Final Report

Setting up of modalities for normative coal requirement for different industries

Sponsored By

Coal India Limited

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CSIR-Central Institute of Mining & Fuel Research

(Digwadih Campus)

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1.0 Project Title : Setting up modalities for normative coal requirement for different industries

2.0 Sponsor : Coal India Limited

3.0 Objective : Fixation of normative quantity of coal requirement for consumer segment of different industries (as per Annexure- I) based on present GCV based grading system.

4.0 Preamble :

The Ministry of Coal (MoC) has issued a New Coal Distribution Policy (NCDP) in Oct, 2007 which broadly covers the approach for coal supply to different end users. The coal consumers, under this NCDP have been classified in two categories viz. a) Power utilities including independent Power Producers (IPPs), Captive Power Plants (CPPs) and Fertilizer, b) consumers including steel, cement, sponge iron, aluminum, paper and others. The policy stipulates that Coal India limited (CIL) will be required to supply coal to all consumers having requirement of more than 4200 tones per annum. As far as consumers having annual requirement is less than 4200 tones are concerned, they would be given the option to either entering into FSA with the coal company as per the terms and conditions, including satisfaction level applicable to the other consumers or they may opt out of FSA regime and access their coal requirement through agencies nominated by State Governments.

As per the provisions of the new policy the entire coal supply to actual consumers as mentioned above shall be only through Fuel Supply Agreement (FSA). In case of new consumers the provision has been kept for issuance of enforceable Letter of Assurance (LOA) prior to entering into FSA subject to fulfillment of the terms and conditions of the LOA by the consumers within the stipulated time. For the purpose of entering into FSA as well as issuance of LOA, it has been provided that 100% of normative coal requirement would be covered in respect of power utilities including IPPs and CPPs and Fertilizer units while 75% of normative requirements would be covered for other consumers.

To identify the normative quantity of coal requirements of different consumer segments it is necessary to evolve a methodology to formulate the basis for making a realistic assessment of the quality and quantity of coal requirement. Coal India Limited has entrusted this job of fixing the normative requirements of coal industry wise to Central Institute of Mining & Fuel Research.

5.0 Background:

Review on the existing and the projected trends of demand supply scenario of coal in the national economy as discussed by different Expert Groups may be relevant before embarking upon micro level analyses of the industry wise requirement of this primary energy resource of the country. The projections on coal & lignite have been summarized by the working Group, MoC on the basis various reports delivered by different Expert Committees, including Draft Coal Vision Document – 2025. Different perspective demand scenarios arising out of reports of the Expert Committees on coal sector reform, Integrated Energy Policy and Draft Coal Vision Document for 2025 are detailed as under:

Table 1: Different perspectives of coal demand scenarios

		X-Plan (2006-07)	XI-Plan (2011-12)	XII-Plan (2016-17)
		In million tones		
X-Plan	Steel	42.7	40	40
Document-	Power (U)	322	469	617
Working	Power (C)	28.26	32	37
Group/	Cement	25.4	24	25
Mid-term	Fertilizer	3.52	5	5
Appraisal	Others	51.3	50	56
	Total	473.18	620	780
Coal	Steel	42.7	53.14	66.57
Vision	Power (U)	322	412.69	517.31
2025 @ 7	Power (C)	28.26	43.26	59.89
% GDP	Cement	25.4	38.44	58.18
	Fertilizer	3.52	-	-
	Others	51.3	63.52	79.87
	Total	473.18	611.05	781.52
Coal	Steel	42.7	54.24	69.47
Vision	Power (U)	322	427.16	552.56
2025 @ 8	Power (C)	28.26	44.33	62.96
% GDP	Cement	25.4	39.39	61.06
	Fertilizer	3.52	-	-
	Others	51.3	64.51	82.11
	Total	473.18	629.63	828.16
Expert	Steel	42.7	51.53	
Committee	Power (U)	322	502.91	
on Coal	Power (C)	28.26	45	
Sector	Cement	25.4	30.81	
Reform	Fertilizer	3.52	-	
	Others	51.3	80	
	Total	473.18	710.25 *	
	* in terms of indigenous coal			

Several expert groups considered the projection of end-users' requirement to be the basis or benchmark to assess sector wise coal demand. Wherever validated details in respect of end-users' assessments are not available, coal demand projections were arrived from indirect estimations.
Indian industrial sector accounts for half of the commercial energy used in the country. There are wide variations in specific energy consumption among different units in the same industry using comparable technologies. However, energy efficient units are improving their specific energy consumption year after year. But a large number of sections of industry to still improve their energy efficiency. Also energy intensity per unit of GDP of Indian economy is very high in comparison with developed countries and Asian and world averages. Growing energy efficiency/conservation measures can reduce peak and average demand.

The six key industries – namely aluminium, cement, fertilizers, pulp & paper, petrochemicals and steel – consumes about 65% of the total energy use in India. The energy intensity values in some of the specific plants of the above industries are higher than in best available technologies (BAT). One of the main reasons for higher energy use is the presence of obsolete and energy inefficient technologies in some of these sectors.

Moreover in Indian context it is very difficult for the small scale entrepreneurs to adopt BAT. In countries like India, survival of those small industrial units is also very important from economic and social point of view. Moreover, it is to be noted even for best available technologies (BATs) various examples of production techniques/ strategies are often followed leading to different specific energy consumption (SEC) on case to case basis. For attaining the energy security of the country, saving of precious fossil fuel is very important. Therefore, strategies adopted by the industries to reduce energy cost through specific energy consumption in a way compliment energy security policies adopted by our country.

As per the policy guideline, actual coal consumers get supply of coal through Fuel Supply Agreement (FSA). The change of commercial grading system for non-coking coals, from UHV based grading system to GCV based grading system w. e. f. 1. 1. 2012 demanded the reframing of norms on new basis. Moreover, during last 5-6 years improving trends of energy efficiency in various industries received momentum. Growing pressure and awareness towards lowering of GHG emission also mobilized the adoption of energy economization strategies. With the change of entire scenario covering both coal grading systems and energy policies, CIL awarded the present project work to CIMFR in September' 2014 to evaluate the normative requirement of coal for various sectors (as mentioned in the proposal documents). In view of above, CIMFR takes attempts to assess the coal requirement (based on the GCV based grading system) in the industrial sectors specified by CIL. As per the inherent requirement of extent possible detailing, assessment was planned to be executed for different technologies/ processes by making subcategories within specified sectors (energy and manufacturing industries). All such exercises expected to serve the basic objective of CIL to formulate well defined mechanisms for judicious allocation of coals to different sectors.

6.0 Approach:

For making a rational estimate of the quality and quantity of coal required in identified industries several factors were considered such as, the technology type, product type, firing cycle, firing type, coal quality requirement, thermal efficiency of furnace/kilns/ hot air generator/ conversion unit etc. Several Industries have been visited to collect the relevant data for fixation of the norms. Information from industrial organizations and expert opinion were taken to resolve various issues on few complicated sectors to fill up some inadequacies/gaps. Required detailing on various issues was also obtained through aforesaid interactions.

In general the specific energy consumption by the industries which utilize heat from fuel combustion has been carefully taken into account. On the other hand the industry which utilizes steam as a source of process heat has also been considered in detail. It was observed that industries adopt some unique fuel economization strategies resulting in the different type of fuel use for a particular sector. Moreover, depending on capacity, technology (which is sometimes raw material based also), vintage factor, product quality, product pattern, heat recovery techniques etc., specific energy consumption for a specific sector varies a lot. The specific energy consumption (SEC) was taken as a basis to fix up normative requirement of coals of different grades as per present GCV based grading system. Variation in specific energy consumption for a particular product/ technology type has been considered and the aforesaid ranges are supported by existing literature, knowledge base or expert opinion(s). Actual specific thermal energy consumption on case to case basis may widely vary from the said SEC figures, which have been taken as the basis for calculation of normative coal requirement. Detailing has been done to the extent possible through consideration of various sub-categories under various industrial sectors.

It may be noted here that different fuel categories such as producer gas, natural gas, biomass, petroleum coke, etc., may be in use and sometimes multi fuel systems are also there. Product conversion units /systems may sometimes be overrated or underrated. Production strategies in a particular year particularly in multi product furnaces/ kilns varies a lot from that of previous years depending on the variable market demand and several other constraints. The present assessment-norms are a general guideline on the basis of GCV based coal grading system. However, actual coal requirement may be worked out through case study after receiving the plant related documents including filled relevant Annexure and/or plant inspection which include scrutiny of last 3-4 years records on trends of production, coal consumption, energy economization and also technological up-gradation, if any.

This report deals with so many technological categories for various manufacturing and energy industries. But it is to be noted here that coal based energy requirement for different industrial processes are fulfilled through basically four different options:

i.) Direct coal firing in the manufacturing furnaces (Coke making Industry, SSF Unit, Brick Industry, Lime Calcination Units, Producer Gas Plant, Steam Generation Boiler, Hot Air Generator)

ii.) Firing/heating through producer gas (Glass manufacturing, Refractory Industry, Rolling Mill, Fine ceramics Industry)

iii.) Heating through hot flue gas from hot air generator unit (Tea manufacturing)

iv.) Steam at elevated temperature/ pressure for which coal fired boiler has to be considered (Fertilizer Industry, Pulp & Papers Industry, Rubber Industries, Textile Industry, Petro-chemical Industry, Chloro-Alkali Industry, Food processing Industry)

Therefore, it has been decided to address the issues related coal consumption in various sectors/ industries/ technologies from both approaches wherever applicable, viz. i.) Individual product/ technology based assessment approach, ii.) Approach based on producer gas plant/ boiler/ hot air generator installed in the respective industries which consumes coal to meet the requirement of process heat in different units/ furnaces/ kilns. If both way assessments are feasible then second approach appears to be more acceptable because of following reasons:

i.) Running of boiler or producer gas plant or hot air generator is the most authentic guiding and basic factor.

ii.) As production is reported based on finished products and does not account for the rejections in between, production based estimation may mislead sometimes.

iii.) Sometimes product pattern is variable and strategies on production of ranges of products from available set up in a particular industry depend on periodic demand and several other factors.

