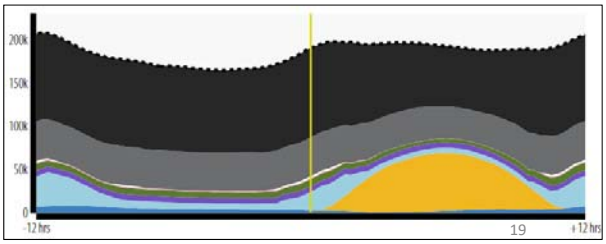
Min Load (141 GW) 28th Feb 2022 03:30



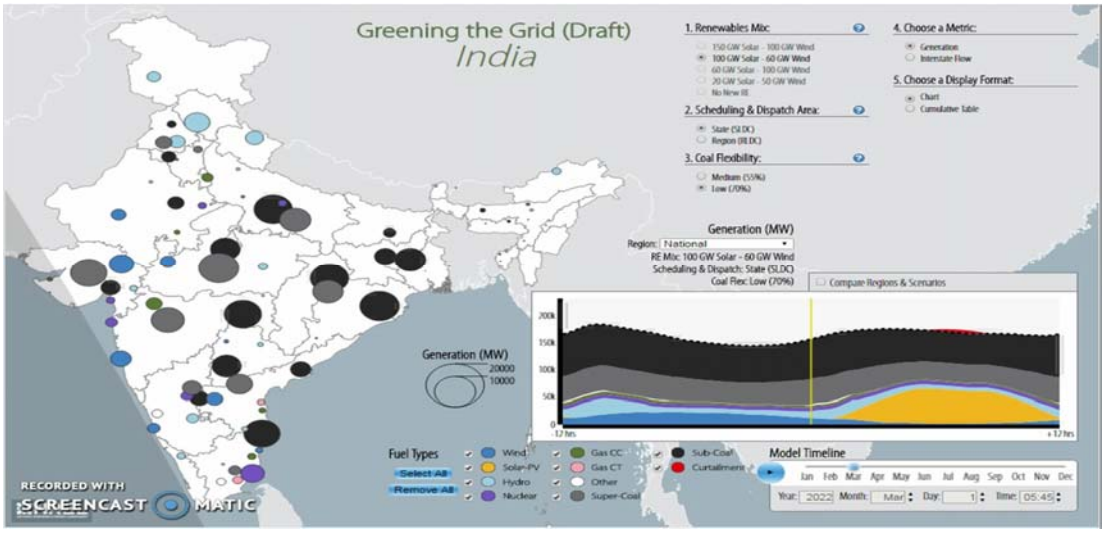
Max RE 25th June 2022 (113 GW) 11:30



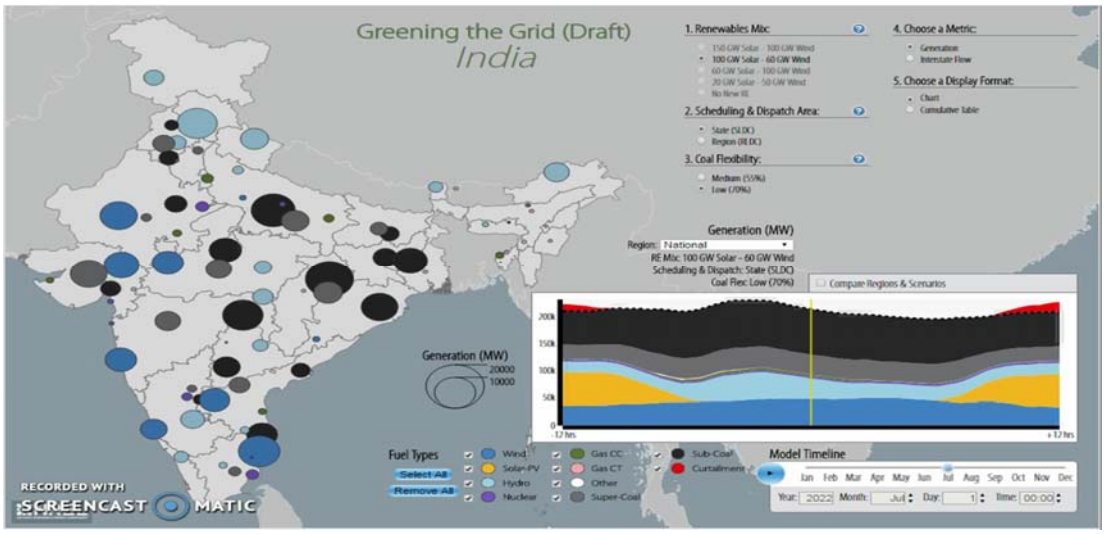
Min RE 29th Nov (3 GW) 2022 06:15



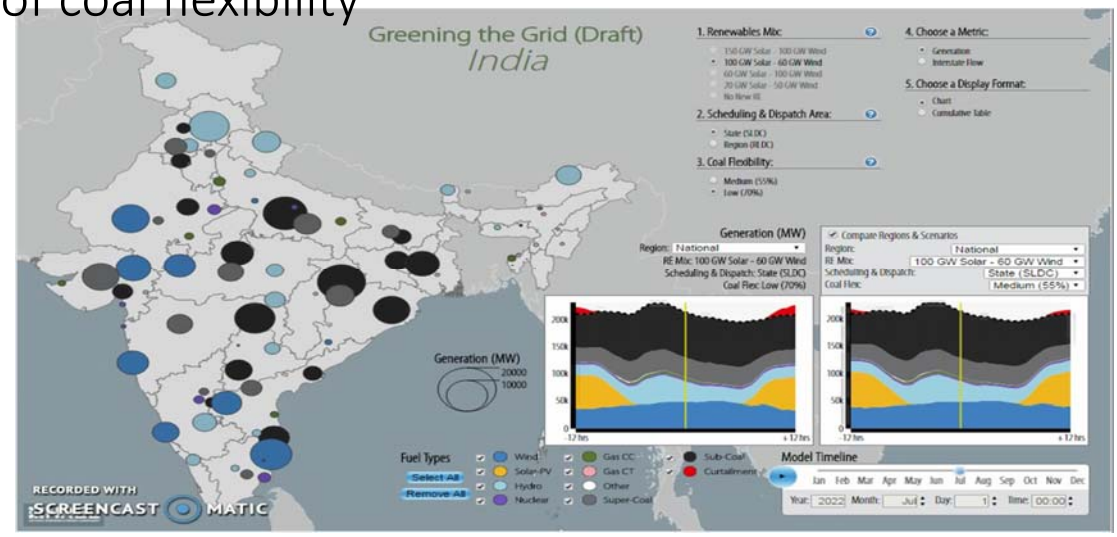
We simulated a year of operations, using high resolution RE, generator, and transmission data



Curtailment increases during monsoon

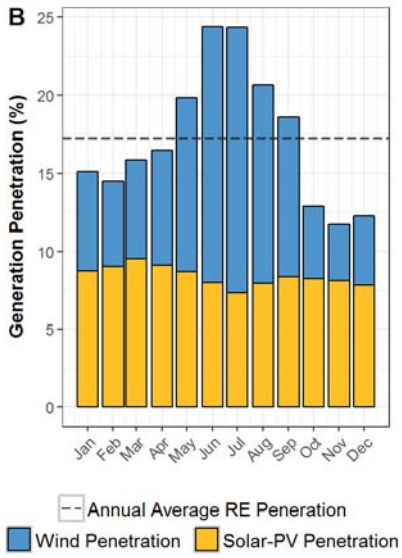


We compare operations under different scenarios of coal flexibility

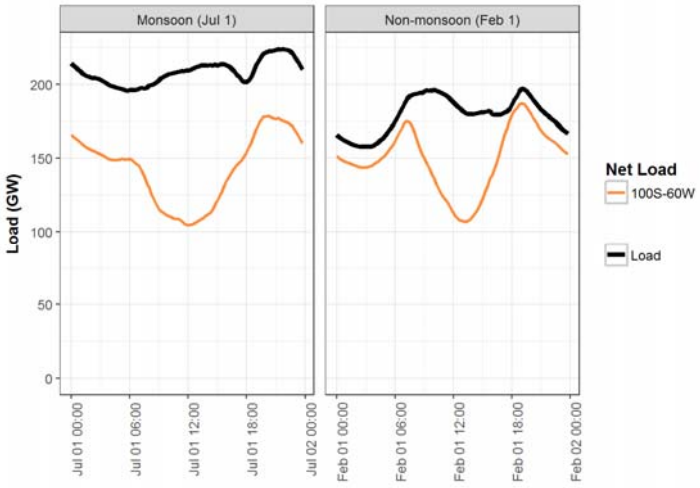


Key Finding # 1: 175 GW RE can be integrated to the grid

- The 2022 power system with 100 GW solar and 60 GW wind can balance every 15 minutes of the year with minimal RE curtailment provided assumptions hold true in 2022
- The system can handle forecast errors, net load changes, and exchanges of energy between regions
- Curtailment averages only 1% nationally, based on no intrastate congestion
- Curtailment is highest in the southern region but still less than 3%



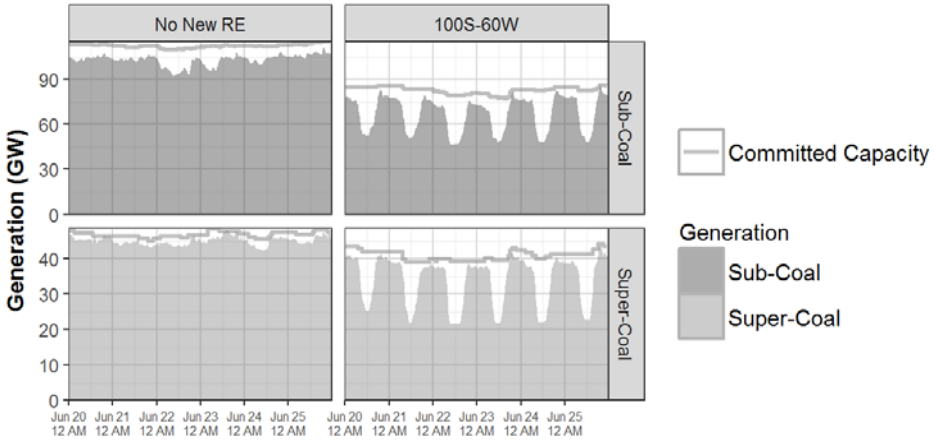
Key Finding # 2 : Net Load ramp increases 28% compared to a system with no new renewables, to almost 32 GW per hour



Net load on a monsoon and non-monsoon day

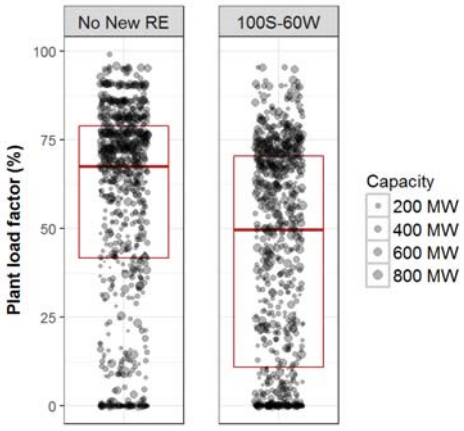
This ramp rate can be met if all generating stations exploit their inherent ramping capability.

