Mapping Study of Indian

Thermal Power Generating Units

K. K. Chakarvarti
Senior Programme Manager
IGEN

Indian Thermal Power Stations

- The contribution of energy generated by thermal stations was 559 billion kWh, which is about 80% of electricity generated (704.5 billion kWh) in 2007-08.
- There has been significant improvement in the plant load factor of thermal stations, which improved from 52.4% in 1985-86 to 78.6 in 2007-08, registering a remarkable improvement of 50 % during the period.
- Since the major power generation contribution is from thermal sector, an average increase of 1% in the thermal power plant efficiency would result in:

  a. Coal savings of approx. 11 million tons per annum for nation (approx) worth 200 Million Euro

  b. 3% CO_2 reduction per annum (approx.13.5 million tons per annum)

Existing Generating Capacity- March 2008

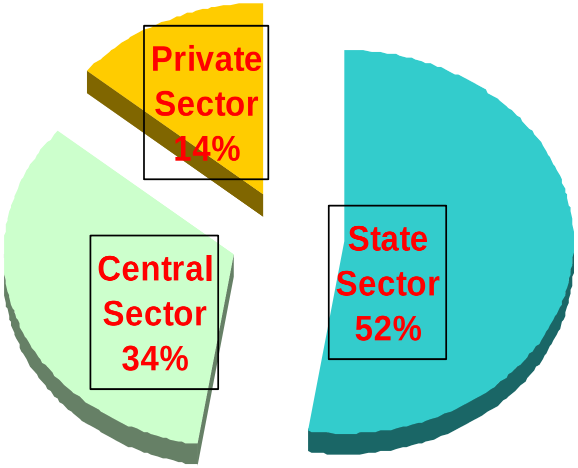
Fuel wise break-up (MW)

Thermal	**92,426**	**63.8%**
Hydro	**36,033**	**24.9%**
Nuclear	**4,120**	**2.8%**
Renewable	**12,194**	**8.5%**
TOTAL	**144,773**	**100.0%**

(Excluding captive capacity of 14636 MW connected to grid)

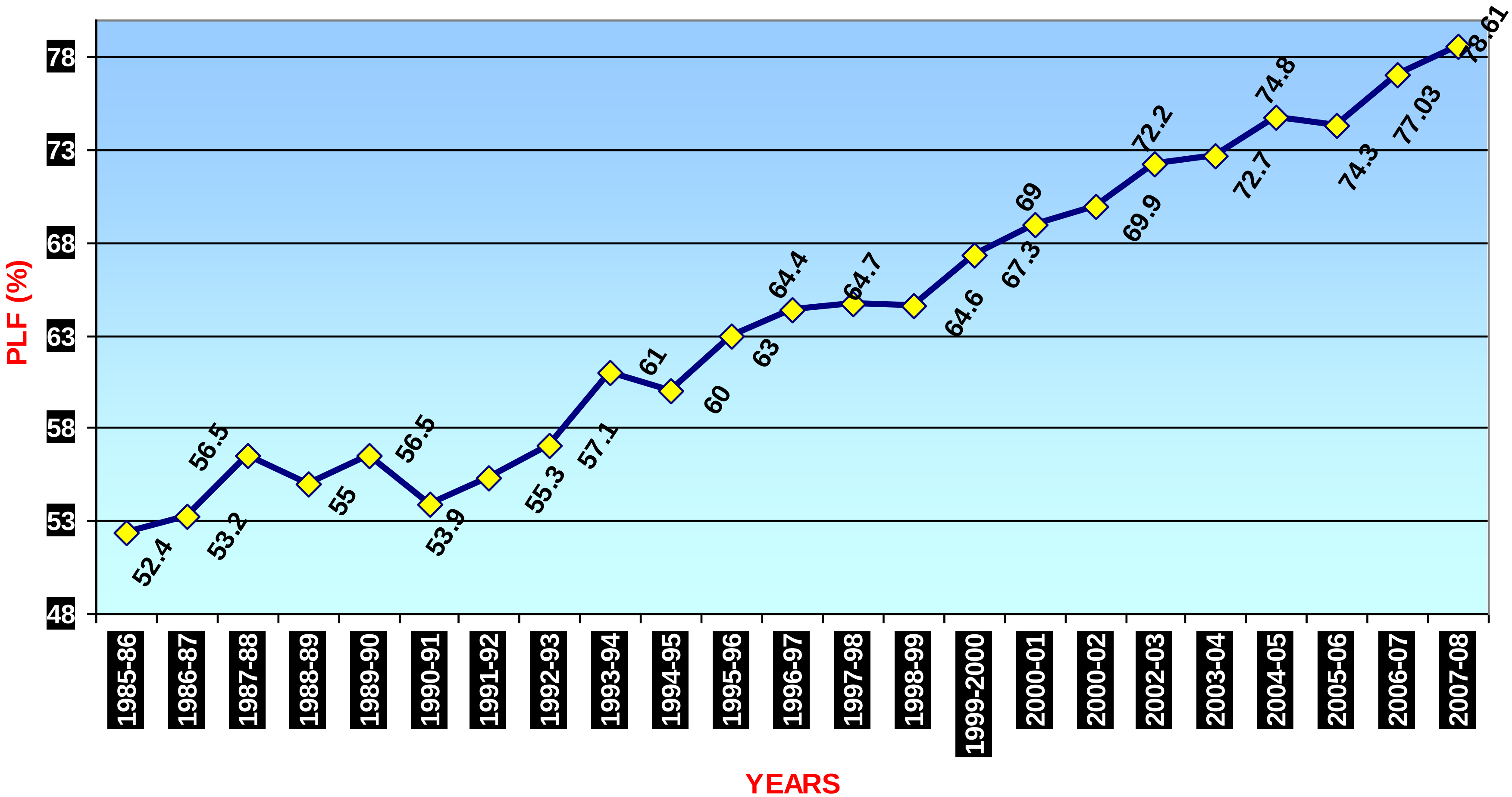
(All figures provisional from CEA)