However, in that case, SEC based approach may help in cross verification/ cross checking.

The mean Gross Calorific Values of the coal grades from G-1 to G-17 utilized in this evaluation are summarized below:

Table 2: Coal grades (G-1 to G-14) and their Mean Gross Calorific Values

Coal grades	GCV range, kcal/kg	Mean GCV, kcal/kg
G-1	Above 7000	7150
G-2	6701-7000	6850
G-3	6401-6700	6550
G-4	6101-6400	6250
G-5	5801-6100	5950
G-6	5501-5800	5650
G-7	5201-5500	5350
G-8	4901-5200	5050
G-9	4601-4900	4750
G-10	4301-4600	4450
G-11	4001-4300	4150
G-12	3701-4000	3850
G-13	3401-3700	3550
G-14	3101-3400	3250
G-15	2801-3100	2950
G-16	2501-2800	2650
G-17	2201-2500	2350

Chapter-1

Normative requirement of coal for different specified industries have been discussed below.

i.) Fertilizers:

The basic chemical that is used to produce nitrogenous fertilizer is ammonia. More than 80% energy required for making fertilizer products goes into manufacture of ammonia. Almost 82% of the nitrogen application in India is in the form of urea and therefore most of the input energy goes to the manufacture of ammonia and urea. Natural gas based fertilizer units, which are more energy efficient than other feed stock-based units, accounts for 65% of the total urea capacity. Coal based units have been closed due to non-economic viability and high specific consumption levels. With continuous efforts for up gradation of technology, plants have brought down energy consumption. The major modernization measures include two stage concentration, more efficient trays in urea reactor, recovery of nutrients from process effluents, recycle of treated process condensate, refurbishing or replacement of rotating machines etc. Most urea plants have energy consumption within range of 5.25 to 6.0 Gcal/t urea [1]. Another literature reports the average energy consumption in the urea production is 6.49 Gcal/tonne [2].

The feed stock for the production of Ammonia and Urea varies from naphtha to natural gas to furnace oil/LSHS to the combination of above and hence the specific consumption norms vary and accordingly the variation in the specific thermal energy consumption is in the range of 4 to 7 Mkcal/tonne [3] The following Table (Table 3) represents normative requirement of coal assuming an average specific thermal energy consumption, i.e. 5.5 Mkcal/tonne.

Table 3: Normative requirement of coal for Fertilizers Industry

Specific Thermal Energy Consumption-5.5 Mkcal/t	
Coal Grade	**Coal req. in kg/t**
G-1	**769.23**
G-2	802.92
G-3	839.69
G-4	880.00
G-5	924.37
G-6	973.45
G-7	1028.04
G-8	1089.11
G-9	1157.89
G-10	1235.96
G-11	1325.30
G-12	1428.57
G-13	1549.30
G-14	1692.31
G-15	1864.41
G-16	2075.47
G-17	2340.43

The above table is given as an example. For different cases normative quantity may be calculated using the following formula.

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in Mkcal/ton (or Gcal/ton) *1000 = SEC in kcal/kg

Sample calculation: 5.5*1000 = 5500 kcal/kg

5500*1000/7150 = 769.23 kg/ton

It is suggested to prefer boiler based assessment to determine normative quantity in Fertilizer industry. This aspect has been described in Chapter-2 of this report.

References:

1. BEE, PAT Booklet, MOP, GoI, July 2012

2. TERI year book, 2005-06.

3. Energy Efficient Technology in India, V. S. Verma, DG, Bureau of Energy Efficiency, 2004.

ii.) Paper and Pulp:

In the Indian paper and pulp Industry energy cost constitutes about 25% of the total manufacturing cost. Pulp and paper production is highly energy intensive with 75-85% of the energy requirement being used as process heat and 15-25 % as electric power. In general, the production process consists of five stages: raw material preparation, pulping, bleaching, chemical recovery and paper making. Most of the energy is used in form of heat within the pulping process. The pulping process accounts for 26% of the energy used, whereas bleaching accounts for about 7% and the rest for chemical recovery process. Two-thirds of the final energy needed to remove water is used in the drying section of a paper machine to remove the final 1% of water.

Paper is an energy intensive product depending primarily upon raw materials like wood based, agro based and waste paper based. The output includes: Kraft, boards, news print and writing and printing.

Values of specific energy consumption have been provided below based on information available from different literatures.

i) Typical specific thermal energy consumption details of Indian Paper Mills [4]

	Type of mill	SEC Thermal, GJ/t
1	Integrated Wood/ Bamboo based	27.3
2	Agro based mill without recovery	27.3
3	Waste Paper Based	11.3

ii) Specific thermal energy consumption is 7.5 to 8 MKcal/ton for Kraft, 5 to 8 MKcal/ton for writing and printing, 4 to 5 MKcal/ton for paper board, 2 to 4 MKcal/ton for news print, 6-7.5 ton of steam with black liquor recover process for Kraft (in acid sulphite process it is 1.40 -1.60 ton of steam) [2].

iii) Specific energy consumption of the paper industry by raw material [5] is for Wood based 9 ton steam/ton paper, for Agro based 8 ton steam/ton paper and for Recycled paper base it is 5 ton steam/ton paper

iv) In order to produce one ton of dried pulp, around 0.215 MkCal of power and 6.5 tonne of steam is used in the Kraft with black liquor recover process while 1.45 tonne of steam and around 3.5 MkCal power is used in the acid sulphite process. The thermal energy consumption of the units are in the range of 7.8 to 7.9 MkCal/ton for Kraft, 4.7 to 8 MkCal/ton for Writing and Printing, 4.3 to 4.8 MkCal/ton for paper board, 2.4 to 3.5 MkCal/ton for News print units [3].

In another literature [6] it was reported that the specific thermal energy of different quality of paper preparation will be different. Also depending on source of raw material the specific thermal energy will be different even when the ultimate product remains same. Depending on raw material, the thermal energy of Writing and printing varies from 12 GJ/ton to 38.6 GJ/ton [6], for Kraft thermal energy varies from 9.9 GJ/ton to 17.6 GJ/ton, for boards it varies from 9.4 GJ/ton to 30 GJ/ton and for news print it is 20.3 GJ/ton [6]. The following Table (Table 4) shows the normative quantity for different categories under this sector. The specific energy consumptions (SEC thermal), considered as illustrative examples for this evaluation, have also been mentioned in the table.

Table 4: Normative requirement of coal for Paper Industry

	Writing and Printing			**Kraft**			**Boards**			**News Print**	
	Wood Based	**Agro Based**	**Waste Paper**	**Wood Based**	**Agro Based**	**Waste Paper**	**Wood Based**	**Agro Based**	**Waste Paper**	**Wood Based**	**Bagasse Based**
SEC,Thermal GJ/ton →	**38.6**	**24.6**	**12**	**36.9**	**17.6**	**9.9**	**30**	**9.4**	**10.3**	**20.2**	**20.2**
Coal req. →	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**
Grade											
G-1	**1285.38**	819.18	399.60	1228.77	586.08	329.67	999.00	313.02	342.99	672.66	672.66
G-2	1341.68	855.06	417.10	1282.59	611.75	344.11	1042.75	326.73	358.01	702.12	702.12
G-3	1403.13	894.22	436.21	1341.33	639.77	359.87	1090.51	341.69	374.41	734.28	734.28
G-4	1470.48	937.14	457.14	1405.71	670.48	377.14	1142.86	358.10	392.38	769.52	769.52
G-5	1544.62	984.39	480.19	1476.59	704.28	396.16	1200.48	376.15	412.16	808.32	808.32
G-6	1626.63	1036.66	505.69	1554.99	741.68	417.19	1264.22	396.12	434.05	851.24	851.24
G-7	1717.85	1094.79	534.05	1642.19	783.27	440.59	1335.11	418.34	458.39	898.98	898.98
G-8	1819.90	1159.83	565.77	1739.75	829.80	466.76	1414.43	443.19	485.62	952.38	952.38
G-9	1934.84	1233.08	601.50	1849.62	882.21	496.24	1503.76	471.18	516.29	1012.53	1012.53
G-10	2065.28	1316.21	642.05	1974.32	941.68	529.70	1605.14	502.94	551.10	1080.79	1080.79
G-11	2214.57	1411.36	688.47	2117.04	1009.75	567.99	1721.17	539.30	590.94	1158.92	1158.92
G-12	2387.14	1521.34	742.12	2282.00	1088.44	612.24	1855.29	581.32	636.98	1249.23	1249.23
G-13	2588.87	1649.90	804.83	2474.85	1180.42	663.98	2012.07	630.45	690.81	1354.80	1354.80
G-14	2827.84	1802.20	879.12	2703.30	1289.38	725.27	2197.80	688.64	754.58	1479.85	1479.85
G-15	3115.42	1985.47	968.52	2978.21	1420.50	799.03	2421.31	758.68	831.32	1630.35	1630.35
G-16	3468.10	2210.24	1078.17	3315.36	1581.31	889.49	2695.42	844.56	925.43	1814.91	1814.91
G-17	3910.84	2492.40	1215.81	3738.60	1783.18	1003.04	3039.51	952.38	1043.57	2046.61	2046.61

However, the normative requirement of coal for any industry under this sector may be calculated using the following formula,

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in GJ/ton *1000/4.2 = SEC in kcal/kg

Sample calculation: 38.6*1000/4.2 = 9190.476

9190.476*1000/7150 = 1285.38 kg/ton

Finally, considering the technology dependent or raw material dependent SEC variation and several other issues it is recommended to consider boiler operational data for assessment of normative quantity of coal for an industry. The methodology has been included in chapter 2 of this report where basis for obtained boiler based assessment of coal requirement have been elaborated in detail.