Key Finding # 3 : Coal units are typically backed down midday to accommodate RE



Coal commitment and dispatch for one week in June

Key Result # 4 : Average coal plant load factors fall 63% to 49%, with over 19 GW of capacity that never starts*



* Compared to No New RE; Plant load factor (PLF) is calculated using weighted averages

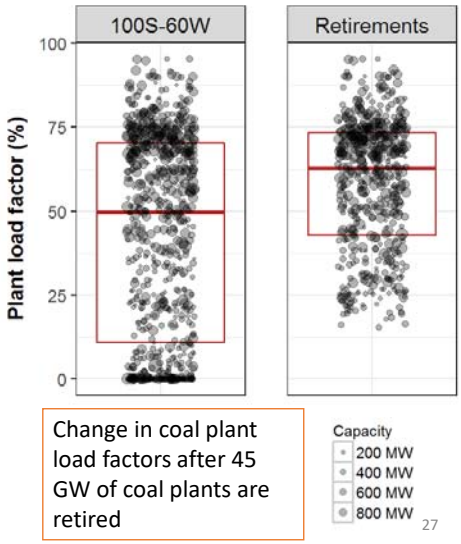
PLF	No New RE	100S-60W
<25% PLF	30 GW	60 GW
>75% PLF	92 GW	36 GW

Coal capacity below 25%, and above 75% PLF

- 21% and 36% reduction of coal and gas generation
- 21% reduction in CO_2 emissions
- Coal plants on average experience 6.8% more starts and spend 94% more time at minimum generation while operating

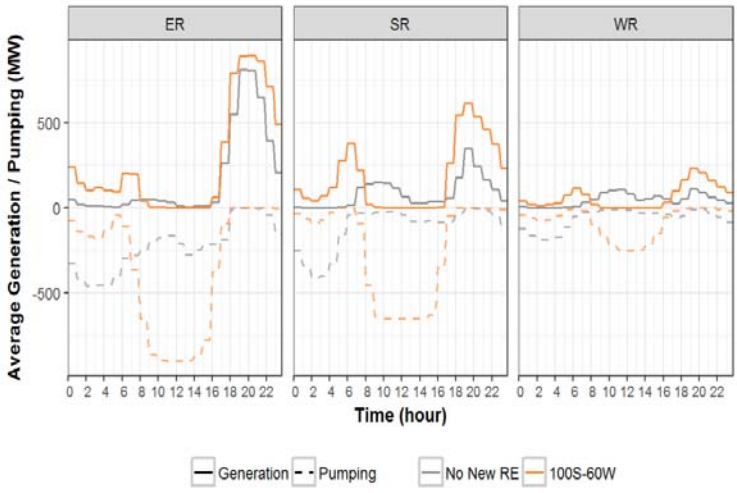
Key Finding # 5 : Retiring 45 GW of coal does not adversely affect system flexibility

- 45 GW coal (198 plants) operate on average less than 15% capacity and contribute just 1% to annual coal generation
- System still operates effectively without these plants, based on adequate intrastate transmission
- Plant load factors of remaining plants increase from 49% to 61%



Change in coal plant load factors after 45 GW of coal plants are retired

Key Finding # 6 : Hydro & Pumped Hydro Operation key to flexibility



Hydro generation may be required to go down to 10% of installed capacity during high RE periods

Pumping mode of pumped storage shifts from nighttime to midday to coincide with greater solar generation output

Key Finding # 6 : Changes to operations leads to cost effective RE Integration

100 GW SOLAR, 60 GW WIND

NORMAL OPERATIONS (STATE-LEVEL DISPATCH)	REGIONAL COORDINATION	NATIONAL COORDINATION
220,000 INR Crore Annual Production Cost	**3.0%** Savings annually	**3.7%** Savings annually
1.1% Renewable Energy Curtailment	**1.0%** Renewable Energy Curtailment	**0.7%** Renewable Energy Curtailment

Key Finding # 7 : Reducing coal min generation levels from 70% to 55% drops RE curtailment from 3.4% to 1.1%

100 GW SOLAR, 60 GW WIND

NORMAL OPERATIONS	LOWER MINIMUM PLANT GENERATION	HIGHER MINIMUM PLANT GENERATION	SLOWER COAL RAMPING	DOUBLE START COSTS	FASTER CYCLING
55% minimum generation, 1% coal ramping, 24 hour up/down time	**40%** of capacity	**70%** of capacity	**0.5%** of capacity per minute	**2x** ₹	**12**hr Minimum up/down time
220,000 INR Crore Annual Production Cost	**0.9%** Savings annually	**1.6%** Increased cost annually	**0.05%** Increased cost annually	**1.6%** Increased cost annually	**0.042%** Increased cost annually
1.1% Renewable Energy Curtailment	**0.51%** Renewable Energy Curtailment	**3.4%** Renewable Energy Curtailment	**1.1%** Renewable Energy Curtailment	**1.2%** Renewable Energy Curtailment	**1.1%** Renewable Energy Curtailment

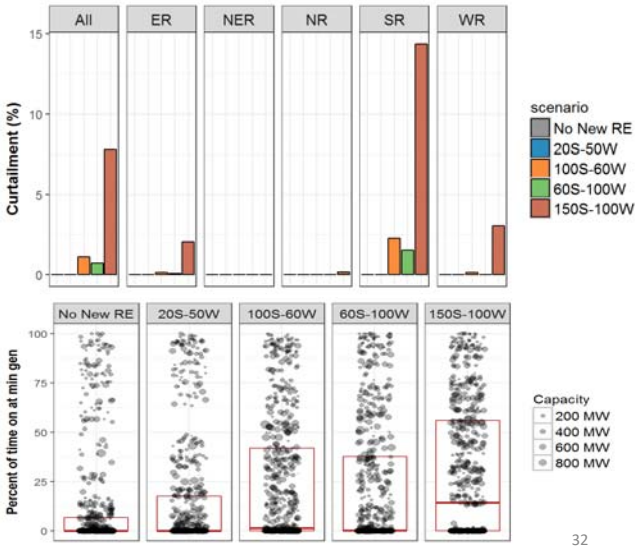
Key Finding # 8 : Copper plate scenario delivers 5% savings and only 0.18% RE curtailment

- This theoretical scenario has no transmission constraints to show flows that allow least-cost dispatch
- Copper plate scenario requires large power transfer from West to North and leads to loop flows from West to North to East
- Fixed cost of transmission not considered

Interconnection	Peak instantaneous power exchange (MW)
ER to NER	2538
ER to NR	2847
ER to SR	8368
ER to WR	5169
NER to ER	2744
NER to NR	3813
NR to ER	8279
NR to NER	3452
NR to WR	-3976
SR to ER	10659
SR to WR	20655
WR to ER	3895
WR to NR	38603
WR to SR	16515

Key Finding # 9 : Wind-dominated system achieves higher RE penetration rates with reduced integration challenges.

- Reversing RE targets (60 GW solar, 100 GW wind)
  - Achieves higher annual RE penetration rate due to higher capacity factors
  - Reduces CO2 emissions
- Timing of wind availability, its smoothing over large geographies, its impacts on net load ramp rates
  → Easier for RE integration
  → More coal plants operate efficiently (above 80% PLF), have fewer starts, and spend less time at minimum generation levels



Policy Recommendations

- Continued investment in both interstate and intrastate transmission
  - Create regulatory or policy guidelines to support institutionalization of cost-optimized capacity expansion planning.
- Larger electrical balancing footprints.
  - Reduce information asymmetry to enable more coordinated dispatch
- Flexibility of Conventional Power Plants
  - Establish at central and state levels comprehensive regulations regarding flexibility of conventional generators, including minimum generation levels, ramp rates, and minimum up and down times

Policy Recommendations

- Dispatch of RE to be maximized when it is economical
  - Merit order dispatch based on production costs; supplementary software may be required to identify economic scheduling and dispatch
- Create and maintain a nationwide model that helps optimize generation and transmission buildouts, which can then be used to inform investment decisions and RE policies
- States to be equipped with state of the art load and RE forecasting technologies.

Future Work

- Power System Analysis Studies for 2022
- State specific studies to understand state specific challenges
  - Production Cost Model prepared to be utilized by states
  - Unit Commitment and Security Constrained Economic Dispatch
  - Hydro-Thermal Coordination
  - RE Integration studies for any year
- Transmission and Capacity Expansion Planning
- Capacity Building in Production Cost Modelling

Introduction of Fast Markets at Inter-State Level in India

Moving to 5-Minute Scheduling, Despatch and Settlement

Meeting of the Technical Committee of Forum of Regulator (FOR)

Chennai, 28th March 2017

Presentation Outline

- Scheduling, Despatch & Settlement at inter-state level
- Imperatives for Moving to Fast Markets
- Policy / Regulatory Mandate
- International Experience
- Action Plan
- Timelines
- Financial Implications
- Way Forward
- References

Scheduling, Despatch & Settlement at inter-state level (1)