Sector wise break-up (MW)



Total generation in 2007-08 – 704.45 BU

ALL INDIA PLANT LOAD FACTOR (%) OF COAL FIRED THERMAL POWER STATIONS

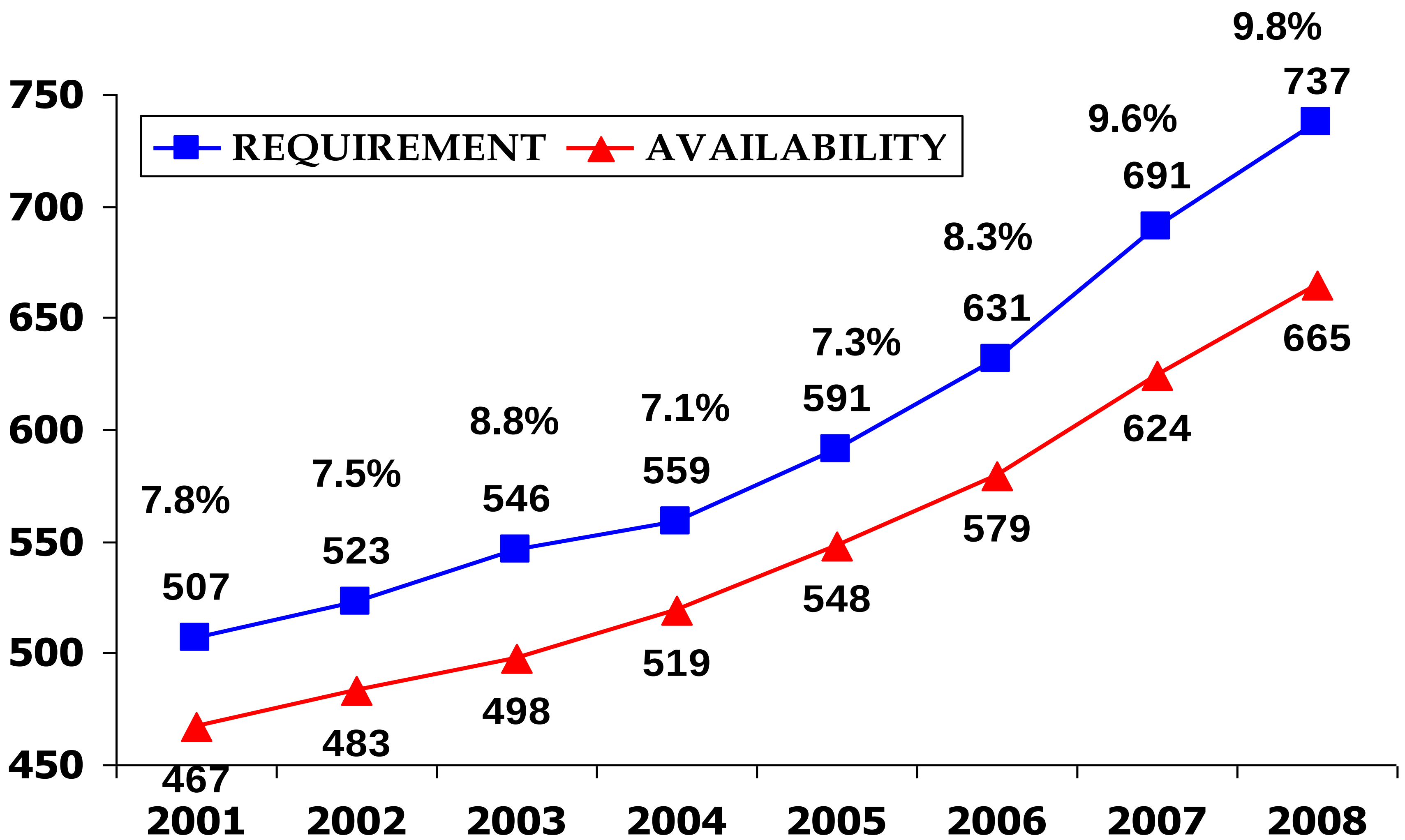


INSTALLED THERMAL CAPACITY – UNIT SIZE- WISE

(AS ON 31ST Oct., 2008)

Unit Size MW	No. of Units	Installed Capacity MW
Upto 195	186	15,099
200/210	164	34,210
250	28	7,000
300	5	1,500
500	39	19,500
Total (Coal based Capacity)	**422**	**77,309**