References:

2. TERI year book, 2005-06

3. Energy Efficient Technology in India, V. S. Verma, DG, Bureau of Energy Efficiency, 2004.

4. Technology compendium on energy savings opportunities, paper and pulp sector, Aug, 2013, CII, Hyderabad

5. TERI year book, 2010

6. Understanding Industrial Energy use. Physical Energy intensity changes in India Manufacturing Section, Indira Gandhi Institute of Development Research, Mumbai).

iii.) Textile:

The textile sector comprises mills, which include the spinning mill or the composite mill. The decentralized power-loom/hosiery and knitting sectors form the largest section of the textile industry. The major sub-sectors of the Indian textile industry consist of the organized cotton/man-made fiber textiles mill industry, man-made fiber/filament yarn industry, wool and woolen textiles industry, sericulture and silk textiles industry, handlooms, handcrafts, jute and jute textiles industry. Coal and furnace oil are used for the generation of steam in boilers for process heating applications in this sector.

Electricity is the main energy consumption in textile industry, which is used for machinery, cooling, temperature, control, lighting, office equipment etc. Mainly Fuel oil and coal are used to generate steam for textile industry. Various end uses of steam are drying and finishing, fiber production, spinning, weaving and clothing etc. In the textile industry energy intensity rose for many products like cloth, cotton yarn, fabric, grey cloth, jute goods, polyester chips, yarn etc.

According to the Asian Regional Research Program in Energy, Environment, and Climate (ARRPEEC) survey, the energy consumption of the textile industry is 3–3.5 kWh/kg of yarn in a modernized spinning mill, 0.09–0.2 kWh/kg of fabric in knitting units, and 0.04–0.15 kWh/kg of fabric in dyeing. In fabric dyeing units, consumption of steam may vary from 4 kg to 9 kg of steam per kg of fabric [1, 7]. Specific thermal energy 4500-5500 kcal/meter is required for cloth [2].

The thermal energy requirement for 1m of cloth processing is about 26.1 MJ. The variation of thermal energy is mainly due to different types of end products. However, energy saving potential in this sector is high. The thermal energy requirement for jute goods is less as compared to other textile end products. For processing one tonne of jute goods the thermal energy requirements is 3.2 GJ .The thermal energy requirement for other textile end products like cotton yarn, fabric, grey cloth, polyester chips, yarn etc. varies from 13.5 GJ to 32.4 GJ for processing 1 tonne of products [8]. The following Table (Table 5) shows the normative quantity for different categories under this sector. The specific energy consumption (thermal) considered for this evaluation for individual categories have also been mentioned in the table.

Table 5: Normative requirement of coal for Textile Industry							
Category							
	Cloth	**Cotton Yarn**	**Fabric**	**Gray Cloth**	**Jute Goods**	**Polyester Chips**	**Yarn**
SEC Thermal ⟶	**26.1 MJ/m**	**15.1 GJ/t**	**32.4 GJ/t**	**15.9 GJ/t**	**3.2 GJ/t**	**13.5 GJ/t**	**21.2 GJ/t**
Coal req ⟶	**kg/m**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**
Grade							
G-1	**0.87**	**502.83**	1078.92	529.47	106.56	449.55	705.96
G-2	0.91	524.85	1126.17	552.66	111.23	469.24	736.88
G-3	0.95	548.89	1177.75	577.97	116.32	490.73	770.63
G-4	0.99	575.24	1234.29	605.71	121.90	514.29	807.62
G-5	1.04	604.24	1296.52	636.25	128.05	540.22	848.34
G-6	1.10	636.33	1365.36	670.04	134.85	568.90	893.38
G-7	1.16	672.01	1441.92	707.61	142.41	600.80	943.48
G-8	1.23	711.93	1527.58	749.65	150.87	636.49	999.53
G-9	1.31	756.89	1624.06	796.99	160.40	676.69	1062.66
G-10	1.40	807.92	1733.55	850.72	171.21	722.31	1134.30
G-11	1.50	866.32	1858.86	912.22	183.59	774.53	1216.29
G-12	1.61	933.83	2003.71	983.30	197.90	834.88	1311.07
G-13	1.75	1012.74	2173.04	1066.40	214.62	905.43	1421.86
G-14	1.91	1106.23	2373.63	1164.84	234.43	989.01	1553.11
G-15	2.11	1218.72	2615.01	1283.29	258.27	1089.59	1711.06
G-16	2.35	1356.69	2911.05	1428.57	287.51	1212.94	1904.76
G-17	2.64	1529.89	3282.67	1610.94	324.21	1367.78	2147.92

However, the normative requirement of coal for any industry under this sector may be calculated using the following formula.

i) For cloth: Coal requirement in kg/m = SEC (kcal/m)/GCV

SEC in MJ/m*1000/4.2 = SEC in kcal/m

Sample calculation: 26.1*1000/4.2 =6238.095

6238.095/7150= 0.87 kg/ton

ii) For other products: Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in GJ/ton *1000/4.2 = SEC in kcal/kg

Sample calculation: 15.1*1000/4.2=3595.238

3595.238*1000/7150= 502.83 kg/ton

Finally, considering the technology dependent or raw material dependent SEC variation and many other factors, it is recommended to consider boiler operational data for assessment of normative quantity of coal for the industries of this sector. The methodologies for boiler based assessment have been included in chapter 2.

References:
1. BEE, PAT Booklet, MOP, GoI, July 2012.
2. TERI Energy Data Directory and year book 2005-2006.
7. Tech compendium on energy savings opportunities textile sector.
8. Understanding Industrial Energy use. Physical Energy intensity changes in India Manufacturing Section, Indira Gandhi Institute of Development Research, Mumbai.

iv.) Petro Chemicals:

The Petro Chemical industry is a technology intensive industry. The obsolescence of technology is quite rapid. Plants should have the adaptability to absorb new technology and should be upgraded and modernized constantly.

It is a capital intensive and high volumes Industry and the minimum economic size of an integrated plant is around 1 million ton per annum of end products. The product range is wide and includes petrochemicals, polymers and other specialty chemicals and the specific consumption is widely varied. The specific thermal energy consumption is in the range of 1.1 to 5.5 Mkcal/tonne depending upon the type of product manufactured [3].

The normative quantity of this sector has been derived using an average figure is 3.3 Mcal/ton as an example. The results have been including in the following table.

Table 6: Normative requirement of coal for Petrochemicals Industry

[SEC Thermal= 3.3 Mcal/ton]

Coal grades	kg/t
G-1	**461.54**
G-2	481.75
G-3	503.82
G-4	528.00
G-5	554.62
G-6	584.07
G-7	616.82
G-8	653.47
G-9	694.74
G-10	741.57
G-11	795.18
G-12	857.14
G-13	929.58
G-14	1015.38
G-15	1118.64
G-16	1245.28
G-17	1404.26

However, based on the technology based SEC consumption figure this may be calculated using the following equation.

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in Mkcal/ton (or Gcal/ton) *1000 = SEC in kcal/kg

Sample calculation

3.3*1000= 3300

3300*1000/7150= 461.54 kg/ton

Finally, considering the technology dependent or raw material dependent SEC variation, etc., it is recommended to consider boiler operational data for assessment of normative quantity of coal for an industry. The methodologies for boiler based assessment have been included in chapter 2.

Ref: 3. Energy Efficient Technology in India, V. S. Verma, DG, Bureau of Energy Efficiency, 2004.

v.) Chloro-alkali Industry:

The Chloro-alkali industry consists of the production of three inorganic chemicals: caustic soda (NaOH), soda ash (Na_2CO_3) and Chlorine (Cl_2). Caustic soda and chlorine are produced simultaneously while soda ash is produced during a different process. The production process of caustic soda and chlorine consists of applying a direct electric current to a solution called brine made of common salt dissolved in water. The caustic soda industry is 65 years old. The production of caustic soda is associated with chlorine. Three processes are currently used to produce caustic soda are diaphragm cell, mercury cell and membrane cell electrolysis. The thermal energy requirement for one ton Caustic soda production: 3.4 GJ in case of diaphragm cell and 0.53 GJ in case of Membrane process [9].