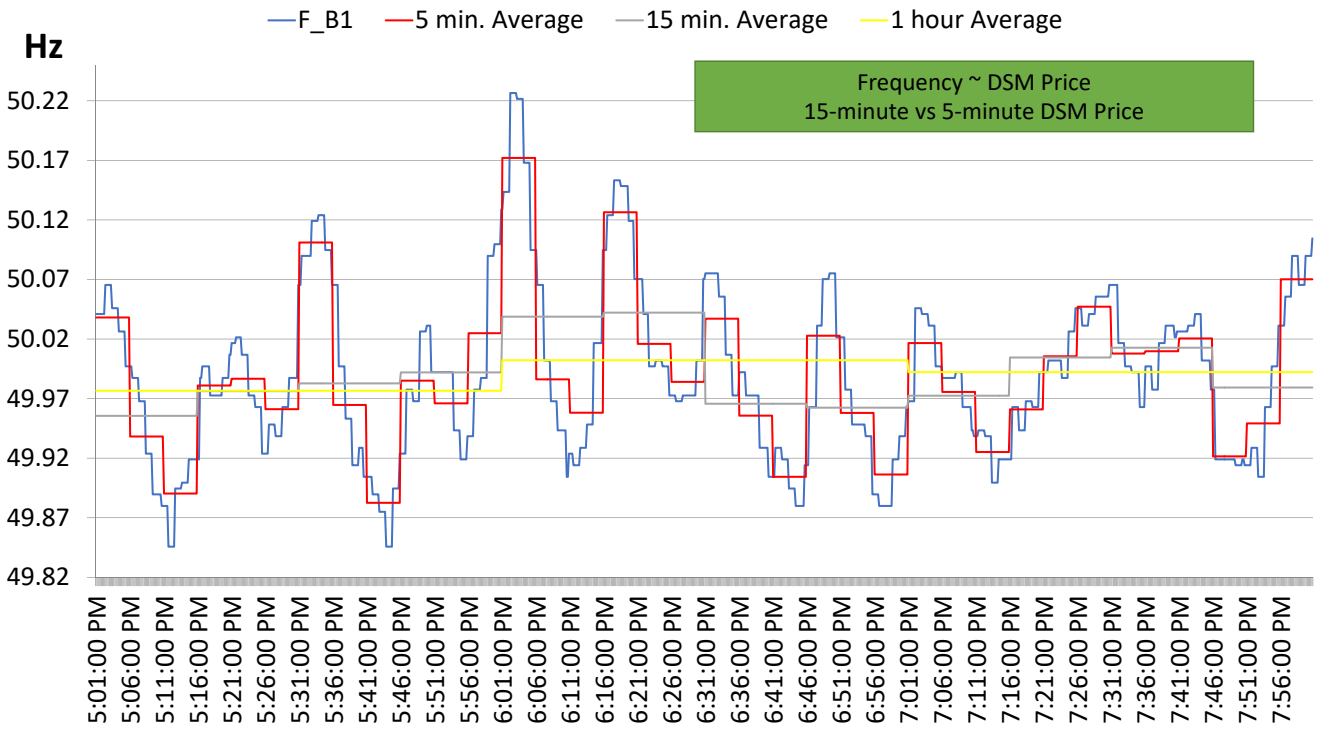
- Pre – ABT era
  - Joint Meter Reading (JMR) based Monthly accounting
  - Daily energy booking
  - Overlay accounts, frequency/drawals taken from SCADA
- Introduction of ABT in 2002-03
  - 15-minute scheduling, despatch
  - 15-minute metering (SEMs), accounting and settlement
  - 15-minute deviation (UI) accounts
- Open access in inter-state transmission, May 2004
  - Bilateral transactions, 15-minute trading in power and settlement
- Collective transactions in Power Exchanges
  - Hourly bidding
  - Intrapolation to 15-minutes for aligning with existing scheduling
  - Hourly clearing and settlement of trades (energy)
  - Deviation accounting at 15-minutes

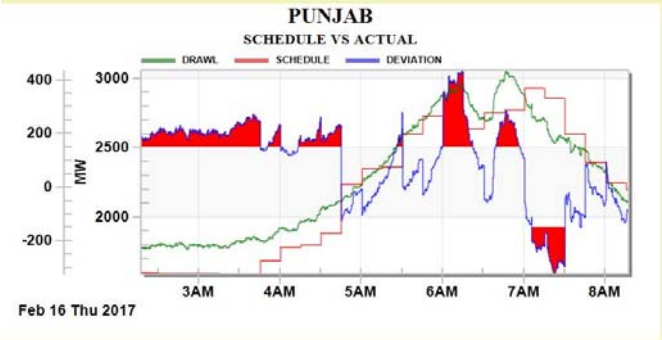
Scheduling, Despatch & Settlement at inter-state level (2)

- Sub-hourly markets in Power Exchanges, 2012
  - Introduction of 15-minute bidding in PXs w.e.f. 1st April 2012
  - 15-minute clearing and settlement (energy)
  - 15-minute deviation accounting
  - Aligning the Power Exchange markets with scheduling, despatch & settlement practice in India
- Ancillary Services, 2016
  - Aligned with existing scheduling, despatch & settlement practice
  - Need for 'fast' / 'quick' response from generators; Para 9.4 of approved procedures:
    "Schedule of the RRAS providers will become effective earliest from the time block starting 15-minutes after issue of despatch instruction ….. "
- Pilot Project for implementation of Secondary Response (AGC)

Imperatives for moving to 'Fast Markets'

- Learning from implementation of Ancillary Services
  - Requirements under ancillary despatch are
    - Quick / Fast response & turnaround time
    - Despatch for short durations
    - Example: hour boundary changeover
  - A costly resource, to be used in limited manner for system reliability
    - Increasing granularity would optimize cost of despatch
  - Earliest possible implementation of RRAS despatch instruction is 16 minutes
  - New products are expected to be introduced in future to expand the ambit
- Re-scheduling of resources
  - 4-blocks of 5 minutes (20 min) vs 4-blocks of 15-minutes (60 min)
- Increasing RE penetration
- Ramping requirements
- Recognizing flexibility as a requirement
- Implementation of Primary, Secondary (AGC) and Tertiary Reserves/Control
- Reserves: Despatch, accounting & settlement

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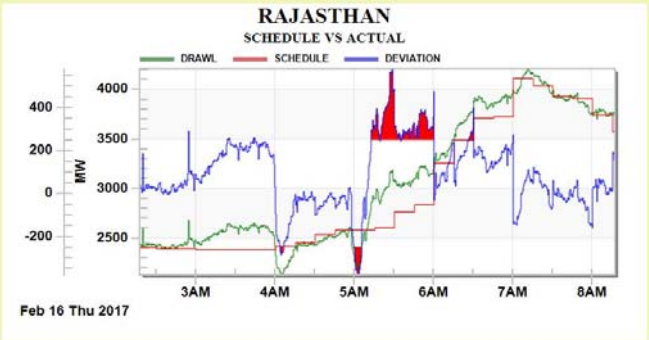
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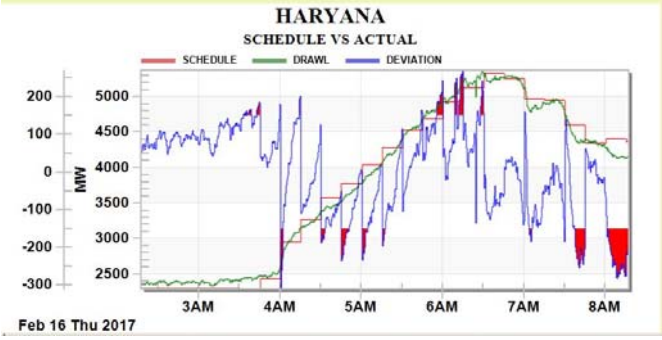
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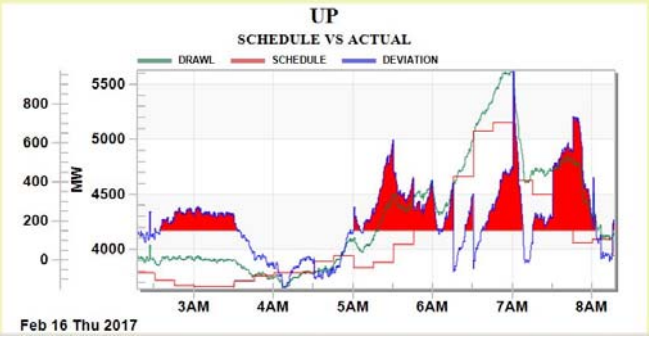
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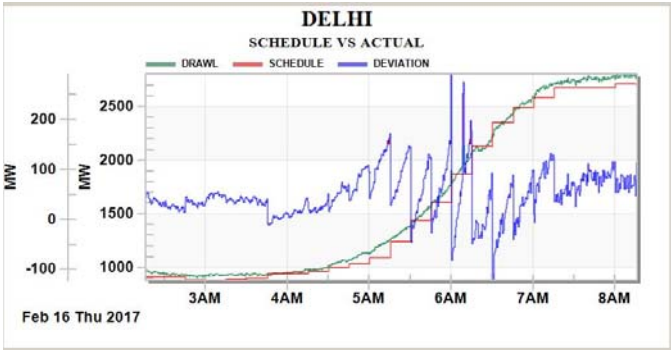
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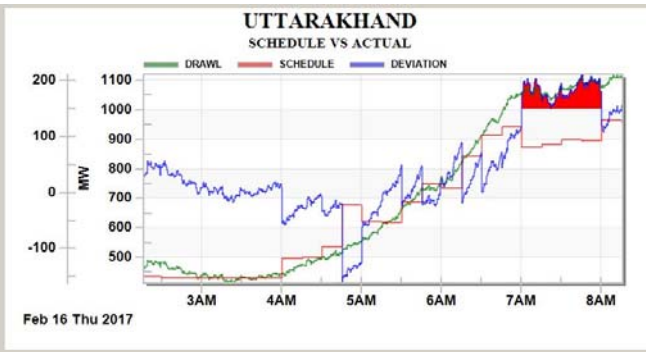
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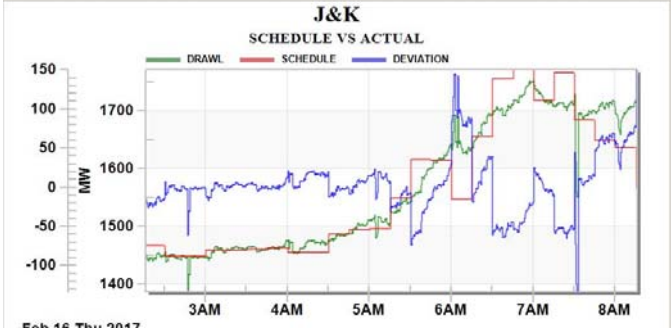
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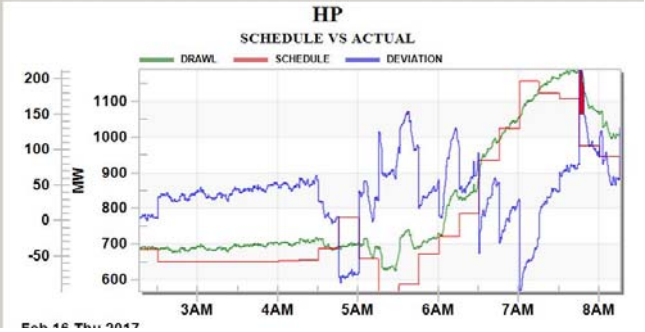
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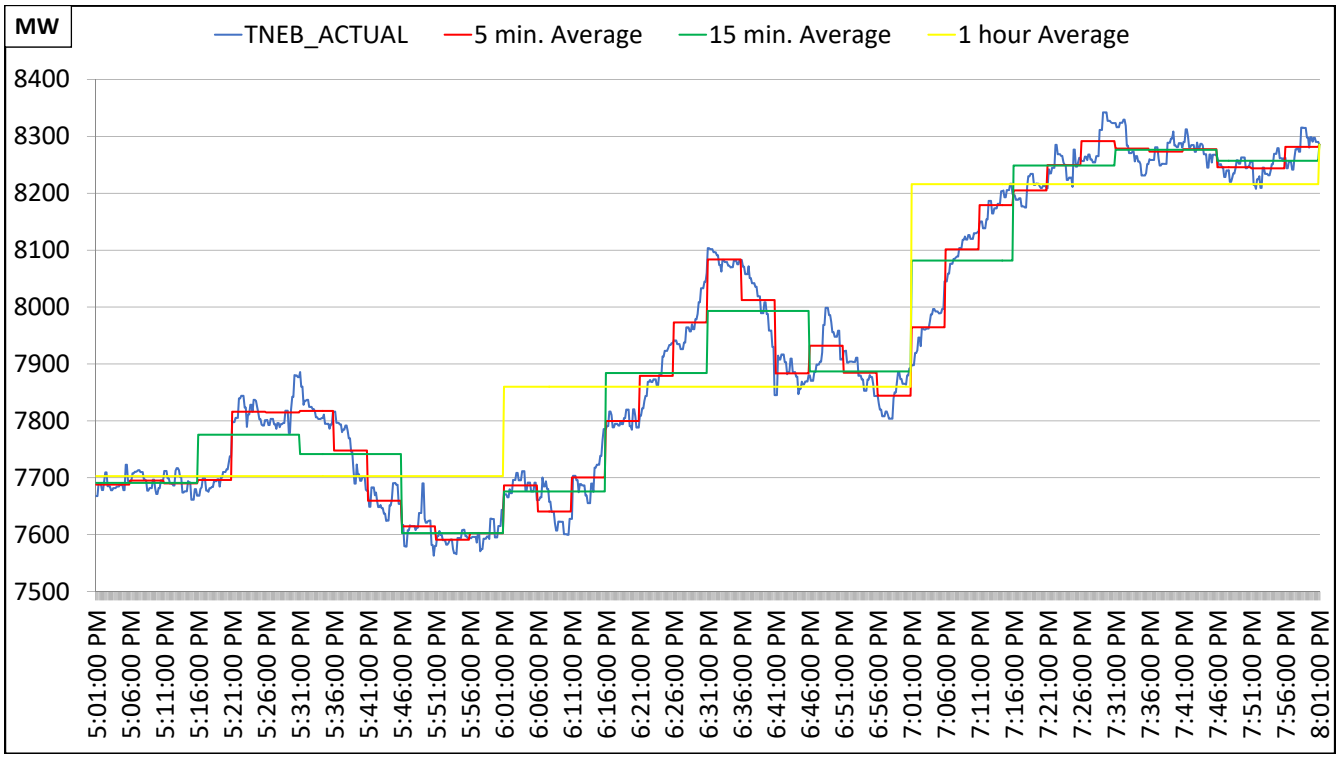
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15 min. Average
1 hour Average
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8200
8100
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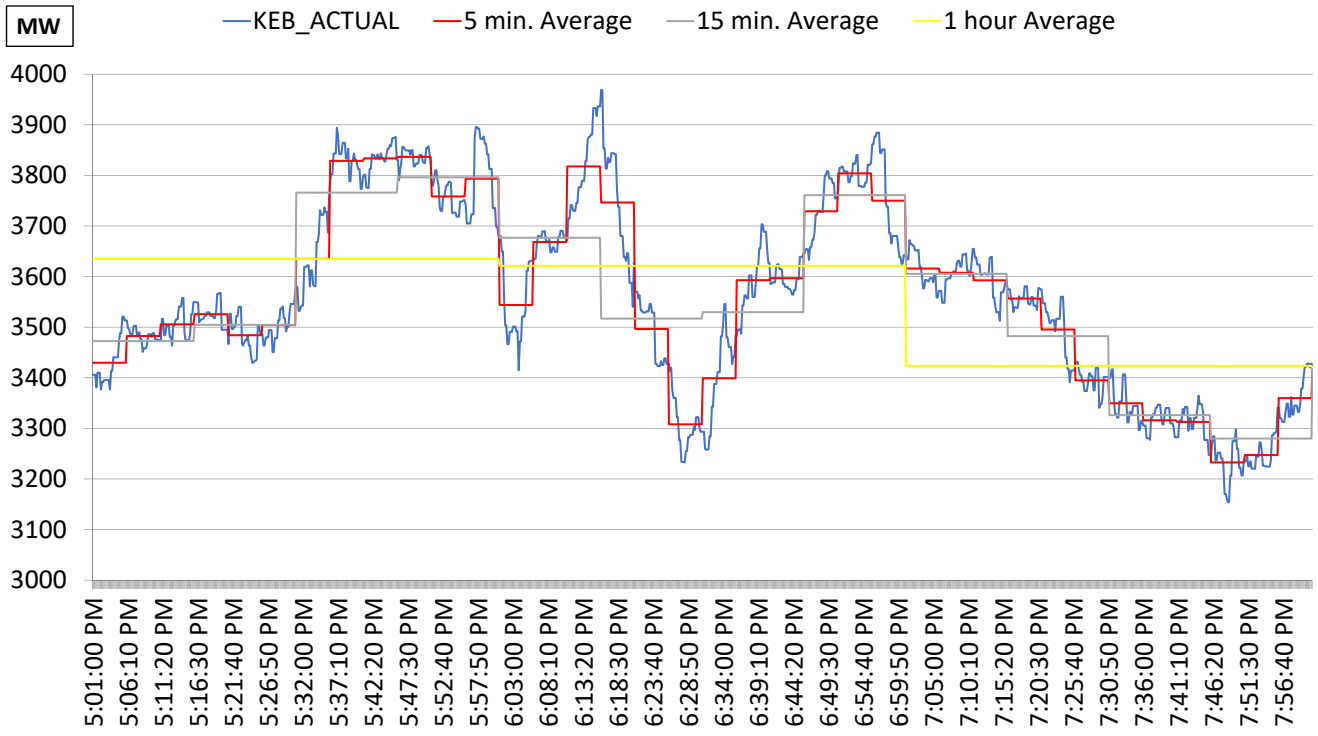
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Policy / Regulatory Mandate (1)