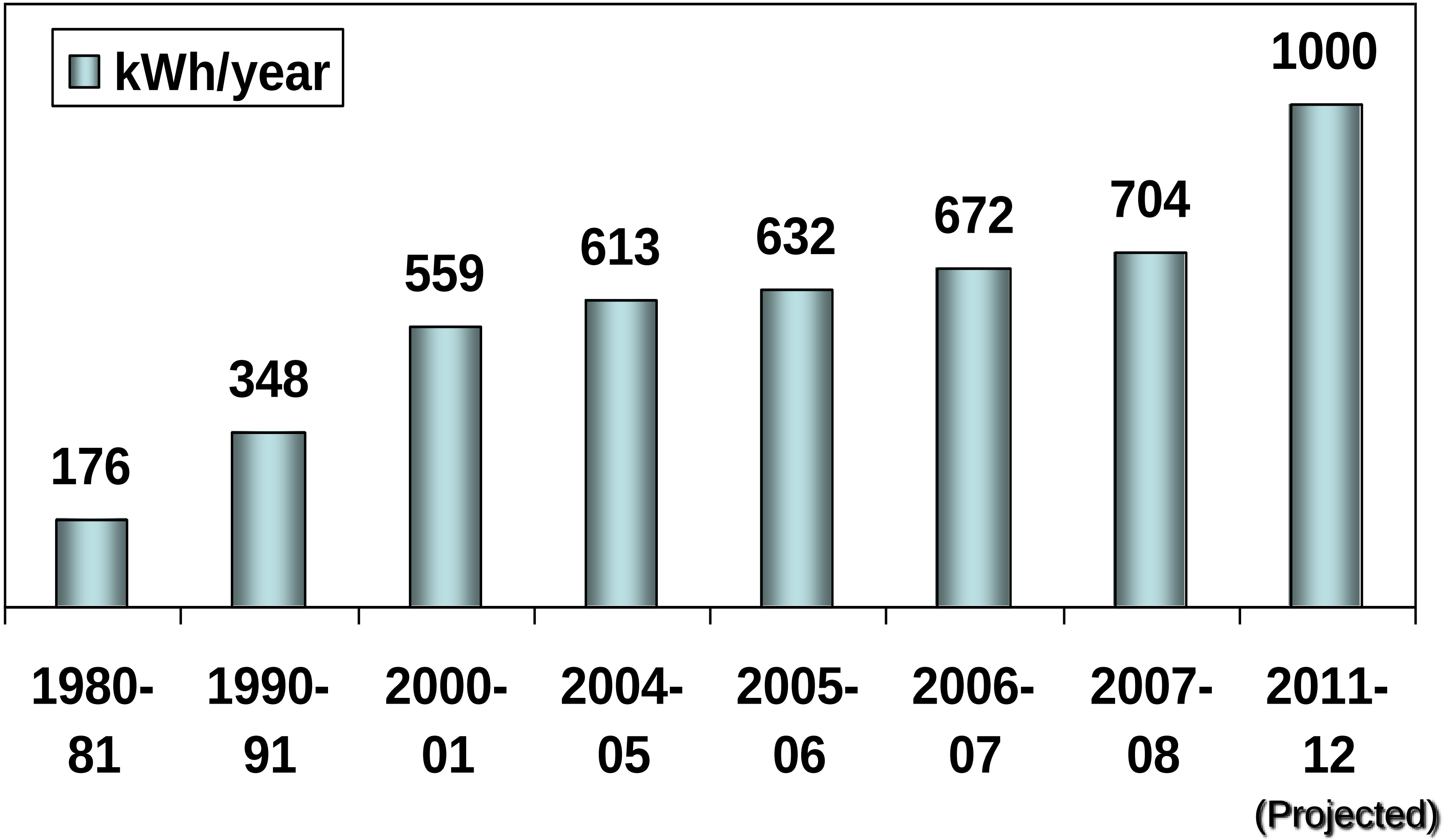
Energy Shortage



DURING 2007-08, PEAKING SHORTAGES WERE 16.6%

PER CAPITA CONSUMPTION OF ELECTRICITY IN INDIA

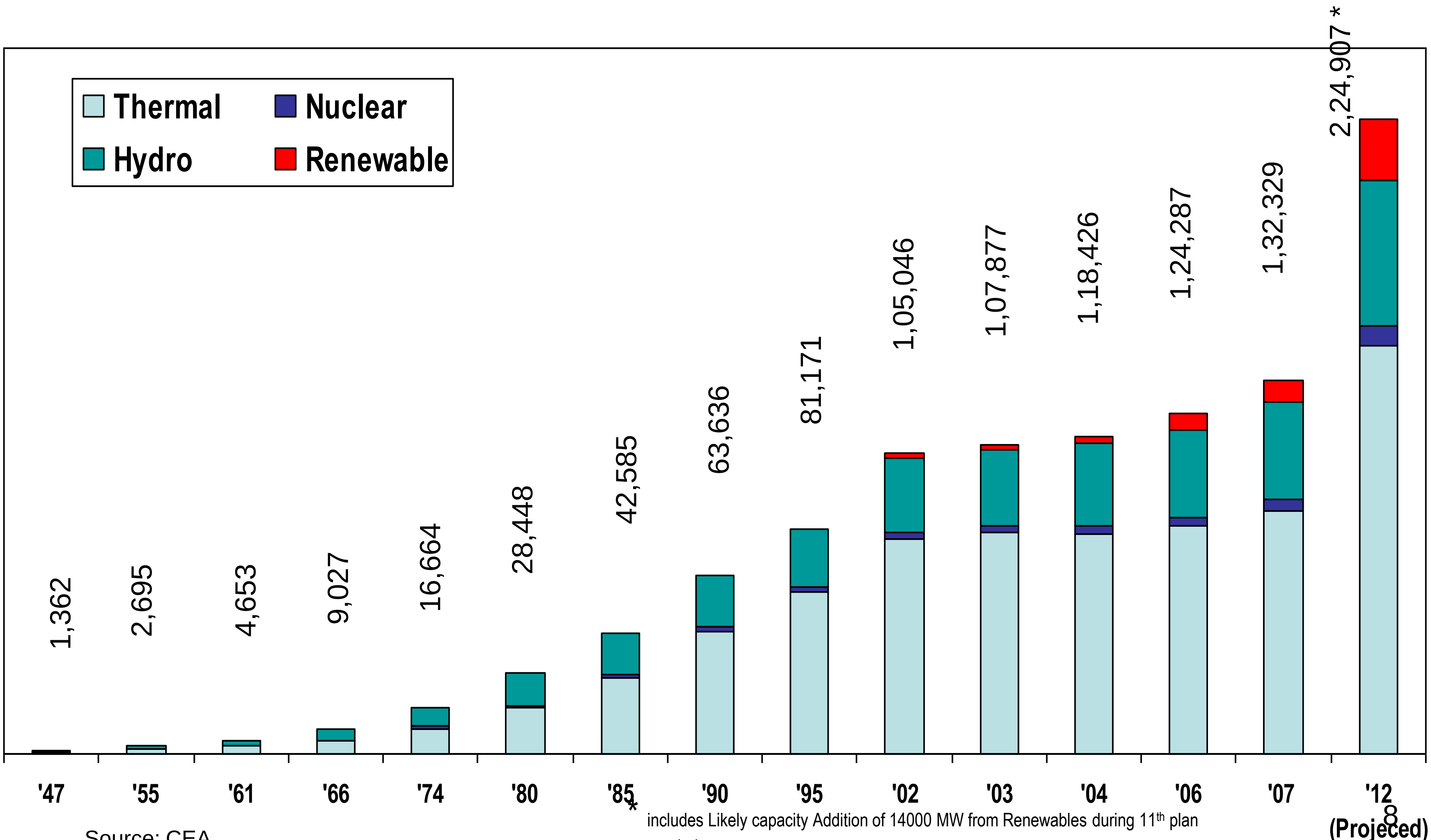
Growth Pattern



As per UN Methodology (Gross Electrical Energy Availability / Population)

GROWTH OF INSTALLED GENERATING CAPACITY IN INDIA

(figs. in MW)



* includes Likely capacity Addition of 14000 MW from Renewables during 11th plan period

Source: CEA

The Indo German Energy Programme (IGEN)

- **The Ministry of Power, Government of India and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH) signed an ‘implementation agreement’ with respect to the Indo-German Energy Programme in 2006.**

- **The Indo German Energy Programme (IGEN) is performing research work and performance assessment in support of the implementation of the Energy Conservation Act 2001 in cooperation with the Ministry of Power and its statutory bodies Bureau of Energy Efficiency (BEE), and Central Electricity Authority (CEA).**

- **Under the IGEN agreement, CEA has been entrusted with the task of ensuring performance optimisation and efficiency of thermal power plants.**

The Indo German Energy Programme (IGEN)

- **The overall aim of this measure under Indo Germany Energy programme is to support and prepare public and private power plant operators for performance reporting as well as implementation of financially attractive and technically viable improvements of power plant net heat rate under the provisions of the Energy Conservation Act.**

- **The project is being executed under two main sub-components:**

  1. Mapping Studies of thermal power generating units

  2. Performance Optimisation of Thermal Power Stations

Mapping Studies of Indian Thermal Power Stations

- IGEN has provided support to CEA in creating a database of the older thermal power plants in India.
- The scope of the work primarily covers the mapping of the 85 thermal power generating units by using Ebsilon software.
- The mapping is done for two-condition design status and the actual operating status based on plant parameters gathered from different plant locations.
- Its primary purpose is to provide a baseline mapping for creating a database within CEA and identify areas both short and long term, needing attention in order to improve energy efficiency.
- The baseline map would permit an objective method of setting targets and monitoring progress.

