Article # 29

The complexity of thermal power plant efficiencies reporting in India and Germany

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A. The draft report of the expert committee on Integrated Energy policy is out. A highly interesting and comprehensive document with lots of vital information and recommendation. The following various statements are made about the efficiency of the Indian coal fired power sector. It is in the nature of such documents that one cannot go too much into details. It is the responsibilities of readers to shed some light on the numbers presented and compare.

B. Statements by the report:

1. "Increase coal use efficiency in power generation from the current average of 30.5% to 39% for all new plants."

2. "Efficiency of future coal power plants increase to 42% from 36% for the present 500 MW super critical boilers."

3. "The best coal fired power plants in the world operate with supercritical boilers and gets an efficiency of 42%. Germany is even claiming conversion efficiency of 46%."

4. "It should be possible to get an efficiency of 40% at economically attractive cost for all new coal-based power plants".

5. "No new thermal power plant to be allowed without a certified fuel conversion efficiency of at least 38%."

Observation 1: Because no unique international standardized and acceptable methodology is available to establish and report the operational efficiency of coal fired power plants it is difficult to compare the efficiency of Indian power plants with other nations.

Observation 2: Depending on which standard or definition official statistics may follow four different versions of power plant efficiency exist. They are:

$$eff(1) = \frac{\text{Net kWh output}}{\text{Energy input as GCV}}$$ Gives the lowest efficiency figure

$$eff(2) = \frac{\text{Net kWh output}}{\text{Energy input as NCV}}$$ It always holds eff(2) > eff(1)

$$eff(3) = \frac{\text{Gross kWh output}}{\text{Energy input as GCV}}$$ eff(3) > eff(2) most likely

$$eff(4) = \frac{\text{Gross kWh output}}{\text{Energy input as NCV}}$$ It always holds eff(4) > eff(3)

Consequently eff(4) > eff(3) > eff(2) > eff(1) in most cases. If a power sector statistics is eager to do window dressing, I would recommend to use the eff(4) definition.

GCV and NCV refer to the gross calorific or net calorific energy content of a fuel. How to determine NCV and GCV is normed by international code. Tests are done in a bomb calorimeter.

The gross kWh output is the amount of electricity the power plant generates at the busbar of the turbine generator set. The net kWh output is the electricity the power plant feeds into the grid for sale. Consequently the difference we may declare as station use, since the power plant is using it for own operation. Station use is usually between 3% and 14% of the gross generation depending on plant technology and fuel fired.

Observation 3: For obvious reasons, a fair and realistic comparison of power plant efficiencies should only be done on net generation of kWh. In other words definition eff(3) and eff(4) are showing a too rosy picture about plant efficiencies since it is not only important how much a plant is generating but also how much can be sold.

Observation 4: Whether definition eff(1) or eff(2) is used is a matter of taste and not substance. In Germany eff(2) is used meaning the NCV is the energy input. This results in high efficiencies in particular with fuels that have either a high moisture (H_2O) or a high atomic fuel Hydrogen (H) content, or both. In the theoretical case of firing pure Carbon it holds GCV = NCV.

Observation 5: The type of coal in a power plant influences together with the environment, the plant efficiency. Consequently as long as the design environment and design coal is not known from the EPC documents it is not possible to compare the efficiency of plants based on their design features.

Observation 6: Whenever the efficiency of a new coal fired plant is reported this number refers to the design efficiency based on a "design coal" and a "design environment". These figures are different from the actual average annual operational efficiency which is usually lower, because nobody operates on a design environment and design coal. Sometimes the design efficiency was wrongly assessed anyway in the first place.

Observation 7: Energy efficient power plants are not build for charity. Consequently the most financially attractive power plant efficiency is the benchmark. In other words the higher the coal price in terms of Rs/kCal (fired) the higher the design plant efficiency could be.