- Report of the Expert Group on 175 GW by 2022, NITI Aayog

  Interventions to reduce overall system costs [Section 3.23(ii)]

  "Scheduling and Dispatch: Through both practice and theory, it has become evident that grids that are operated in a manner where scheduling and dispatch are implemented over short time durations (e.g., as low as five minutes) have significantly lower overall costs to consumers as the need for ancillary resources decreases.

  Currently, in India, scheduling occurs on a day-ahead basis while dispatch occurs on a 15-minute basis. System operations technologies and protocols need to be updated to enable five-minute scheduling and dispatch of all resources connected to the grid and automated incorporation of RE forecasts.

  It should be noted that accuracy of RE forecasts is significantly higher the closer they get to dispatch. Consequently, the ancillary service requirements will also be lower"

Policy / Regulatory Mandate (2)

- CERC order dated 24-May-2011 in Suo Motu Petition No. 127/2011

".....Thereafter matter was discussed in the Central Advisory Committee (CAC) meeting held on 29th September, 2010 with the agenda "How to make power markets more efficient". The CAC recommended for modification in the bidding time block from one hour to fifteen minutes....."

- Samast Report, Technical Committee of the Forum of Regulators, 2016

  "5.6……The States who are about to implement the intrastate accounting and settlement system could leapfrog and go for scheduling and settlement at 5-min interval. The scheduling software and the energy meters specifications could in line with the above. All the other States and the Regional Pools shall also endeavor to have systems and logistics for 5-min scheduling and settlement system…."

  "Apendix – 6: .....One static type composite meter shall be installed for each EHV circuit, as a self-contained device for measurement of active energy (MWh) transmittals in each successive 5 minute block and certain other functions, as described in the following paragraphs……"

CERC ABT Order dated 4th Jan 2000

"5.9.12 We have also considered the views of some of the beneficiaries to change the time block of 15 minutes. We are convinced that a short time block of 15 minutes can be expected to ensure alertness on the part of the dispatcher to take quick corrective action for maintaining desirable system parameters. If the interval is larger, there may be a tendency to defer the action with possibilities of steep frequency excursions thereby inviting damages to the system."

International Experience (1)

- Australia Energy Market Operator (AEMO)
  - "Scheduling and Despatch" decoupled with "Settlement" from 1998, prior to large scale RE integration
    - Scheduling and despatch at 5-minute interval
    - Settlement at 30 minute interval using average of 5-minute prices in that interval
  - 2016: Debate/Stake holder consultations being held to align "scheduling & despatch" interval and the "settlement" interval
- USA

RTO / ISO	Despatch Interval	Settlement Interval
CAISO	5-minute	5-minute
ISO - NE	5-minute	Hourly average
MISO	5-minute	Hourly average
NYISO	5-minute	5-minute
PJM	5-minute	Hourly average
SPP	5-minute	5-minute

International Experience (2)

- FERC Final Rule on "Settlement Intervals and Shortage Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators", 16th June 2016

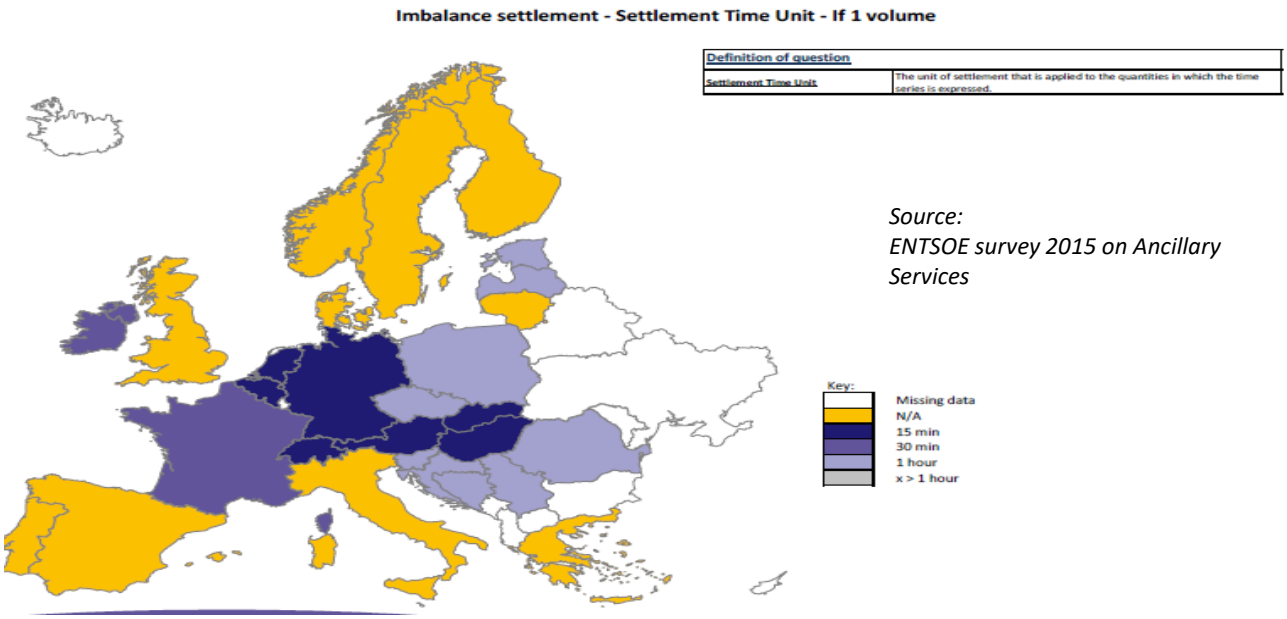
".....We require that each regional transmission organization and independent system operator align settlement and dispatch intervals by:

(1) settling energy transactions in its real-time markets at the same time interval it dispatches energy;

(2) settling operating reserves transactions in its real-time markets at the same time interval it prices operating reserves; and

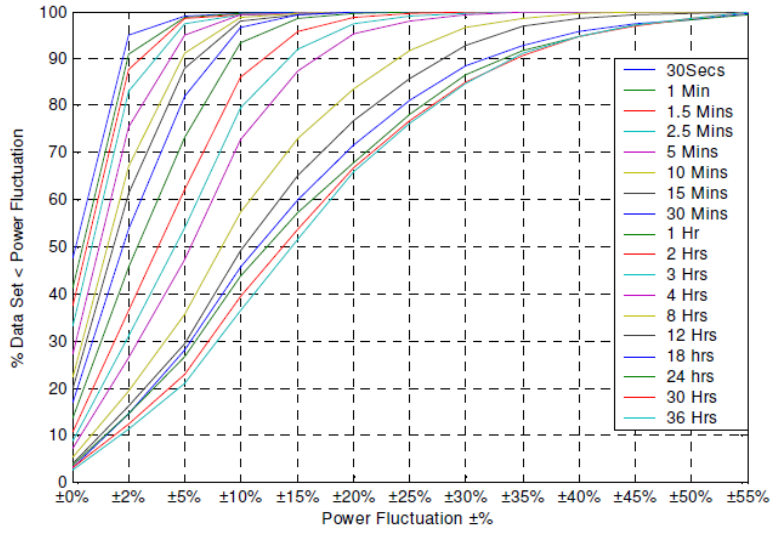
(3) settling intertie transactions in the same time interval it schedules intertie transactions....."