Sodium carbonate or soda ash can either be obtained through a process by reacting trona (the principal ore from which soda ash is made) with water, or it can be produced by the Solvay process referred to as the synthetic process. Soda ash is then produced by reacting with ammonical brine with carbon dioxide to produce bicarbonate, which is then calcined to produce carbonate. Soda Ash is mostly used in the production of glass, chemicals, soap, detergents, paper, paper pulp production and water treatment. To produce one tone Soda ash the thermal energy requirement is 15.9 GJ for Solvay process and 9.2 GJ for dual process [9]. All soda ash units have coal based CPP for co-generation of steam and power required by the Industry.

The following Table (Table 7) shows the normative quantity for different categories under this sector. Average thermal specific energy consumption considered for this evaluation has also been mentioned in the Table.

Table 7: Normative requirement of coal for Chloro-alkali Industry

Category				
	Soda Ash		**Caustic Soda Lye**	
	Solvay process	**Dual process**	**Diaphragm**	**Membrane**
SEC Thermal GJ/t →	**15.9**	**9.2**	**3.4**	**0.53**
Coal req →	**kg/t**	**kg/t**	**kg/t**	**kg/t**
Grades ↓				
G-1	**529.47**	306.36	113.22	17.65
G-2	552.66	319.78	118.18	18.42
G-3	577.97	334.42	123.59	19.27
G-4	605.71	350.48	129.52	20.19
G-5	636.25	368.15	136.05	21.21
G-6	670.04	387.69	143.28	22.33
G-7	707.61	409.43	151.31	23.59
G-8	749.65	433.76	160.30	24.99
G-9	796.99	461.15	170.43	26.57
G-10	850.72	492.24	181.92	28.36
G-11	912.22	527.83	195.07	30.41
G-12	983.30	568.95	210.27	32.78
G-13	1066.40	617.04	228.03	35.55
G-14	1164.84	673.99	249.08	38.83
G-15	1283.29	742.53	274.41	42.78
G-16	1428.57	826.59	305.48	47.62
G-17	1610.94	932.12	344.48	53.70

However, based on the technology based SEC consumption figure this may be calculated using the following equation.

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in GJ/ton *1000/4.2 = SEC in kcal/kg

Sample Calculation:15.9*1000/4.2= 3785.714

15900*1000/7150= 529.47 kg/ton

Finally, considering the technology dependent or raw material dependent SEC variation, etc., it is recommended to consider boiler operational data for assessment of normative quantity of coal for an industry. The methodologies for boiler based assessment have been included in chapter 2.

Ref: 9. Chloro-Alkali Industry, TERI Report.

vi.) Rubber Industries:

Rubber sheet production uses heat energy in drying step more than 80% of the total energy consumption. While in the rubber-block production uses heat energy in the same amount as electrical energy. Totally opposite to the sheet production, the concentrated latex production consumes mainly electrical energy in the centrifugal machines. In tire manufacturing both heat and electrical energy are utilized in the same proportion. The dipping, extruding and forming production consume energy in the different proportion. In dipping process, heat is used most in curing process. In forming process, electrical energy is mainly consumed by the injection molding machines. Extruding process uses both types of energy in the same proportion.

Out of total energy consumed in Rubber industry, the total electrical energy in the rubber industry varies from 16-66% and thermal energy varies from 7-84%.The thermal energy varies from 0.07 MJ to 74.59 MJ for one kg production [10] The maximum thermal energy is required in dipping and minimum thermal energy is required in concentrated product. For dipping the thermal energy requires 74.59 MJ/kg, whereas for concentrated product it requires 0.07 MJ/kg.

Some specific Energy consumptions data stated in literature:

Specific energy consumption (Thermal) = 1.24 MKcal/ton [11]

Specific energy consumption (Thermal) = 0.233 MTOE/ton [12].

The following Table (Table 8) shows the normative quantity for different categories under this sector. Average thermal specific energy consumption figures considered for the evaluation of various categories have also been mentioned in the table.

Table 8: Normative requirement of coal for Rubber Industry

	Category							
	Block	**Sheet**	**Concentrated**	**Tyre**	**Dipping**	**Extruding**	**Forming**	**Miscellaneous**
SEC Thermal→ MJ/kg	**1.16**	**3.2**	**0.07**	**8.67**	**74.59**	**8.74**	**20.49**	**3.65**
Coal req.→	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**
Grade↓								
G-1	**38.63**	106.56	2.33	288.71	2483.85	291.04	682.32	121.55
G-2	40.32	111.23	2.43	301.36	2592.63	303.79	712.20	126.87
G-3	42.17	116.32	2.54	315.16	2711.38	317.70	744.82	132.68
G-4	44.19	121.90	2.67	330.29	2841.52	332.95	780.57	139.05
G-5	46.42	128.05	2.80	346.94	2984.79	349.74	819.93	146.06
G-6	48.88	134.85	2.95	365.36	3143.28	368.31	863.46	153.81
G-7	51.62	142.41	3.12	385.85	3319.54	388.96	911.88	162.44
G-8	54.69	150.87	3.30	408.77	3516.74	412.07	966.05	172.09
G-9	58.15	160.40	3.51	434.59	3738.85	438.10	1027.07	182.96
G-10	62.07	171.21	3.75	463.88	3990.90	467.63	1096.31	195.29
G-11	66.55	183.59	4.02	497.42	4279.40	501.43	1175.56	209.41
G-12	71.74	197.90	4.33	536.18	4612.86	540.51	1267.16	225.73
G-13	77.80	214.62	4.69	581.49	5002.68	586.18	1374.25	244.80
G-14	84.98	234.43	5.13	635.16	5464.47	640.29	1501.10	267.40
G-15	93.62	258.27	5.65	699.76	6020.18	705.41	1653.75	294.59
G-16	104.22	287.51	6.29	778.98	6701.71	785.27	1840.97	327.94
G-17	117.53	324.21	7.09	878.42	7557.24	885.51	2075.99	369.81

However, based on the technology based SEC consumption figure this may be calculated using the following equation.

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in MJ/kg*1000/4.2 = SEC in kcal/kg

Sample Calculation:1.16*1000/4.2= 276.19 kcal/kg

276.19*1000/7150= 38.63 kg/ton

Finally, considering the technology dependent or raw material dependent SEC variation, etc., it is recommended to consider boiler operational data for assessment of normative quantity of coal for an industry. The methodologies for boiler based assessment have been included in chapter 2.

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10. Project on studying of Energy Efficient Index in Rubber Industry – Development of Alternative Energy, Energy Development and Efficiency, Ministry of Energy.

11. Goodyear India Limited, Ballavgarh Plant, tyre
12. Balkrishna Industry Limited, Rajasthan

vii.) Coal requirement for Coke making Industries:

Beehive cookeries of different capacity and types are under operation with wide variations in the coking time which is primarily dependent on the efficiency of the waste heat utilization. The estimation of the coal requirement for any working ovens can be made from the empirical formula

Total coal/oven/month= $24*30*A/T_c$

A= Coal charge per oven (t)

Tc = Coking time (hrs)

Sample calculation:

Total coal/oven/month =24*30*7/52=96.92 ton/month/oven

An illustration of the method of calculation is given in Table 9

Table 9: Normative requirement of Coal for coke making			
		Assuming 30 days use in a month	Coal Type - Washery III & IV
A	Coke Oven Type		Total coal charged ton/month/oven
1	Non Recovery old beehive type	Feed @7ton/ batch & carbonization time 52 hrs.	**96.92**
2	Non Recovery Improved type	Feed @9ton/ batch & carbonization time 48 hrs.	135.00
3	Pusher type	Assume 15ton/oven and time 48hrs.	225.00
4	Stamping Tech.	VM:21-27%; Ash:13-32%	
		Assume feed 25te: time 62hr	290.32
B			
	Recovery (by product) assume coking time 1"/hr.	Coal : ash:17-19%,VM:22-26%	
1	14" oven	Assume feed 14ton/oven coking time 14.5 hrs.	695.17
2	16" oven	Assume feed 16ton/ oven coking time 16.5 hrs.	698.18
3	18" oven	Assume feed 18ton/ oven coking time 18.5 hrs.	700.54
C ….	Domestic soft coke oven …*Coke quality* VM- 7-8%, M-2-4%, Ash- <40 %	Assume feed 2.5 ton/oven/batch carbonization time 15 hrs *Coal quality* : M-2-6%, VM-<20%, Grade W3, W4, E, F	120.00

This estimation is based on washery grade III & IV. It may be noted that in coke making if the VM is outside the range of 22-26 % the coking time increases.

viii.) Glass Industries:

The most energy intensive process in glass industry is the melting and refining of glass. In general 30-35% energy is actually consumed in melting and refining process and rest is lost. The flue gas temperature for a common medium to high capacity glass tank furnace is around 350^{o}C and around 30% of thermal energy input is lost through flue gas.

Glass industry is comprised of different categories of which main glass types are sheet glass, float glass, container glass, Borosilicate glass, specialty glass, fiberglass, etc. Although new technologies are developed continuously, this report is focused on practices that are proven and currently commercially available in India. The specific energy of glass production (i.e., energy use per ton of product) depends heavily on the end product type (i.e. chemical composition), the percentage of cullet in the feed, the efficiency of the processes, the furnace type, glass draw, etc. Table 10 summarizes the average specific energy use of the major glass manufacturing technologies/ processes in India as well as the corresponding grade wise coal requirement. The energy requirement may vary based on the chemical composition and the use of cullet. Specific energy consumption as shown in Table 10 considers use of ~ 30% cullet as a general trend / rational approximation. The specific energy consumption in Table 10 is for glass melting and refining, which is the most energy-intensive processes within each industry segment. Batch preparation is usually the least energy-intensive process step which uses electrical energy. Full electric glass melting furnaces are also used globally but those are mainly used by smaller producers, as well as by producers of specialty glass and fiberglass products. It is to be noted here that fiber glass production may use gaseous fuel such as natural gas, producer gas etc., as fuel for melting. Grade wise coal-requirement for a particular category of glass manufacturing has been calculated based on current GCV based grading system. The grade wise coal requirement have been summarized in the Table 10 which essentially considers the supply of lump coal as desired by the consumer industry to run the coal based producer gas plant or direct coal fired furnaces.