MAPPING STUDIES - PROGRESS ACHIEVED

- **Mapping studies of 85 Thermal power generating units (49 units of 210 MW + 5 units of 200 MW+ 5 units of 250 MW + 5 units of 500 MW + 21 units of 110 MW-140 MW) completed during 2007-09 of the 14 Indian States viz.**

- **AndhraPradesh, Chhattisgarh, Gujarat, Haryana, Jharkhand, Madhya Pradesh, Karnataka ,Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh & West Bengal have been completed.**

- **The mapping studies carried out by using Ebsilon Software have brought out the deviations between design and operating parameters such as gross heat rate, turbine heat rate, boiler efficiency , specific coal consumption of the power generating units .**

Units Completed State wise and Capacity wise

STATE WISE	PLANTS COVERED (Nos.)
PUNJAB	6
MAHARASTRA	13
GUJRAT	11
RAJASTHAN	5
UTTAR PRADESH	10
HARAYANA	3
ANDHRA PRADESH	9
TAMIL NADU	8
KARNATAKA	2
ORISSA	2
DVC	5
WEST BENGAL	4
MADHYA PRADESH	3
CHATTISGARH	3
JHARKHAND	1
TOTAL	85

CAPACITY WISE	PLANTS COVERED (Nos)
210 MW	49
200 MW	4
250 MW	5
500 MW	5
110 MW	7
120 MW	8
125 MW	1
100 MW	2
140 MW	4
TOTAL	85

Design and average operating values of gross heat rate and percentage deviation for each group size
(Preliminary findings of Mapping Studies of 85 Thermal Power Generating Units in 2007-08 under IGEN Programme)

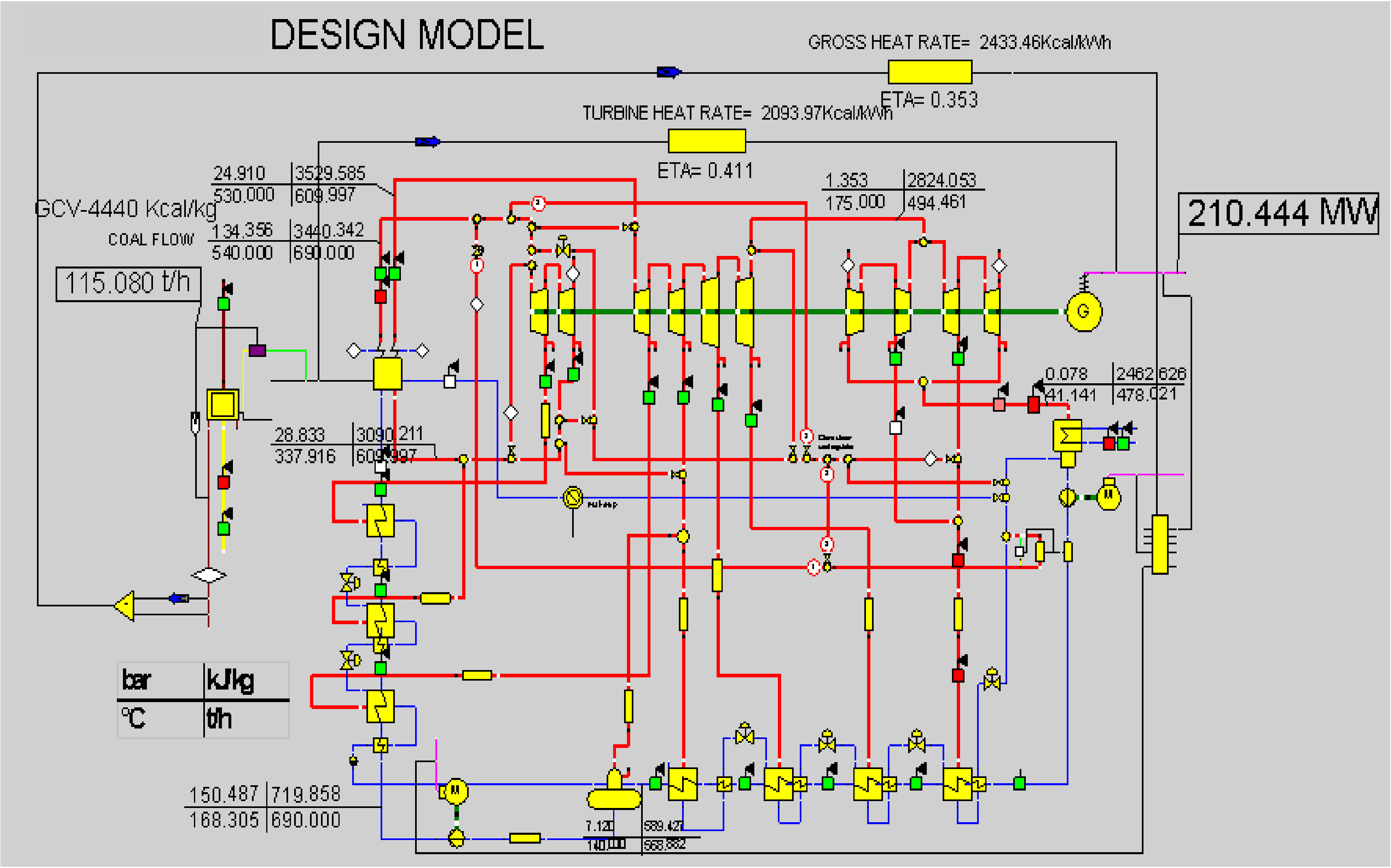
Capacity Range of Units	No. of Units	Average Design Gross Heat Rate (kcal/kWh)	Avg. Design Efficiency (%) on GCV basis	Avg. Operating Gross Heat Rate (kcal/kWh)	Avg. Operating efficiency (%) on GCV basis	Drop in efficiency from design (percentage points)	Percentage Deviation from design GHR(avg.) (%)	Range of Operating GHR (kcal/kWh)
100-110MW	8	2421	35.52	2943	29.22	6.3	21.6	2696-3600
120-125MW	9	2387	36.03	2922	29.43	6.6	22.4	2690-3730
140MW	4	2360	36.44	2824	30.45	5.99	19.7	2750-2905
195-200MW	5	2399	35.84	2989	28.77	7.07	24.6	2392-3962
210MW	49	2362	36.41	2709	31.74	4.67	14.7	2383-3063
250MW	5	2339	36.77	2687	32.01	4.76	14.88	2546-2773
500MW	5	2254	38.15	2566	33.5	4.65	13.8	2508-2646