Settlement Interval in Continental Europe



Source:
ENTSOE survey 2015 on Ancillary Services

Optimal trade off with 5-minute forecasting, scheduling, despatch and settlement



Source:
CIGRE Technical Brochure 293: Electrical Power System Planning with uncertainty of wind generation

Figure 3.6 – Variability in different time periods

NREL Report on Integrating Variable Renewable Energy (1)

"Five –minute dispatch is currently the norm in ISOs throughout the country, serving over 2/3 of the national load. Five minute scheduling was adopted because it reduces power system operating costs, not to enable renewable generation integration. Five minute scheduling has helped reduce regulation requirements to below 1% of peak daily load in many ISO/RTOs.

Studies have shown that integration costs are lower in areas with faster dispatch. For example, integration costs have ranged from $0/MWh to $4.40/MWh in areas with five-minute dispatch, compared to $7/MWh to 8/MWh in areas with hourly dispatch (WGA 2012) .

Integration studies have also demonstrated savings from faster dispatch and scheduling. For example, the Western Wind and Solar Integration Study Phase 1 found that the use of sub-hourly scheduling cut in half the amount of fast maneuvering required by combined-cycle plants. It also found that hourly scheduling had a greater impact on regulation requirements than the variability introduced by wind and solar power in the scenarios studied"

NREL Report on Integrating Variable Renewable Energy (2)

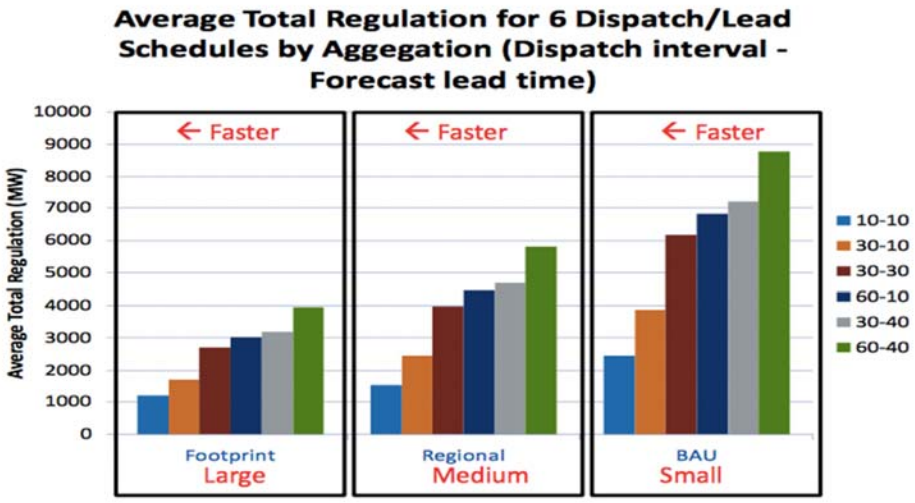


Figure 3. The size of the balancing authority area and increasing frequency of dispatch can reduce regulating reserve (Milligan et al. 2011).

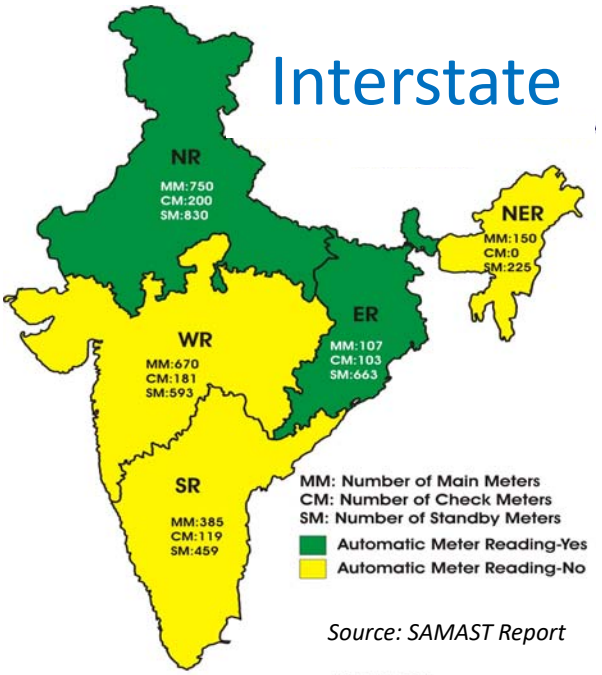
Actions Needed for implementation of Fast Markets in India

- Forecasting
- Scheduling & Despatch
- Markets : 5-minute bilateral markets; Power Exchanges – 5 minute price discovery
- Deviation Settlement 5-minute prices in DSM
- Commercial interface metering
- Settlement system – energy accounting, financial settlement
- Changes in various CERC/SERC Regulations
- Gate closure provisions
- Changes in CEA Metering Standards
- Replacement of meters
- Software upgrade at the RLDCs/SLDCs –
  - Scheduling, Short Term Open Access (STOA), meter data processing, accounting, settlement
- Software upgrade at the RPCs
- Holding workshops, dissemination, stakeholder capacity building

Interstate Metering and Deviation Settlement

3261 : Interface points
5435 : Interface Energy Meters
0.2s : Accuracy Meters
189 : Active Pool members
Accounts Settled in 21 days
~ Rs.200 Crore settled weekly

STOA and Ancillary Services functioning on
- Two-part ABT
- Multi-part settlement
- Maker-Checker
- Transparency



Source: SAMAST Report

Timelines & Financial Implications

- Timelines required for
  - Regulatory Framework
  - Changes in Procedures
  - Software changes
  - Metering hardware changes / upgradation
  - Transition handling / Trial operations
  - Roll out

- Cost Estimates
  - Software changes
    - Scheduling software
    - Meter data processing
    - Accounting software
    - Settlement systems
    - MIS Systems
  - Meter upgradation / replacement

Way Forward

- Constitution of a sub-group under FOR Technical Committee
- Members:
  - CERC
  - CEA
  - RPCs
  - CTU
  - NLDC, RLDCs
- Submission of report within 2 months to Technical Committee by the sub-group
- Acceptance and Recommendation of the report by Technical Committee
- Adoption by Forum or Regulators

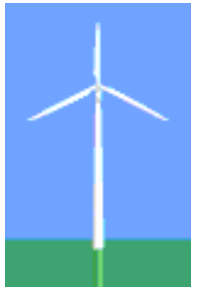
References

- Report of the Expert Group on 175 GW by 2022, NITI Aayog
- CERC ABT Order 4th Jan 2000
- FERC Final Rule on Settlement Intervals and Shortage Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators, June 2016 https://www.ferc.gov/whats-new/comm-meet/2016/061616/E-2.pdf
- Examination of Potential Benefits of an Energy Imbalance Market in the Western Interconnection, NREL http://www.nrel.gov/docs/fy13osti/57115.pdf
- CERC order dated 24-May-2011 in Suo Motu Petition No. 127/2011 http://www.cercind.gov.in/2011/May/signed_order_in_suo_motu_pet_No_127-2011.pdf
- Five Minute Settlement Working Paper by AEMO http://www.aemc.gov.au/Rule-Changes/Five-Minute-Settlement/Consultation/AEMO-Documents/AEMO-Five-Minute-Settlement-working-paper
- Survey on Ancillary services procurement, Balancing market design 2015 https://www.entsoe.eu/Documents/Publications/Market%20Committee%20publications/WGAS%20Survey_04.05.2016_final_publication_v2.pdf?Web=1
- Integrating Variable Renewable Energy: Challenges and Solutions, NREL http://www.nrel.gov/docs/fy13osti/60451.pdf

Discussion

Thank You !