The major glass melting furnaces are tank furnace with regenerative systems. Large scale producers generally use furnace oil, natural gas and pet coke and coal based producer gas as fuel. Very few manufacturers use gas produced from static coal producer or use flue from direct coal firing as a source of heat, but these manufacturing technologies are less energy efficient and are becoming obsolete even in India. Some low capacity (15-25 TPD) glass tank furnace are fired by coal directly and direct coal firing is also observed in some open pot glass product and closed pot glass product.

Specific energy requirement for glass melting furnaces basically include energy requirement for melting of batch materials and different types of losses and heat gain through preheated secondary air. It depends on type of glass, batch composition, temperature of glass melt, heat losses through port, throat, wall, crown, batch feeding zone, flue gas, as well as heat losses through melt drawn from the furnace, etc. As such, specific energy consumption is significantly related to the furnace dimensions, glass production capacity, loading, furnace age, and cullet percent. For a particular type of furnace variations of specific heat requirement are due to various combination of raw materials, cullet content in batch, batch composition, age and material of construction (quality of refractory/ insulation). Moreover, heat recovery systems also regulate specific energy consumption, e.g., specific energy consumption for regenerative furnaces are lower than that for Recuperative furnaces. Therefore, it is very difficult to lay down uniform norms for specific heat requirement for melting of specific glass categories. Within these limitations specific energy requirement data collected from reliable sources and published documents have been taken into account to estimate specific coal requirement for different categories of manufacturing processes [13-21]. Small furnaces and furnaces operating at less than nominal capacity are generally less efficient, since specific heat losses are high. As a consequence category wise specific energy requirement values (per ton of glass drawn) are covered by broad ranges as it is reflected from different literatures. Therefore expert opinion has been taken to identify appropriate specific energy consumption range for different glass categories, particularly in Indian context.

Annealing and finishing of glass items again require some amount of process heat which is met either by LPG/producer gas/natural gas/ fuel oil firing or by electrical heating. As a general trend, electrical heated annealing systems are getting switched over to gas fired annealing systems. Specific energy consumption for annealing operation of glass products is 400-500 kcal/ kg of glass products [14, 15].

Although variability in SEC for annealing operation is always there for different kinds of glass items, minimum specific energy requirement irrespective of glass categories has been taken into account. Table 11 has been added to account for the additional specific energy requirement on account of Annealing. Corresponding grade wise requirements of additional quantity of coal in case of producer gas fired annealing lehr have also been incorporated in the same Table (Table 11).

Formula for calculation Glass melting / annealing

Coal requirement (in kg/t of product) = (SECcoal *1000)/GCV
Where SEC coal denotes coal based specific energy consumption in kcal/kg.

For producer gas fired units the SEC coal has been estimated using the following relationship to generate different normative figures, as examples, which have been incorporated in Table 10.

SEC coal = SEC in Melter or in annealing Lehr/A
Where, 'A' is the thermal efficiency factor which corresponds to percent thermal energy transfer from coal to producer gas.

A = (Percent thermal energy transfer from coal to producer gas)/ 100
In the examples given in Tables 10, 11 percent thermal energy of coal transferred to producer gas has been taken as 55%. i.e., A = 55/ 100 = 0.55

Sample calculation:
SEC PG based for sheet glass is 2000 kcal/kg, A=0.55
2000 kcal/kg /0.55 = 3636.364 kcal/kg
3636.374*1000/7150 = 508.6 kg/t

If transfer of heat from coal to producer gas be higher, then the corresponding thermal efficiency factor has to be taken. For example, thermal efficiency factor has to be taken as 0.7 for 70% transfer of coal heat to producer gas heat.

For producer gas fired furnaces or annealing lehrs it is recommended to go for Producer gas plant based assessments. Producer gas plant based assessments of coal requirements (grade wise) have been elaborated in chapter 2 of this report.

Table 10: Normative requirement of different grades of coal for manufacturing of different kinds of glass- melting and refining

Products	Normal cap/ Fuel	SEC	SEC (PG based), MV	Coal based SEC, MV	Coal requirement by different grades, kg of coal/ t of product							
		kcal/ kg	kcal/ kg	kcal/ kg	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8
Sheet Glass	60T max, 2mm thick, PG	1800-2200	2000	3636.4	**508.6**	530.9	555.2	581.8	611.2	643.6	679.7	720.1
Float glass	>= 600TPD, 900TPD max, PG	1400-1500	1450	2636. 4	368.7	384.9	402.5	421.8	443.1	466.6	492.8	522.1
Container glass	15-25 TPD, COAL	3600-3700	–	3650	510. 5	532.8	557.3	584	613.4	646.1	682.2	722.8
Container glass	< 100 TPD, PG	1600-18000	1700	3090.9	432.3	451.2	471.9	494.5	519.5	547.1	577.7	612.1
Container glass	100 -250TPD, PG	1200-1400	1300	2363.7	330.6	345.1	360.9	378.2	397.2	418.3	441.8	468.0
Container glass	> 250, PG	900-1100	1000	1818.2	254.3	265.4	277.6	290.9	305.6	321.8	339.8	360.0
Borosilicate	~ 10-15 TPD, PG	2400-2600	2500	4545. 5	635.7	663.6	694.0	727.3	763.9	804.5	849.6	900.1
Borosilicate	30-50TPD, PG	1800-2200	2000	3636. 4	508.6	530.9	555.2	581.8	611.2	643.6	679.7	720.1
Lead crystal glass	30-50TPD, PG	1800-2200	2000	3636. 4	508.6	530.9	555.2	581.8	611.2	643.6	679.7	720.1
Glass shell, Recuperative	~12 TPD, PG	3500-3700	3600	6545. 5	915.4	955.5	999.3	1047.3	1100.1	1158.5	1223.4	1296.1
Glass shell, other	60-70TPD, PG	1900-2100	2000	3636. 4	508.6	530.9	555.2	581.8	611.2	643.6	679.7	720.1
Fiber glass	20-30 TPD, PG	1250-1650	1450	2636. 4	368.7	384.9	402.5	421.8	443.1	466.6	492.8	522.1
Specialty glass	100-150 TPD, PG	1750-1950	1850	3363. 7	470.4	491.0	513.5	538.2	565.3	595.3	628.7	666.1
Open pot glass product	5-7 TPD, COAL	5000-6000	–	5500	769.2	802.9	839.7	880.0	924.4	973.5	1028.0	1089.1
Closed pot glass product	2-4 TPD, COAL	9000-10000	–	9500	1328.67	1386.9	1450.382	1520.0	1596.6	1681.416	1775.7	1881.2

Table 10: (contd.) Normative requirement of different grades of coal for manufacturing of different kinds of glass- melting and Refining

Products	SEC (PG based), MV	Coal based SEC, MV	Coal requirement by different grades, kg of coal/ t of product								
	kcal/ kg	kcal/ kg	G-9	G-10	G11	G12	G13	G14	G15	G16	G17
Sheet Glass	2000	3636. 4	765.6	817.2	876.2	944.5	1024.3	1118.9	1232.7	1372.2	1547.4
Float glass	1450	2636. 4	555.0	592.4	635.3	684.8	742.6	811.2	893.7	994.9	1121.9
Container glass	-	3650	768.4	820. 3	879.5	948.1	1028.2	1123.1	1237.3	1377.4	1553.2
Container glass	1700	3090. 9	650.7	694.6	744.8	802.8	870.7	951.0	1047.8	1166.4	1315.3
Container glass	1300	2363.7	497.6	531.2	569.6	613.9	665.8	727.3	801.2	891.9	1005.8
Container glass	1000	1818. 2	382.8	408.6	438.1	472.3	512.2	559.4	616.3	686.1	773.7
Borosilicate*	2500	4545. 5	956.9	1021.5	1095.3	1180.6	1280.4	1398.6	1540.8	1715.3	1934.2
Borosilicate	2000	3636. 4	765.6	817.2	876.2	944.5	1024.3	1118.9	1232.7	1372.2	1547.4
Lead crystal glass	2000	3636. 4	765.6	817.2	876.2	944.5	1024.3	1118.9	1232.7	1372.2	1547.4
Glass shell, Recuperative	3600	6545. 5	1378.0	1470. 9	1577.2	1700	1843.8	2013.9	2218.8	2470.0	2785.3
Glass shell, other	2000	3636. 4	765.6	817.2	876.2	944.5	1024.3	1118.9	1232.7	1372.2	1547.4
Fiber glass	1450	2636. 4	555.0	592.4	635.3	684.8	742.6	811.2	893.7	994.9	1121.9
Specialty glass	1850	3363. 7	708.1	755. 3	810.5	873.7	947.5	1034.9	1140.2	1269.3	1431.3
Open pot glass product	_	5500	1157.9	1236.0	1325.3	1429	1549.3	1692.3	1864.4	2075.5	2340.4
Closed pot glass product	_	9500	2000.0	2134.8	2289.157	2468	2676.1	2923.1	3220.3	3584.9	4042.6

Table 11: Normative requirement of coals for annealing of glass, if fired by Producer Gas (PG)

Post forming unit	Fuel	SEC range, PG based	Avg SEC, PG based	Avg SEC, Coal based	Coal requirement by different grades (kg of coal/t of product)								
					G-1	**G-2**	**G-3**	**G-4**	**G-5**	**G-6**	**G-7**	**G-8**	**G-9**
Annealing	PG	400-500	450	818.2	114.4	119.4	124.9	130.9	137.5	144.8	152.9	162.0	172.2
					Coal requirement by different grades (kg of coal/t of product)								
					G-10	**G11**	**G12**	**G13**	**G14**	**G15**	**G16**	**G17**	
					183.9	197.2	212.5	230.5	251.7	277.3	308.7	348.2	

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ix.) Refractory's:

Refractory manufacturing is a complex subject. Hundreds of products are there and for a specified product several production techniques are available to meet the requirement of refractory products in various industries.