C. The situation in Germany:

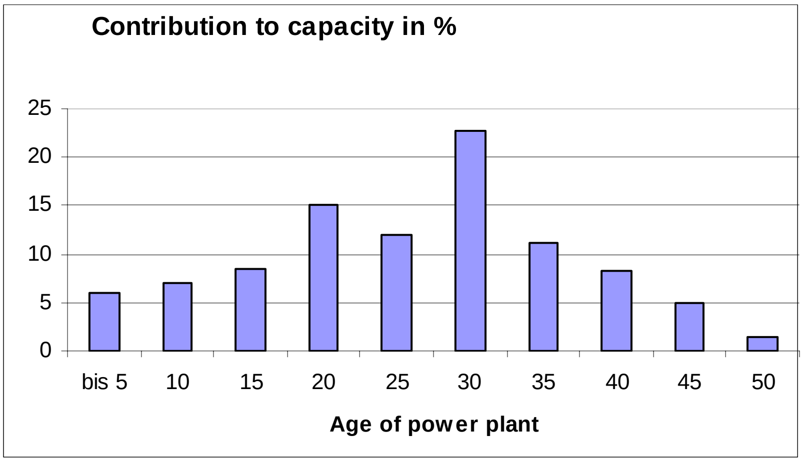
There is a standard approach to derive at power plant efficiencies eff(2) by dividing the published net GWh generated by the reported energy consumption in SKE based on NCV.

An SKE (Steinkohleeinheit = hard coal unit) is exactly 8.140 MWh of energy content as NCV of a ton of hard coal. This figure has been derived from the average 7000 kCal per kg of hard coal. Since units such as kWh, MW, GWh are not reserved for electricity but as well units to describe the energy content of any fuel, it is customary to express energy contents of fuels in kWh or GWh in Germany.

German Fact 1: The reduction of the specific energy consumption of thermal power plants has been only 5% over 10 years from 1991 through 2000. This is mainly due to replacing inefficient power plants in former East Germany through newer coal and gas fired power plants. The reduction has not been due to new developments in power plant technology.

German Fact 2: The eff(2) figure improved from 33.9% in 1991 to 35.8% in 2001. Observe that in eff(2) the NCV of the fuel is used and useful energy output are the net GWh supplied by the plant to the grid. Specifically for lignite power plants the improvement in eff(2) was from 29.4% to 34.2% and for hard coal it was 31.1% to 37.3% as national average.

German Fact 3: The age structure of thermal power plants in Germany is of interest and shown in the graphics below. It would be of interest to compare this with the Indian power plant age distribution.



German Fact 4: The Indian report mentions a German technology of reaching eff(2) = 46%. This is based on hard coal as a fuel. The plant will be operational in 2012. So far it is a claimed design efficiency based on a high grade coal.

German Fact 5: Of more interest are how eff(2) of lignite fired power plants are improved by the new BoA concept. This is best described by taking the old 600 MW Neurath subcritical power plant at eff(2) = 35.5% and comparing it with the new supercritical 1000 MW Niederaussen at eff(2) = 45.2%. Both are lignite fired.
Individual efficiency gains by the BoA concept are as follows:

a)	Improved steam turbine design	+ 2.3%
b)	Supercritical steam parameters	+ 1.6%
c)	Process optimisation and control improvement	+ 1.6%
d)	Reduction of station use	+ 1.5%
e)	Condensation vacuum improvement	+ 1.4%
f)	Stack gas loss and waste heat reduction	+ 2.3%

German Fact 6: Due to some thermal power plants also operating as district heating plants or providing process heat to industry there is a whole range of eff(2) from 55% to 82% reported. However these are all combined heat and power plants (CHP) whenever process heat can be synchronized with electricity demand.

German Fact 7: GuD power plants i.e. gas turbine followed by steam cycle may reach 55% on coal and 65% on natural gas in the future. Combined with district heating the German vision is to have a eff(2) = 90%. However CHP works only if demand for process heat or cold, and power can be synchronized. While coal based GuD plants are in the planning stage, standard GuD on natural gas alone reach already eff(2) = 58%.