National Institute of Wind Energy



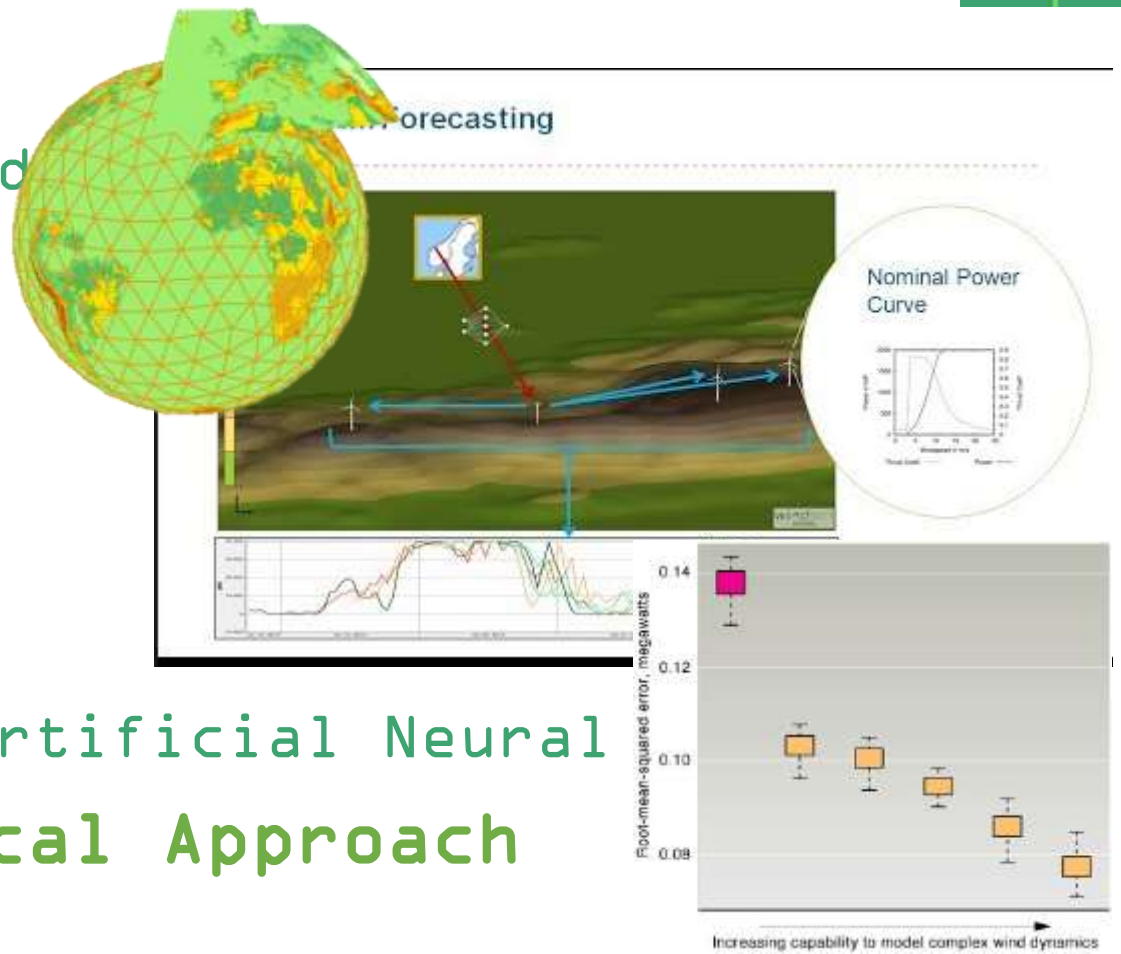
Wind Power Forecasting Technology

A.G.Rangaraj

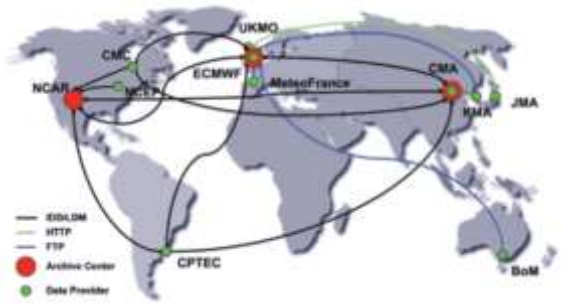
Deputy Director
(Technical)

Methods of Wind Power Forecasting

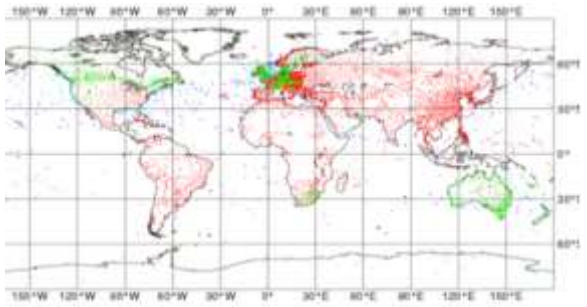
- Physical Approach
  - Using Numerical Weather Pred
    - ✓ Power Curve to convert power
  - Using Wind Flow Modeling
    - ✓ Computational Fluid Dynamics
    - ✓ Linear wind flow modeling
- Statistical Approach
  - Using Regression
  - Using Machine Learning / Artificial Neural
- Mixed Physical - Statistical Approach



Numerical Weather Prediction

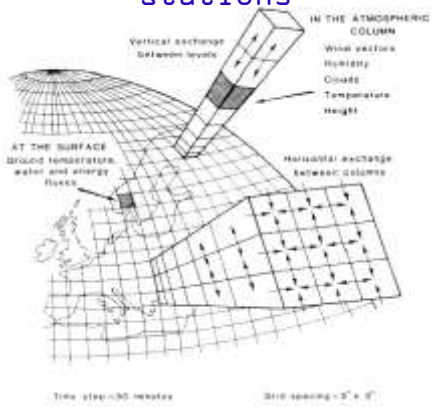


NWP Sources



Weather Measurement Stations

Source of Weather Measurement



Gridding the World

- ✓ NWP Model components
  - ➢ Initial Conditions:
    - Input data and Initialization
  - ➢ Governing Equations
  - ➢ Numerical Procedures
    - Grid Point Models
    - Spectral Models

- ✓ NWP Model components
  - ➢ Physical Process
    - Modeling Local Effects
    - Parameterization
  - ➢ Model Output
    - File with Model forecast
    - Post processing

Momentum:

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} - w\frac{\partial u}{\partial z} - \frac{1}{\rho}\frac{\partial p}{\partial x} - fv$$

$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - w\frac{\partial v}{\partial z} - \frac{1}{\rho}\frac{\partial p}{\partial y} + fu$$

$$\frac{\partial w}{\partial t} = -u\frac{\partial w}{\partial x} - v\frac{\partial w}{\partial y} - w\frac{\partial w}{\partial z} - \frac{1}{\rho}\frac{\partial p}{\partial z} - g$$

Mass:

$$\nabla \cdot (\rho \vec{u}) = -\frac{\partial \rho}{\partial t}$$

Heat

$$Q = c_p\frac{dT}{dt} + \frac{1}{\rho}\frac{dP}{dt}$$

Moisture

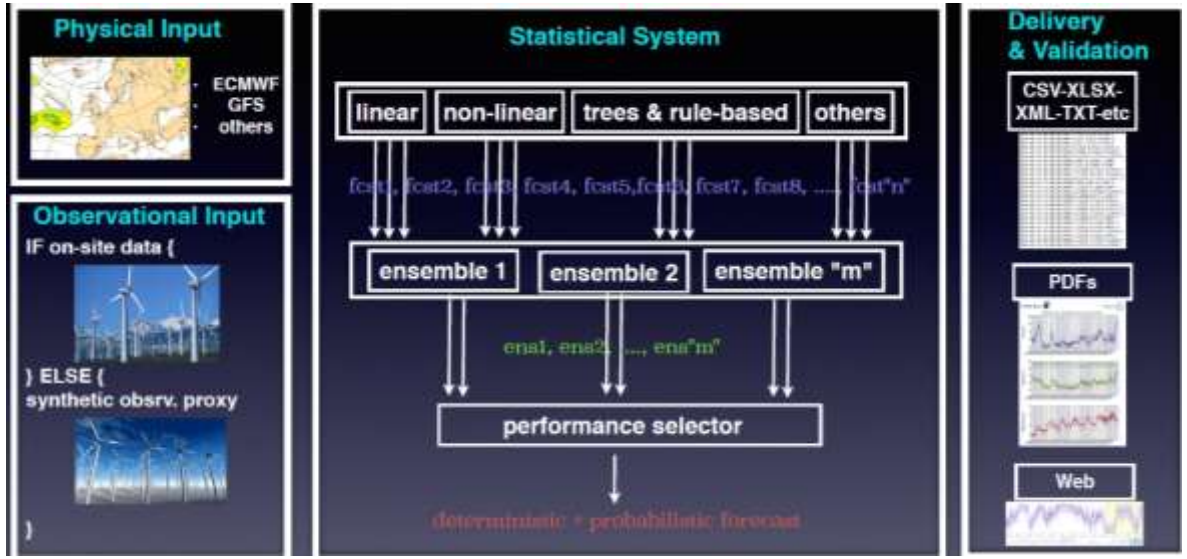
$$\frac{\partial q}{\partial t} + \vec{u}u \cdot \nabla q = E - C$$

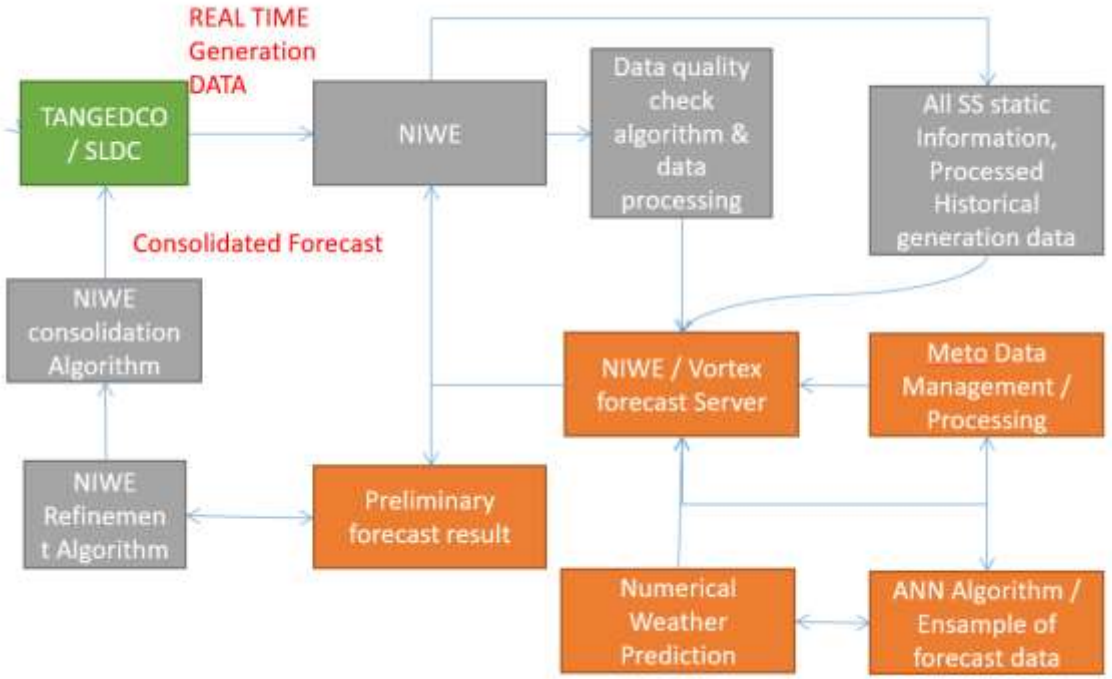
Gas law

$$P = \rho RT$$

- ✓ Conservation of Momentum
  - ➢ 3 equations for accelerations of 3-d wind (F=ma)
- ✓ Conservation of mass
  - ➢ 1 Eqn for conservation of air
  - ➢ 1 Eqn for conservation of water
- ✓ Conservation of energy
  - ➢ 1 Eqn for the first law of thermodynamics
- ✓ Relationship among p, V and T
  - ➢ 1 Eqn of State (Ideal Gas law)