Coal requirement in refractory industry is basically for two process steps, viz., raw material calcinations and firing of refractory materials in different kilns. There is wide variation in the specific energy consumption in the refractory industries depending on the raw materials, process parameters (like batch composition, moisture content in green product , pressure employed in the mechanical press), temperature and temperature schedule, firing cycle, type of furnaces and furnace design, heat recovery systems, production capacity, age of the furnace/ kiln, material of furnace construction(refractory/ insulation), product type and desired product specification, etc. In several occasions calcined raw materials are also outsourced by refractory plants. Calcined raw materials also go to cast able manufacturing process. Depending on the detailed specification of an ordered refractory product, firing temperature/ firing cycle/ firing schedule in a particular kiln may have to be changed and correspondingly similar changes are also likely in raw material calcinations unit(s). This is the main reason for variation of SEC in a particular kiln/ calciner for a particular product category and sometimes this variation becomes substantial. Apart from the product specification (porosity, density, CCS, PLCAR, PCE, RUL, creep, etc.) given by the party for a particular product type, different condition of thermal-treatment may have to be adopted depending on the 'combination and composition of raw materials', as well as depending on size, 'shape and design of the product (hollow/ tubular, perforated, etc.)', design of furnace loading, etc. Variation in condition/schedule of thermal-treatment leads to variation in SEC.

Based on the information received from Indian Refractory Makers' Association (IRMA) and interaction with few experts of the user industries the following coal requirement is being presented as examples separately for calcinations and firing purposes. For refractories the product types are many. Adopted techniques for economization of energy in different plants are also not similar. Therefore, specific energy requirement for a particular variety of product can not be very precise and rather the range of variation is wide. It is also very much difficult to cover all product ranges in refractory industry. Moreover for a particular product, kiln options and thermal treatment varies and therefore categories can be many. The category types mentioned in the following tables (Tables 12, 13) are very common for refractory production and raw material calcinations. In general, average energy requirements irrespective of temperature of firing, product type, kiln type and firing system, etc. may vary from < 1 GJ / ton of product to even 18 GJ/t of product [1-5]. Specific energy consumption values obtained from various sources [22-26] for different categories have been shown in the tables. Sometimes furnace oil (FO) boosting is necessary for producer gas (PG) based firing systems depending on the firing temperature and firing schedule, particularly when temperature of firing is above 1400^{o}C. In those cases SEC as indicated in the example-tables have been considered to be based on producer gas as fuel.

Calculation for the sake of presenting the examples of firing systems using producer gas plant considers a practical situation of thermal efficiency, i.e., 55%. This thermal conversion efficiency data indicates the percentage of coal heat which gets transformed into producer gas heat. It is important to note that the thermal conversion efficiency depends on the design of the PG plant and quality of the feed coal. With the inferior supply of coal the thermal conversion efficiency drops down. Although the thermal conversion efficiency as per the PG-plant design data may be even up to 75%, practically it is sometimes very difficult to obtain in PG units in refractory plants or similar other industries.

The normative requirement is different grades of coals (as mentioned in example tables 12, 13) have been computed for several examples of manufacture of refractory's and calcinations of raw materials. The formula used for such computation of normative coal requirement is as follows:

$$\text{Coal requirement (in kg/t of product)} = \frac{\text{SEC coal x 1000}}{\text{GCV}}$$

Where SEC coal is the coals based specific energy consumption in kcal/kg.

For producer gas fired kilns/furnaces.

$$\text{SEC coal} = \frac{\text{SEC kiln}}{\text{A}},$$

Where A = (Percent thermal energy transfer from coal to producer gas)/ 100 and SEC kiln represents the specific energy required in kiln utilized for firing of process. 'A' in denominator represents thermal efficiency factor. It is to be noted that SEC kiln and SEC PG based (as mentioned in the tables) are synonymous. The examples of PG fired systems in the tables have been calculated considering thermal conversion efficiency is 55% i.e. ‘A’=0.55.

Sample calculation:

i) Rotary kiln:

SEC PG based for rotary kiln 1830 kcal/kg, A=0.55

1830 /0.55 = 3327.3 kcal/kg

3327.3*1000/7150 = 465.4 kg/ton

ii) DD kiln (coal fired)

SEC= 2600 kcal/kg

2600*1000/7150=363.6 kg/ton

However, it is recommended to adopt coal allocation strategies in refractory plants based on operational details of PG plant, wherever applicable. Assessment of coal requirement based on PG plant has been described on chapter 2.

Table 12: Normative requirement for coal for Calcinations of Raw Material

Sl.No.	Kiln type	Product type	Fuel type	Temperature oC	PG based SEC	Coal based SEC kcal/ kg	kg of coal/t of product	
							G1	G2
1	Rotary kiln	Calcined Bauxite, Kyanite, Diaspore	P G	1500-1550	1830	3327.3	**465.4**	485.7
2	Shaft kiln	Calcined Dolomite	PG		1015	1845.5	258.1	269.4
3	Shaft kiln	D B Dolomite	PG		1612	2930.9	409.9	427.9
4	Chamber Kiln	Calcined RM (Diaspore, kyanite)	PG	1300-1400	830	1509.1	211.1	220.3
5	Rotary kiln	Calcined Kaolin	PG	1650	1637	2976.4	416.3	434.5
6	Rotary kiln	Calcined Dolomite	PG	1100	1746	3174.5	444.0	463.4
7	Rotary kiln	DBM	PG	1600-1800	2300	4181.8	584.9	610.5
8	Rotary kiln	D B Dolomite	PG	1500-1600	2700	4909.1	686.6	716.7
9	DD kiln	calcined kyanite , bauxite, fireclay, diaspore	coal	1300-1400		2400	335.7	350.4
10	Fluidised bed kiln	Calcined Dolomite	PG		1200	2181.8	305.1	318.5

Table 12 (contd.): Normative requirement for coal for Calcinations of Raw Material

	Kg of coal/t of product														
	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17
1	508.0	532.4	559.2	588.9	621.9	658.9	700.5	747.7	801.8	864.2	937.3	1023.8	1127.9	1255.6	1415.9
2	281.7	295.3	310.2	326.6	344.9	365.4	388.5	414.7	444.7	479.3	519.8	567.8	625.6	696.4	785.3
3	447.5	468.9	492.6	518.7	547.8	580.4	617.0	658.6	706.2	761.3	825.6	901.8	993.5	1106.0	1247.2
4	230.4	241.5	253.6	267.1	282.1	298.8	317.7	339.1	363.6	392.0	425.1	464.3	511.6	569.5	642.2
5	454.4	476.2	500.2	526.8	556.3	589.4	626.6	668.8	717.2	773.1	838.4	915.8	1008.9	1123.2	1266.5
6	484.7	507.9	533.5	561.9	593.4	628.6	668.3	713.4	765.0	824.6	894.2	976.8	1076.1	1197.9	1350.9
7	638.4	669.1	702.8	740.1	781.6	828.1	880.4	939.7	1007.7	1086.2	1178.0	1286.7	1417.6	1578.0	1779.5
8	749.5	785.5	825.1	868.9	917.6	972.1	1033.5	1103.2	1182.9	1275.1	1382.8	1510.5	1664.1	1852.5	2089.0
9	366.4	384.0	403.4	424.8	448.6	475.2	505.3	539.3	578.3	623.4	676.1	738.5	813.6	905.7	1021.3
10	333.1	349.1	366.7	386.2	407.8	432.0	459.3	490.3	525.7	566.7	614.6	671.3	739.6	823.3	928.4