Turbine Heat Rate Variations

Capacity range of units	No. of units	Average Design Turbine Heat Rate (kcal/kWh)	Average Operating Turbine Heat Rate (kcal/kWh)	Average Deviation (%)	Range of operating THR
100-110 MW	8	2107.8	2364.4	12.1	2155 - 2881
120-125 MW	9	2063.2	2333.9	13.1	2162 - 2796
140 MW	4	2054.0	2279.6	11.0	2243 - 2325
195-200 MW	5	2063.6	2367.9	14.7	2034 - 2893
210 MW	49	2026.6	2213.8	9.2	2045 - 2442
250 MW	5	2039.2	2239.9	9.9	2179 - 2294
500 MW	5	1981.1	2109.1	6.5	2087 - 2179

Boiler Efficiency Variations

Capacity range of units	No. of units	Average Design Boiler Efficiency (%)	Average Operating Boiler Efficiency (%)	Average Deviation (%)	Range of operating Boiler Eff.
100-110 MW	8	86.94	80.26	-7.7	78.8 - 82.3
120-125 MW	9	86.45	80.09	-7.4	75.0 - 82.5
140 MW	4	86.01	80.70	-6.1	80.0 - 81.5
195-200 MW	5	86.02	79.89	-7.1	73.0 - 85.0
210 MW	49	85.77	81.67	-4.8	71.0 - 86.0
250 MW	5	87.06	83.38	-4.2	82.7 - 85.6
500 MW	5	87.44	82.21	-6.0	79.0 - 84.1



DESIGN MODEL
GROSS HEAT RATE= 2433.46Kcal/kWh
ETA= 0.353
TURBINE HEAT RATE= 2093.97Kcal/kWh
ETA= 0.411
210.444 MW
GCV-4440 Kcal/kg
COAL FLOW
115.080 t/h
24.910
3529.585
530.000
609.997
134.356
3440.342
540.000
690.000
1.353
2824.053
175.000
494.461
0.078
2462.626
41.141
478.021
28.833
3090.211
337.916
609.997
150.487
719.858
168.305
690.000
bar
kJ/kg
°C
t/h

Performance of 210 MW Units

Performance of 210 MW Units having age < 15 Years

(as mapped under Mapping Studies)

No. of Units= 16

Description	Average of 16 Units	Best Value observed among 16 Units	Deviation from the Best Value	% Deviation from Best Value
GHR (kcal/kWh)	2610	2383	+227	+9.5
THR (kcal/kWh)	2160	2044	+116	+5.7
Boiler Eff. (%)	82.86	86.0	- 3.14	-3.6
Capacity (MW)	199.62	211.9	- 12.28	-5.8

Performance of 210 MW Units having age > 15 Years

(as mapped under Mapping Studies)

No. of Units= 33

(Note: Values indicated in Red Colour are for 16 units having age<15 Years)

Description	Average of 33 Units	Best Value observed among 33 Units	Deviation from the Best Value	% Deviation from Best Value
GHR (kcal/kWh)	2764 2610	2529 2383	+235 +227	+9.3 +9.5
THR (kcal/kWh)	2240 2160	2109 2044	+131 +116	+6.2 +5.7
Boiler Eff. (%)	81.1 82.86	85.1 86.0	-4.0 -3.14	-4.7 -3.6
Capacity (MW)	199.54 199.62	215.26 211.9	-15.72 - 12.28	-7.3 -5.8

Performance Comparison of 210 MW Units having age >15 years(33 Units) and age< 15 years(16 units)

(Note: Values indicated in Red Colour are for 16 units having age<15 Years)

Description	Average Value	Best Value observed	Deviation in Average values of theses two age groups	Deviation in Best value of theses two age groups
GHR (kcal/kWh)	2764 2610	2529 2383	+154 (5.9%)	+146 (6.13%)
THR (kcal/kWh)	2240 2160	2109 2044	+80 (3.7%)	+65 (3.2%)
Boiler Eff. (%)	81.1 82.86	85.1 86.0	-1.76 (2.12%)	-0.9 (1.04%)
Capacity (MW)	199.54 199.62	215.26 211.9	-0.08 (0.04%)	+3.36 (1.56%)

Overall Performance of 49 Nos. of 210 MW Units (ignoring vintage)

(as mapped under Mapping Studies)