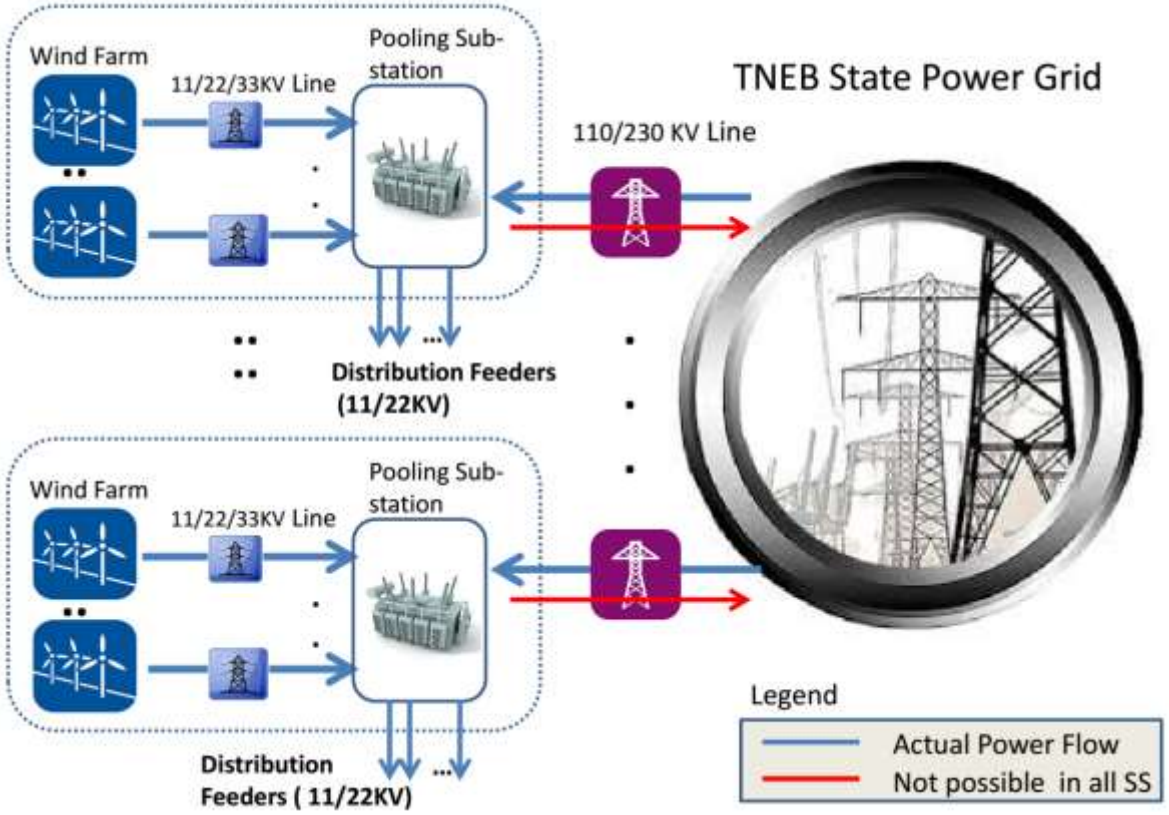
NIWE Forecast System





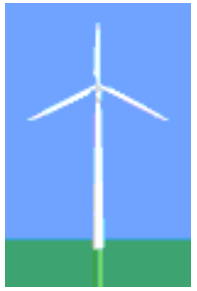
- Training of Model
- Performance Selector
- Power forecast Ensambling

Real Time Generation data setup



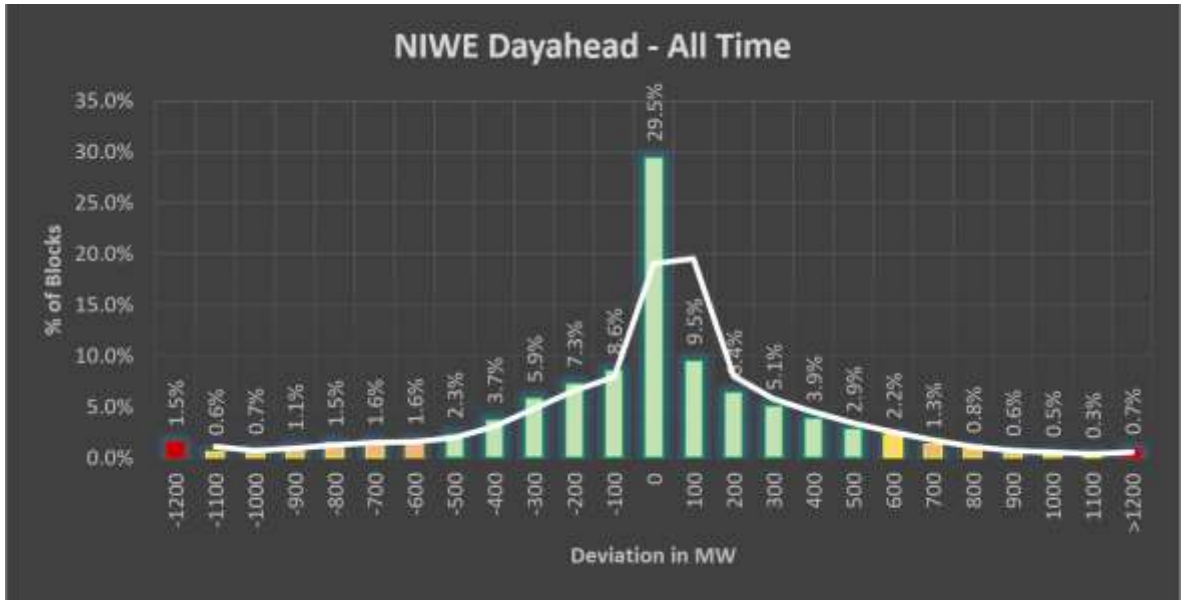
- 107 Numbers of Substations finalized in Tamil Nadu
- Meter Fixed at GC feeder of each Substation
- Cumulative kWhr reading collected
- Automation system established to convert to kW and also to do various data quality checks
- Class CT / PT used
- Many Substations are having mixed feeder and Distribution load
- Effective Power injected to the grid will be recorded by the

Uncertainties in any Forecast System



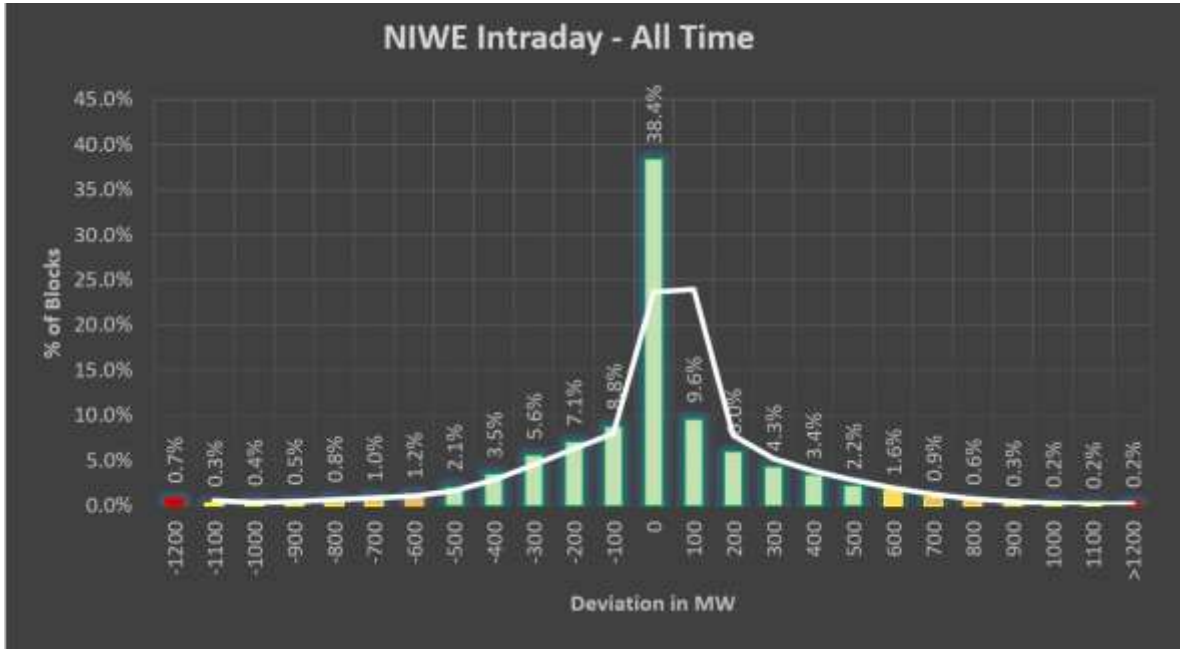
- Forecast System - Model Error
  - Uncertainties in NWP data set
    - ✓ Initial Condition
    - ✓ Data Assimilation Process
    - ✓ Approximation of Governing Equations
    - ✓ Low Temporal Resolution
    - ✓ Spatial Resolution
    - ✓ Local Terrain Model Parameterization
    - ✓ NWP Model Error
  - Interpolation Error
    - ✓ Time Interpolation
    - ✓ Vertical Height Interpolation
    - ✓ Spatial Interpolation
  - Poor quality of Input data
- Actual Generation data System
  - Metering at Substation
    - ✓ Net Generation is measured
    - ✓ Mixed Feeders
    - ✓ Distribution Load Effects
    - ✓ Time Synchronization
    - ✓ No Mechanism to capture grid outages
    - ✓ Individual Machine Performance not known
    - ✓ No Mechanism to capture individual machine details
  - SCADA
    - ✓ Wind speed recorded in WTG may not be reliable
    - ✓ Old WTG does not have SCADA facility
    - ✓ No Access to SCADA by NIWE
  - Communication

NIWE Forecast - Error Analysis



Month	Dayahead			
	Within 600 MW	Within CERC Limit	MAE	RMSE
Sep-15	46.3%	89.2%	656	790
Oct-15	88.4%	99.7%	250	369
Nov-15	97.9%	100.0%	95	163
Dec-15	93.0%	100.0%	213	295
Jan-16	91.8%	99.4%	242	334
Feb-16	95.5%	99.5%	183	277
Mar-16	98.7%	100.0%	119	174
Apr-16	99.1%	100.0%	129	184
May-16	66.8%	90.6%	495	683
Jun-16	76.9%	97.7%	398	514
Jul-16	70.8%	93.6%	470	609
Aug-16	82.9%	99.8%	359	434
Sep-16	84.6%	99.8%	343	427
Oct-16	84.3%	99.0%	371	447
Nov-16	96.6%	99.9%	349	376
Dec-16	90.4%	96.9%	399	511
Jan-17	95.4%	100.0%	228	294
Feb-17	99.1%	100.0%	141	189
All Time	85.1%	97.8%	311	444

NIWE Forecast - Error Analysis



Month	Intraday			
	Within 600 MW	Within CERC Limit	MAE	RMSE
Sep-15	72.1%	93.9%	435	590
Oct-15	96.6%	99.9%	158	236
Nov-15	99.0%	100.0%	82	134
Dec-15	97.7%	100.0%	140	214
Jan-16	99.5%	100.0%	118	175
Feb-16	99.5%	100.0%	103	150
Mar-16	99.8%	100.0%	73	111
Apr-16	100.0%	100.0%	84	127
May-16	84.8%	98.9%	309	422
Jun-16	84.1%	99.4%	327	420
Jul-16	76.8%	96.7%	412	538
Aug-16	87.3%	99.9%	328	396
Sep-16	90.9%	99.8%	284	361
Oct-16	84.3%	99.0%	371	447
Nov-16	96.5%	99.9%	349	377
Dec-16	90.4%	96.9%	399	511
Jan-17	95.3%	100.0%	228	294
Feb-17	99.1%	100.0%	141	189
All Time	91.1%	99.0%	241	355