Table 13: Normative requirement for coal for Firing of Bricks and Shapes

Sl.No.	Kiln type	Product type	Fuel Type	Temperature oC	PG based kcal/ kg	Coal Based kcal/ kg	kg of coal/t of product	
							G1	G2
1	DD kiln	Fire clay, < 40% Alumina	Direct Coal	1400oC		2600	**363.6**	379.6
2	DD kiln	High alumina, 40 - 88 %	Direct Coal	1450		2860	400	417.5
3	DD kiln	Silica Bricks	Direct coal	1500-1550(50 days cycle)		3750	524.5	547.4
			Direct coal	1200-1300(7 days cycle)		7500	1048.9	1094.9
4	Tunnel Kiln	high alumina bricks	P G	1420-1500	1275	2318.2	324.2	338.4
5	Tunnel kiln, 4tph	Fire clay	P G	1260	764	1389.1	194.3	202.8
6	Tunnel Kiln	Basic refectories (Magnesite,Chrome Mag, Mag-Chrome Direct bonded Basic brick)	P G	1700-1750	1600	2909.1	406.9	424.7
7	Tunnel Kiln	Dolomite Bricks	P G	1620-1660	1100	2000	279.7	292.0
8	Tunnel kiln, 2-8 tph	Magnetite bricks	P G	1760-1850	1875	3409.1	476.8	497.7
9	Tunnel kiln, 2.1 tph	Silica bricks	P G	1450	2161	3929.1	549.5	573.6
10	Tunnel kiln, 4 tph	Bauxite bricks		1400	1075	1954.5	273.4	285.3
11	Chamber Kiln	Fire clay,< 40% Alumina	P G	1400 -1480	1300	2363.6	330.6	345.1
12	Chamber Kiln	High Alumina, 40%-88%	P G	1450-1480	1200	2181.8	305.2	318.5
13	Chamber Kiln	Silica Bricks	P G	1400	3000	5454.5	762.9	796.3
14	Chamber Kiln	Silica Bricks	P G	1450	4150	7545.5	1055.3	1101.5
15	Shuttle Kiln, 153 tpc	Silica bricks	P G	1540	1314	2389.1	334.1	348.8
16	Shuttle Kiln, 40-50tpc	High alumina	P G	1340-1650	1493	2714.5	379.7	396.3
17	Shuttle Kiln, 18 tpc	Fireclay bricks	P G	1430	1266	2301.8	321.9	336.0

Table 13 (contd.): Normative requirement for coal for Firing of Bricks and Shapes (previous table continued)

	kg of coal/t of product														
	G3	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**	**G15**	**G16**	**G17**
1	396.9	416	437.0	460.2	486.0	514.9	547.4	584.3	626.5	675.3	732.4	800	881.4	981.1	1106.4
2	436.6	457.6	480.7	506.2	534.6	566.3	602.1	642.7	689.1	742.9	805.6	880	969.5	1079.2	1217.0
3	572.5	600	630.3	663.7	700.9	742.6	789.5	842.7	903.6	974	1056.3	1153.8	1271.2	1415.1	1595.7
	1145.0	1200	1260.5	1327.4	1401.9	1485.1	1578.9	1685.4	1807.2	1948	2112.7	2307.71	2542.4	2830.2	3191.5
4	353.9	370.9	389.6	410.3	433.3	459.0	488.0	520.9	558.6	602.1	653	713.3	785.8	874.8	986.5
5	212.1	222.3	233.5	245.9	259.6	275.1	292.4	312.2	334.7	360.8	391.3	427.4	470.9	524.2	591.1
6.	444.1	465.5	488.9	514.9	543.8	576.1	612.4	653.7	700.9	755.6	819.5	895.1	986.1	1097.8	1237.9
7	305.3	320	336.1	354.0	373.8	396.0	421.1	449.4	481.9	519.5	563.4	615.4	678.0	754.7	851.1
8	520.5	545.5	573.0	603.4	637.2	675.1	717.7	766.1	821.5	885.4	960.3	1048.9	1155.6	1286.5	1450.7
9	599.9	628.7	660.4	695.4	734.4	778.0	827.2	882.9	946.8	1020.5	1106.8	1208.9	1331.9	1482.7	1672.0
10	298.4	312.7	328.5	345.9	365.3	387.0	411.5	439.2	470.9	507.7	550.6	601.4	662.5	737.5	831.7
11	360.9	378.2	397.2	418.3	441.8	468.0	497.6	531.2	569.5	613.9	665.8	727.3	801.2	891.9	1005.8
12	333.1	349.1	366.7	386.2	407.8	432.0	459.3	490.3	525.7	566.7	614.6	671.3	739.6	823.3	928.4
13	832.8	872.7	916.7	965.4	1019.5	1080.1	1148.3	1225.7	1314.3	1416.7	1536.5	1678.3	1849.0	2058.3	2321.1
14	1152.0	1207.3	1268.1	1335.5	1410.4	1494.1	1588.5	1695.6	1818.2	1959.8	2125.5	2321.7	2557.8	2847.4	3210.9
15	364.7	382.3	401.5	422.8	446.6	473.1	503.0	536.9	575.7	620.5	672.9	735.1	809.9	901.5	1016.6
16	414.4	434.3	456.2	480.5	507.4	537.5	571.5	610.0	654.1	705	764.6	835.3	920.2	1024.3	1155.1
17	351.4	368.3	386.9	407.4	430.2	455.8	484.6	517.3	554.7	597.8	648.4	708.3	780.3	868.6	979.5

Reference:

22. *European Commission Reference Document on Best Available Techniques in the Ceramics Manufacturing Industry, Aug 2007, http://eippcb.jrc.es*
23. *CII(Confederation of Indian Industry)- Godrej GBC, Total Cost Management, GLASS AND CERAMIC INDUSTRY, http://greenbusinesscentre.com/ceramicindustry.asp*
24. *DGTD development Panel For Refractory Industry Reports 1991-93*
25. *TRL Krosaki Refractories Ltd. through IRMA*
26. *INTERNATIONAL ENERGY EGENCY, Tracking Industrial Energy Efficiency and CO2 Emissions, In Support of G8 Plan of Action*

x.) Lime Calcinations:

The fuels those are most often burnt in lime kilns are natural gas, heavy fuel oil, pet coke and coal. Some plant also use alternative fuels such as biomass. The temperatures of calcinations as well as heat treatment schedule do change depending on the usage pattern of cacined lime. For example, to retain reactivity of lime for slaking and causticising purpose sintering of the product is undesired whereas for refractory use sintering of the product is desired one. The overall heat energy consumption of a modern kiln operating at or near nominal capacity is typically in the range of 4-7GJ/t of CaO [27]. For common purpose lime is produced at 900-1100^{o}C but for refractory purposes lime may be required to be produced at higher temperature. Examples of lime production in different kilns have been shown in Table 14, which accounts for the use of coal as a fuel. The example of lime production for refractory use in rotary kiln [28] at a temperature of 1300-1350^{o}C has also been included in the table.

Formula for direct coal firing : Coal requirement = (SEC_{coal} x 1000)/ GCV

For producer gas fired kiln (if there), Coal based SEC (i.e., SEC_{coal}) in PG plant has to be considered.

Coal based SEC in PG plant may be calculated as:

$SEC_{coal} = SEC_{kiln} / A$,

Where A = (Percent thermal energy transfer from coal to producer gas)/ 100.

And SEC_{kiln} indicates specific energy consumption in kilns through PG firing, and 'A' is the thermal efficiency factor. If the percentage of coal thermal energy being transferred to producer gas be 70%, then thermal efficiency factor will be 0.7.

Sample calculation:

SEC 4.35 GJ/ton *1000/4.187= 1038.93kcal/kg

1038.93*1000/7150 = 145.3 kg/t

However, it is recommended to adopt the producer gas plant based coal allocation strategies in case lime is calcined through firing of producer gas. This approach will be irrespective of kiln used in calcinations process.

References:

27. *INTERNATIONAL ENERGY EGENCY: Tracking Industrial Energy Efficiency and CO2 Emissions, In Support of G8 Plan of Action, OECD/ IEA, 2007*
28. *DGTD development Panel For Refractory Industry Reports 1991-93*

Table 14: Normative requirement for coal for Lime Calcinations

KILNS	THERMAL SEC, GJ/t			kg of coal/ t of product (calcined lime)													
	RANGE	MV															
	GJ/t	GJ/t	kcal/ kg	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9	G-10	G11	G12	G13	G14
Mixed feed shaft kiln	4-4.7	4.35	1038.9	**145.3**	151.7	158.6	166.2	174.6	183.9	194.2	205.7	218.7	233.5	250.3	269.9	292.7	319.7
Double inclined shaft kiln	4.3	4.3	1027.0	143.6	149.9	156.8	164.3	172.6	181.8	192.0	203.4	216.2	230.8	247.5	266.8	289.3	316.0
Multi chamber shaft kiln	4-4.5	4.25	1015.0	142.0	148.2	155.0	162.4	170.6	179.7	189.7	201.0	213.7	228.1	244.6	263.6	285.9	312.3
Annular shaft kiln	4-4.6	4.3	1027.0	143.6	149.9	156.8	164.3	172.6	181.8	192.0	203.4	216.2	230.8	247.5	266.8	289.3	316.0
Parallel flow regenerative shaft kiln	3.6-4.2	3.9	931.5	130.3	136.0	142.2	149.0	156.5	164.9	174.1	184.4	196.1	209.3	224.4	241.9	262.4	286.6
Other shaft kiln	4.0-5.0	4.5	1074.8	150.3	156.9	164.1	172.0	180.6	190.2	200.9	212.8	226.3	241.5	259.0	279.2	302.7	330.7
Long rotary kiln	6.5-7.5	7	1671.8	233.8	244.1	255.2	267.5	281.0	295.9	312.5	331.1	352.0	375.7	402.9	434.2	470.9	514.4
Grate preheated rotary kiln	5.0-6.1	5.55	1325.5	185.4	193.5	202.4	212.1	222.8	234.6	247.8	262.5	279.1	297.9	319.4	344.3	373.4	407.9
Shaft preheated rotary kiln	4.8-6.1	4.95	1182.2	165.3	172.6	180.5	189.2	198.7	209.2	221.0	234.1	248.9	265.7	284.9	307.1	333.0	363.8
Cyclone preheated rotary kilns	4.6-5.4	5	1194.2	167.0	174.3	182.3	191.1	200.7	211.4	223.2	236.5	251.4	268.4	287.8	310.2	336.4	367.4
Traveling grate kiln	3.7-4.8	4.25	1015.0	142.0	148.2	155.0	162.4	170.6	179.7	189.7	201.0	213.7	228.1	244.6	263.6	285.9	312.3
Gas suspension calcinations	4.6-5.4	5	1194.2	167.0	174.3	182.3	191.1	200.7	211.4	223.2	236.5	251.4	268.4	287.8	310.2	336.4	367.4
Fluidised bed kiln	4.6-5.4	5	1194.2	167.0	174.3	182.3	191.1	200.7	211.4	223.2	236.5	251.4	268.4	287.8	310.2	336.4	367.4
Rotary kiln (Refractory use)			1460	204.2	213.1	222.9	233.6	245.4	258.4	272.9	289.1	307.4	328.1	351.8	379.2	411.3	449.2