Description	Average of 49 Units	Best Value observed among 49 Units	Deviation from the Best Value	% Deviation from Best
GHR (kcal/kWh)	2714	2383	+331	+13.9%
THR (kcal/kWh)	2214	2044	+170	+8.3%
Boiler Eff. (%)	81.67	86.0	- 4.33	-5.03%
Capacity (MW)	199.56	215.26	- 15.7	-7.29%

Salient features of outcome of Mapping Studies of Forty-Nine nos. of 210 MW units

1. The mapped thermal generating units were characterized by a wide band of energy performance

2. Few of them were very closed to their designed energy performance, but majority of them had deviated from their designed performance by a bigger margin

3. Gross Heat Rate :

   a) For 33 units, having age > 15 years

   Operating average Gross Heat Rate was found to be 2764 kcal/kWh against the best operating value of 2529 kcal/kWh , exhibiting average deviation of 235 kcal/kWh (9.3%) from the best observed value.

   b) For 16 units, having age < 15 years

   Operating average Gross Heat Rate was found to be 2610 kcal/kWh against the best operating value of 2383 kcal/kWh , exhibiting average deviation of 227 kcal/kWh (9.5%) from the best observed value.

Salient features of outcome of Mapping Studies of Forty-Nine nos. of 210 MW units- Contd.

4.Turbine Heat Rate (THR):

The operating gross heat rate of turbines was found to be the major contributor in the deterioration in the energy performance of 210 MW units.

a) For 33 units, having age > 15 years

- **The average turbine gross heat rate was observed as 2240kcal/kWh against the best observed value of 2109 kcal/kWh indicating a deviation of 131 kcal/kWh from the best value observed, which is about 56% of the total deviation (235kCal/kWh) observed for 210 MW generating units.**

a) For 16 units, having age > 15 years

- **The average turbine gross heat rate was observed as 2160 kcal/kWh against the best observed value of 2044 kcal/kWh indicating a deviation of 116 kcal/kWh from the best value observed, which is about 51% of the total deviation (227kCal/kWh) observed for 210 MW generating units.**

Generally Observed Problems

- Gross heat rate deviations from the best observed operating value

  9.3 - 9.5%

- Boiler efficiency deviations from the best observed operating value

  3.6 - 4.7%

- Turbine heat rate deviations from the best observed operating value

  5.7 – 6.2%

Generally Observed Problems

Boilerplate

Boiler

- Combustion control not on auto
- Air fuel ratio not maintained
- Un burnt carbon content high
- Air ingress in to furnace from outside very high

APH

- Outlet air temperature low
- Flue gas temperature high
- Air pre-heater seals require adjustment

ID Fan

- Generally found to be overloaded with no operating margins.

Generally Observed Problems

- **Steam Temperature & Steam Pressure**
  - Generally lower than rated value
  - This is due to auto control non functional and spray control not effective.
- **Soot Blowers**
  - Soot Blowing not optimized owing to lack of online monitoring and control.
  - Soot Blowers not available

Generally Observed Problems

Turbine

- Average operating Turbine heat rate is high by 8.3% from the best operating value
  - Low HP, IP, and LP Efficiency needs steam path audit to determine actual status
  - Cooling Towers maintenance needs to be improved since cooling water temperature is high
  - Condenser cleaning system either not provided or non-functional

Coal Saving Potential
(Preliminary Findings)

- Assumptions:
- *All the units work at a PLF of 83% and use coal with a gross calorific value of 3540kcal/kg and costing Rs.1200 per ton, and would have the same gross heat rate as the most observed efficient unit in the concerned age group*
- **For Units having Age<15 Years:**

❑ Coal Savings Potential/ 210 MW unit:

✓ 97.9 Thousand Tons /Year/ 210 MW Unit

✓ 8.7% of the annual coal consumption per 210 MW unit

✓ Rs.117.48 Million /Year/ 210 MW Unit

❑ Coal Savings Potential for 15 nos. of 210 MW unit

✓ 1.468 Million tons/Year for 15 units of 210 MW

✓ Rs. 1762 Million /Year for 15 units of 210 MW

Coal Saving Potential (Preliminary Findings)

- Assumptions:
- *All the units work at a PLF of 83% and use coal with a gross calorific value of 3540kcal/kg and costing Rs.1200 per ton, and would have the same gross heat rate as the most observed efficient unit in the concerned age group*

- **For Units having Age >15 Years:**

❑ **Coal Savings Potential/ 210 MW unit:**

✓ 101Thousand Tons /Year/ 210 MW Unit

✓ 8.5% of the annual coal consumption per 210 MW unit

✓ Rs.121.2 Million /Year/ 210 MW Unit

❑ **Coal Savings Potential for 32 nos. of 210 MW unit**

✓ 3.232 Million tons/Year for 32 units of 210 MW

✓ Rs. 3878 Million /Year for 32 units of 210 MW

Coal Saving Potential (Preliminary Findings)

- Assumptions:
- *All the units work at a PLF of 83% and use coal with a gross calorific value of 3540kcal/kg and costing Rs.1200 per ton, and would have the same gross heat rate as the most observed efficient unit in the respective age groups*