Forecasting Portal developed by NIWE

Login Page

Wind Power Forecast portal - Public view

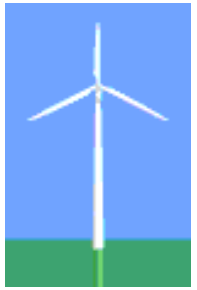
5 days ahead Forecast

Wind Power Forecast portal - SLDC / RLDC / NLDC / Client's View

Wind Power Forecasting

Presentation to Forum of Regulators, CERC, TNERC and TANGEDCO officials

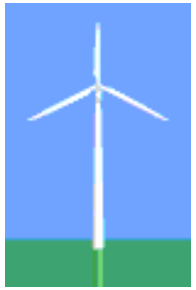
NIWE Indigenous Forecast Model

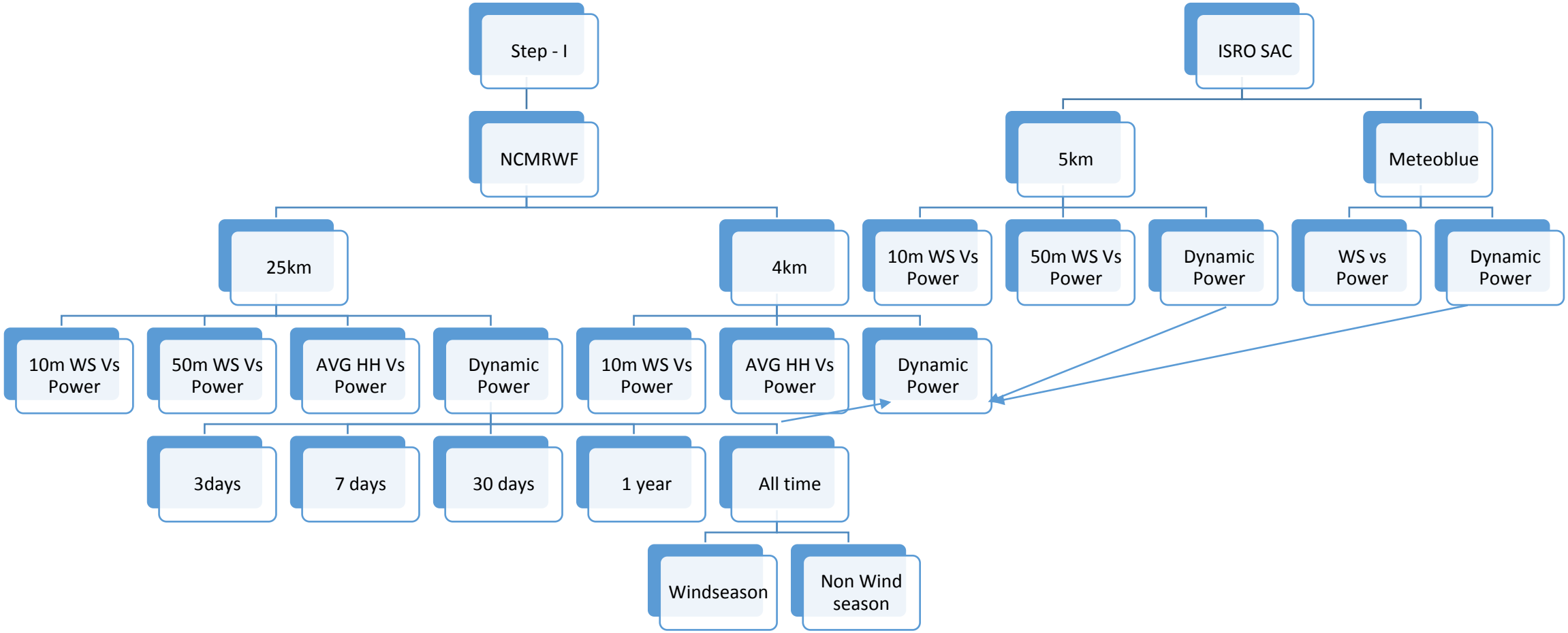


- **NCMRWF**
  - 25 km regional model
  - 4km High resolution model
  - 25 km - 120 Hours ahead with hourly interval
  - 4km - 72 Hours ahead with hourly interval
  - NIWE developed system to carry out time interpolation
  - Forecast is disseminated through IMD (Indian Meteorological Department)
  - Data Assimilation
    - ✓ NCEP GTS
    - ✓ IMD stations
    - ✓ Satellite Observation
  - Model - UK met office

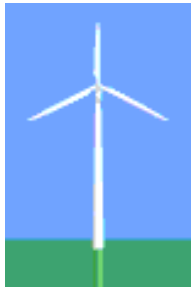
- **ISRO - SAC**
  - 5km high resolution
  - 72 hours weather forecast with 3 hours interval
  - 72 Hours weather forecast with 15 mins interval (Under progress)
  - Forecast is disseminated through MOSDAC (Meteorological and Oceanographic Satellite Data Archival Centre)
  - Data Assimilation
    - ✓ NCEP GTS
    - ✓ Assimilated conventional
    - ✓ Satellite Observation
      - ➢ INSAT
      - ➢ MT
      - ➢ SCATSat -1 etc.,
    - ✓ KSNDMC - used for Agricultural purposes and warnings
  - Model - WRF

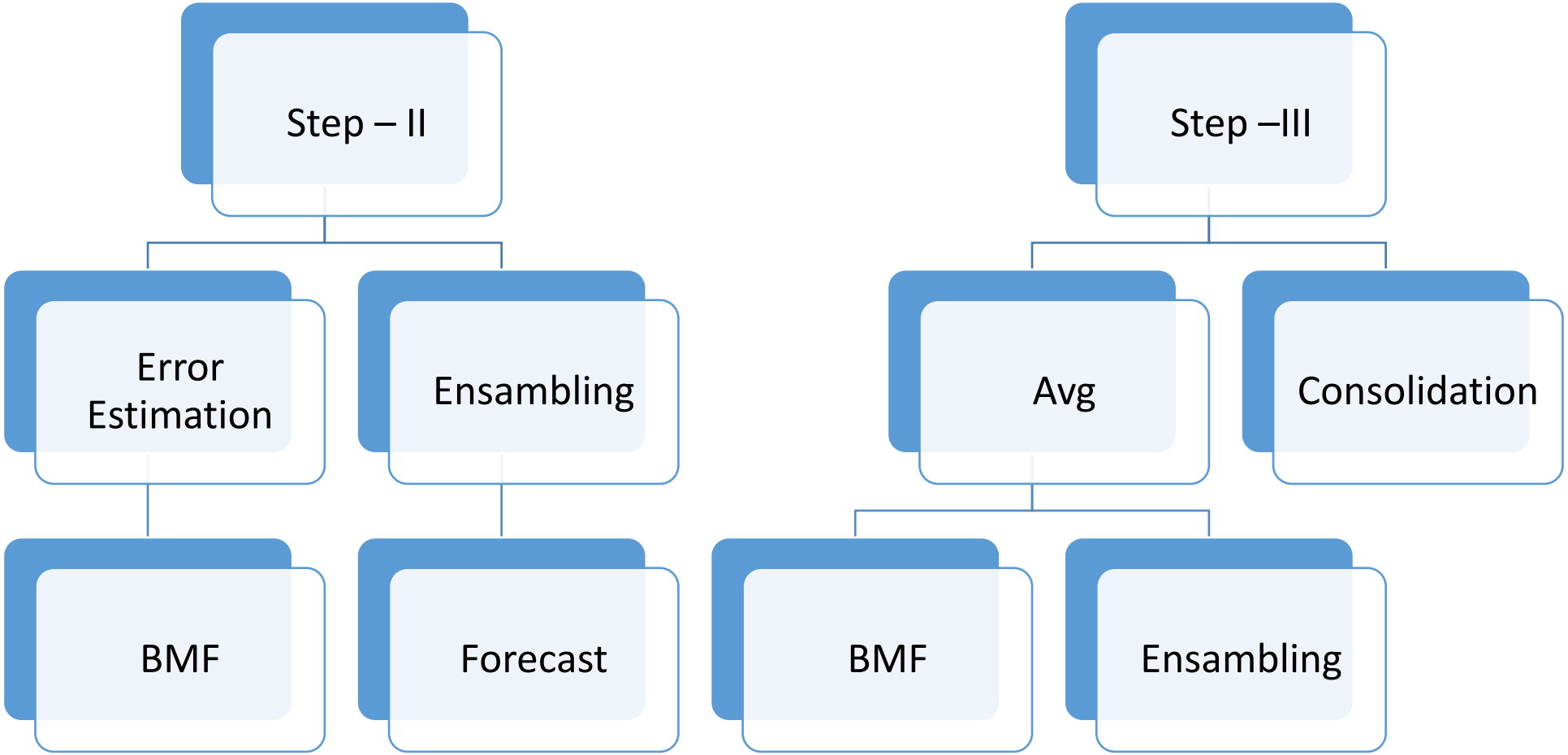
NIWE Indigenous Forecast Model



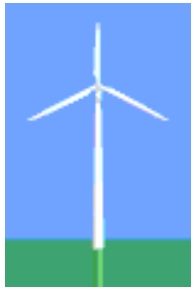


NIWE Indigenous Forecast Model





NIWE Indigenous Forecast Model



Present System

- Statistically linking NWP data set with Actual Generation
- Using different combination of NWP output NIWE developed 6 Major Module
- 6 Major Module produces - 197 Forecasts for each substations
- Indigenously developing Ensambling system
  - ✓ Dynamic Error Control (Completed)
  - ✓ ANN Machine learning (Under Progress)
- Performance Selector System - Training
  - ✓ Identification of Station wise BMF
  - ✓ Identification of Station wise worst Forecast
- Consolidation System

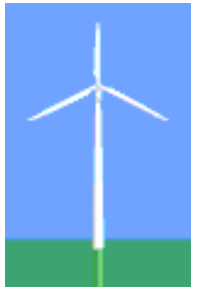
Future Improvements Plan

- Obtaining Machine wise data
- Improvement in existing statistical system developed by NIWE
- System to adapt Machine availability details
- System to segregate the distribution load details
- Benchmarking in upcoming wind season with other Forecast models
- Implementation of necessary correction in the model based on benchmark result
- Inclusion of individual machine / park performance

Highlights of the Model

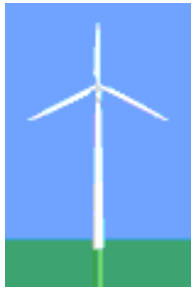
- Preliminary verification carried out

Conclusion / Summary



- All Forecasting is based on good weather model (Large and Meso-scale)
- Wind speed forecast improves from 60% to >95% by coupling HRM with MOS
- Downscaling with measurements through MOS is best
- Multi-model and Ensembles allow probability function and risk calculations for better balancing of uncertainty
- Now casting to balance very short term changes
- In most of the Substations, NIWE indigenously developed model performs better than other 2 models
- NIWE expecting to deliver better forecast to TN-SLDC with the newly developed indigenous forecasting model.

National Institute of Wind Energy



Thank you