D. Examples to illustrate the difficulties of eff comparison

(i) Take a power plant operating on hard coal with 74.9% C, 4.6% H, 3.7% Ash and 5.3% water, at GCV = 8.455 MWh and NCV = 8.137 MWh i.e. a 3.76% difference between GCV and NCV.

Assume eff(1) = $\frac{3.0438}{8.455}$ = 36%

Where 3.0438 MWh is the net GWh generation from 8.455 GWh of GCV input.

It follows eff(2) = $\frac{3.0438}{8.137}$ = 37.4% based on NCV

Furthermore assume station use is 8% i.e. eff(3) = $\frac{3.308}{8.455}$ = 39.1% on GCV

and eff(4) = $\frac{3.308}{8.137}$ = 40.7% on NCV

This first example is based on a low moisture and low Hydrogen fuel with a difference between GCV and NCV of 3.76%. Nevertheless depending on the definition for (eff) there is already a spread of 36.0% to 40.7% in the efficiency calculation for the same power plant.

(ii) Lignite fuel 52.19% C, 16% H_2O, 4.30% H, 2.9% S, 10.00% Ash with GCV = 6.069 MWh and NCV = 5.698 MWh.

Assume eff(1) = $\frac{2.094}{6.069}$ = 34.5% on GCV

then eff(2) = $\frac{2.094}{5.698}$ = 36.7% on GCV

Furthermore assume 10% station use than $\quad eff(3) = \frac{2.327}{6.069} = 38.3\%$ on GCV

and $eff(4) = \frac{2.327}{5.698} = 40.8\%$ on NCV

In this case a spread of 34.5% to 40.8% is observed for the same power plant because of the higher difference between GCV and NCV of 6.2%.

The reader may be convinced that it makes little sense to publish and compare power plant efficiencies as long as it is not known what basis for eff is used.

E. The Indian coal fired power plant efficiency

There is no standard and no enforced norm how to report efficiencies consequently it is difficult to judge the plant efficiencies in India. However since all of them are mandated to operate on coal with a very high ash content of 30% to 45% it is by nature of the coal composition not possible to operate as efficiently as in Germany even if the same technology is used. Additional efficiency reductions are due to the higher ambient temperature of 30^oC to 48^oC for most of the year.

A summary of the reported efficiencies of public utilities is given below. There are no supercritical power plants in India as of Jan 2006. $\quad eff(3) = \frac{\text{Gross MWh}}{\text{GCV value}}$

Thermal Efficiency	No of generating stations	Installed Capacity (MW)	Energy Generated (GWh)
Up to 15%	7	609.38	5.90
Above 15% & Upto 20%	7	2,628.00	4,195.92
Above 20% & Upto 25%	15	6,187.00	29,869.39
Above 25% & Upto 30%	20	11,616.50	64,113.31
Above 30%	49	43,915.00	3,09,099.30
Total	**98**	**64,956**	**407,284**

Source: Central Electricity Authority

Thermal Efficiencies for some key coal based power plants

Power Station	Capacity (MW)	2003-04
TTP (State I & II)	440	32.85%
IB Valley (Unit I & II)	420	36.42%
NTPC – Farakka STPS	1,600	37.66%
NTPC – Kahalgaon STPS	840	34.79%
NTPC – Talcher STPS	840	34.79%

F. Are high efficiency supercritical power plants economical in India?

Prices of hard coal for power plants has reached an all time high in Germany of Rs. 3500 per ton for 8.140 MWh (= 7000 kCal/ kg coal).

Indian coal prizes for the Indian power sector vary from Rs. 800 to Rs. 2200 per ton depending on transportation distance. New coal fired power plants cost about 4.8 to Rs. 5.6 Crore per MW in Germany. The most commonly used average figure in India is 4 Crore Rs/ MW.

It is therefore highly unlikely that high efficiency coal fired power plants are financially attractive at many locations in India as long as the tariffs for generation are not increased or the coal price goes up, or both.