❑ Coal Savings Potential for 47 nos. of 210 MW units

- ✓ 4.7 Million tons/Year for 47 units of 210 MW
- ✓ Rs. 5640 Million /Year for 47 units of 210 MW
- ✓ 8.56% of the annual coal consumption per 210 MW units

Coal Saving Potential (Preliminary Findings)

At National Level

- *For 141 nos. of 210 MW Thermal Power Generating Units(assuming the similar situations as observed for 47 units of 210 MW plants and similar assumptions as considered for 47 units mapped under the mapping studies)*
- *Coal Saving Potential: 14 Million Tons/year*

  : 4.2% of coal consumption in Power Sector (Thermal Power stations consumed 329.6 Million Tons of coal in 2007-08)
- ***Note****: Since the Mapping studies were carried out in SEB's stations and did not covered Central Utilities (NTPC), which have comparatively better Gross Heat Rate, the above saving potential may work out less than the projected values.*
- ***On a conservative estimates, coal saving potential of 10 million ton can be assumed in 210 MW Coal fired Thermal Generating Units, which is about 50% of the coal imported during 2008-09***
- ***This coal is sufficient to operate a 2000 MW thermal power station throughout a year (Assumptions: Coal GCV-3540kcal/kg, GHR-2383kcal/kg, PLF- 0.83)***

Performance Optimisation of Thermal Power Plants (Sub Component- II)

- Energy Audit Manual for Power Stations has been prepared.
- Capacity Building programmes of power station professionals in India and Germany have been taken.
- Best practice survey of German power plants has been completed.
- NPTI faculty have been trained by German Experts on the best practices of Thermal Power Stations of Germany and Europe.

NMEEE-4 New Initiatives

- BEE has evolved a market based mechanism to enhance cost effec-tiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. (Perform Achieve and Trade)
- Accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable. (Market Transformation for Energy Efficiency))
- Creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings. (Energy Efficiency Financing Platform (EEFP))
- Developing fiscal instruments to promote energy efficiency namely Framework for Energy Efficient Economic Development (FEEED)
- IGEN is extending its support under IGEN Phase-II to BEE to effectively implement PAT

Objectives of NMEEE

- The basic tenet of the mission is to ensure a sustainable growth by an appropriate mix of 4 E's namely- Energy, Efficiency, Equity and Environment.

- Promote development objectives, while also yielding co-benefits for addressing climate change effects.

- By 2014-15:
  - -Annual fuel savings in excess of 23 million toe
  - -Cumulative avoided electricity capacity addition of 19,000 MW
  - -CO_2 emission mitigation of 98 million tons per year

- Market based approach to implementation of energy efficiency – market size of USD 18 billion to be unlocked

Perform Achieve and Trade (PAT)

(a) Methodology for setting Specific Energy Consumption (SEC) norm for each designated consumer

- Differential targets for different Designated Consumers on a gate-to-gate basis
- For thermal power plants and fertilizer plants, the SEC targets to be harmonised with current tariff setting context – CERC and Ministry of Fertilizer to undertake this
- Detailed baselines to be measured and verified by BEE

(b) Promotion of Trading of ESCerts

- Verification by accredited verification agency or by energy auditors,
- Issuance process for Energy Savings Certificates (ESCerts) who exceed their target SEC reduction- transparent regulatory framework for their issuance, monitoring and verification, and reconciliation protocols outlined.
- Trading Process for ESCerts - can be carried out bilaterally between any two designated consumers (within or across the designated sectors), or on special platforms for their trading which are created in the power exchanges
- Compliance and reconciliation process for ESCerts- accounting and depository protocols to be evolved

Perform Achieve and Trade (PAT) (2)

(c) Fungibility of ESCerts

- MNRE may take this fungibility into consideration while formalizing the REC structure.
- A joint group of the agencies to agree to the linkage mechanism between the RECs and the ESCerts once both the mechanisms are operational
- The conversion factor must be transparent based on verifiable parameters like kgoe

(d) Amendments to EC Act, 2001

- Financial Penalty for Non-compliance u/s 26 of EC Act to be enhanced- The penalty should be greater than the cost of equivalent energy to meet the shortfall in targets
- DCs may be allowed to meet their obligation through purchase of ESCerts, by way of an enabling amendment in section 14 of the Act.

(e) PAT mechanism is a purely national scheme.

- SEC reduction targets under the PAT mechanism do not create any international obligations. Has no linkage to any international financial instrument for emission reductions.

CONCLUSIONS

- *The increasing preference for commercial energy has led to a sharp increase in the demand for electricity and fossil fuels.*
- *Use of Fossil Fuels result in emission of huge quantity of carbon dioxide causing serious environmental damages.*
- *There is a considerable potential for reducing energy consumption by adopting energy efficiency measures at Thermal power Stations*
- *Energy efficiency will not only reduce the need to create new capacity requiring high investment, but also result in substantial environmental benefits*.
- *With the enactment of the Indian Energy Conservation Act, 2001, an institutional framework is now available for promoting energy efficiency in all sectors of the economy, which has been strongly supported by IGEN Programme of GTZ*
- *The support extended and contribution made by IGEN Programme of GTZ has been very well recognized and appreciated by the Indian partners , Industries and Thermal Power Sector and has been considered to be one of the successful programmes implemented under the bilateral cooperation.*


Thank You!