Table 14(contd.): Normative requirement for coal for Lime Calcinations

	SEC range	SEC MV	SEC	kg of coal/ t of product (calcined lime)		
	GJ/t	GJ/t	kcal/ kg	G-15	G-16	G-17
Mixed feed shaft kiln	4-4.7	4.35	1038.9	352.2	392.0	442.1
Double inclined shaft kiln	4.3	4.3	1027.0	348.1	387.5	437.0
Multi chamber shaft kiln	4-4.5	4.25	1015.0	344.1	383.0	431.9
Annular shaft kiln	4-4.6	4.3	1027.0	348.1	387.5	437.0
Parallel flow regenerative shaft kiln	3.6-4.2	3.9	931.5	315.7	351.5	396.4
Other shaft kiln	4.0-5.0	4.5	1074.8	364.3	405.6	457.3
Long rotary kiln	6.5-7.5	7	1671.8	566.7	630.9	711.4
Grate preheater rotary kiln	5.0-6.1	5.55	1325.5	449.3	500.2	564.1
Shaft preheater rotary kiln	4.8-6.1	4.95	1182.2	400.8	446.1	503.1
Cyclone preheatwer rotary kilns	4.6-5.4	5	1194.2	404.8	450.6	508.2
Traveling grate kiln	3.7-4.8	4.25	1015.0	344.1	383.0	431.9
Gas suspension calcinations	4.6-5.4	5	1194.2	404.8	450.6	508.2
Fluidised bed kiln	4.6-5.4	5	1194.2	404.8	450.6	508.2
Rotary kiln (Refractory use)			1460	494.9	550.9	621.3

xi.) Manufacturing of Tea:

Energy is a critical input for tea manufacture. Thermal energy is required to remove the moisture from the green leaf as well as fermented tea, whereas critical energy is required at almost all stages of unit operations.

The process of tea manufacturing consists of different energy intensive units operations viz. withering, processing (rolling/CTC cuts), fermentation, drying, shifting and packaging. These make huge of three different forms of energy i.e. electrical, thermal and human. More than 80% of the energy required is thermal energy to remove moisture from tea during withering and drying. Normally, every kg of made tea requires 3.5 to 6.0 kWh of thermal energy, 0.21-0.5 kWh of electrical energy and 0.11 kWh of manpower depending on the method [29].

Specific thermal energy – withering [1.04 kWh/kg] for orthodox and CTC, drying process 3.24-5.0 kWh/kg of tea [30]. Depending on the installation of dryer ECP dryer efficiency 36% whereas it is 54% in FBD technology of dryer for tea industries for drying. For withering and drying operation the actual energy consumption varies from 4 to 7 kWh. This depends on various process parameters and regional climate sectors. The specific energy consumption is varies from 4-10.4 kWh/kg of tea [31].

Specific thermal energy consumption for withering and drying for various methods of tea manufacture [32].

CTC: withering –0.005 kWh/kg, Drying-5.900 kWh/kg
Orthodox: withering 0.010 kWh/kg, drying-4.700 kWh/kg
Dual: withering 0.850 kWh/kg, drying 5.610 kWh/kg

In Tea industry thermal energy is required to remove the moisture from the green leaf as well as fermented tea, whereas electrical energy energy is required at almost all stages of unit operations viz withering, processing, fermentation, drying, packing etc.

The two methods of tea manufacture are Orthodox method and CTC method. Orthodox is a traditional method in which the green leaves are first withered, twisted gradually by the slow rolling process, then fermented and dried. CTC method is a high volume process. In this, the withered leaves suffer more severe cutting to strong liquors, then fermented and dried.

Thermal energy contributes about 88-92% of the total energy consumption in tea factories. Thermal energy requires in tea industry depend on efficiency of hot air generator and also depends on the efficiency or type of dryer. Depending on efficiency of hot air generator the coal consumption varies .The efficiency of normal ECP dryer is 36% but efficiency of fluidized bed dryer is 54%.The specific thermal energy consumption for the withering operation in India is about 1.04 KWh/kg for orthodox tea while it is about 0.59 KWh/kg for CTC tea. The drying process has a specific thermal energy consumption of about 3.24-5.00 KWh/kg of made tea. Some factories produce both Orthodox and CTC tea using dual type processing. The dryer exhaust is used for the withering operation. The thermal efficiency of the dual process is higher than the CTC process probably due to the use of FBD. Electrical energy required for processing Tea is 0.58-0.8 KWh/kg. Electricity is used mainly for running the machineries and small fraction is used for lighting [30, 31, 33].

Table 15: Normative requirement of coal for tea industry (Category: Orthodox)
Basis: Thermal Energy 5.76Kwh/kg, assuming overall efficiency 25.2% (including hot air generator efficiency 70% and dryer efficiency 36%), ECP Dryer efficiency 36%, FBD Dryer efficiency 54%

Hot Air Generator Efficiency								
	60%		65%		70%		75%	
	ECP	FBD	ECP	FBD	ECP	FBD	ECP	FBD
	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg
G-1	0.81	0.54	0.74	0.50	**0.69**	**0.46**	0.64	0.43
G-2	0.84	0.56	0.78	0.52	0.72	0.48	0.67	0.45
G-3	0.88	0.59	0.81	0.54	0.75	0.50	0.70	0.47
G-4	0.92	0.61	0.85	0.57	0.79	0.53	0.74	0.49
G-5	0.97	0.65	0.89	0.60	0.83	0.55	0.77	0.52
G-6	1.02	0.68	0.94	0.63	0.87	0.58	0.82	0.54
G-7	1.08	0.72	0.99	0.66	0.92	0.62	0.86	0.57
G-8	1.14	0.76	1.05	0.70	0.98	0.65	0.91	0.61
G-9	1.21	0.81	1.12	0.75	1.04	0.69	0.97	0.65
G-10	1.29	0.86	1.19	0.80	1.11	0.74	1.04	0.69
G-11	1.39	0.93	1.28	0.85	1.19	0.79	1.11	0.74
G-12	1.50	1.00	1.38	0.92	1.28	0.85	1.20	0.80
G-13	1.62	1.08	1.50	1.00	1.39	0.93	1.30	0.87
G-14	1.77	1.18	1.64	1.09	1.52	1.01	1.42	1.22
G-15	1.95	1.30	1.80	1.20	1.67	1.12	1.56	1.35
G-16	2.17	1.45	2.01	1.34	1.86	1.24	1.74	1.50
G-17	2.45	1.63	2.26	1.51	2.10	1.40	1.96	1.69

For ECP dryer:

Coal requirement in kg/kg= SEC in kcal/kg/GCV

SEC kwh/kg*3600/4.2= SEC in kcal/kg

5.76 (kwh/kg)*3600/4.2= 4937 kcal/kg

Coal requirement in kg/kg= SEC (kcal/kg) /GCV

= 4937/7150 = 0.69 kg/kg

For FBD dryer:

Conversion factor to convert ECP to FBD dryer =36/54

Coal requirement in kg/kg = [SEC (kcal/kg) /GCV]*[36/54]

(4937/7150)*(36/54) = 0.46 kg/kg

Table 16: Normative requirement of coal for tea industry (Category: CTC)
Basis: Thermal Energy 5.25Kwh/kg, assuming overall efficiency 25.2% (including hot air generator efficiency 70% and dryer efficiency 36%), ECP Dryer efficiency 36%, FBD Dryer efficiency 54%

Hot Air Generator Efficiency								
	60%		65%		70%		75%	
	ECP	FBD	ECP	FBD	ECP	FBD	ECP	FBD
	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg
G-1	0.73	0.49	0.68	0.45	0.63	0.42	0.59	0.39
G-2	0.77	0.51	0.71	0.47	0.72	0.44	0.61	0.41
G-3	0.80	0.53	0.74	0.49	0.75	0.46	0.64	0.43
G-4	0.84	0.56	0.78	0.52	0.79	0.48	0.67	0.45
G-5	0.88	0.59	0.81	0.54	0.83	0.50	0.71	0.47
G-6	0.93	0.62	0.86	0.57	0.87	0.53	0.74	0.50
G-7	0.98	0.65	0.91	0.60	0.92	0.56	0.79	0.52
G-8	1.04	0.69	0.96	0.64	0.98	0.59	0.83	0.55
G-9	1.11	0.74	1.02	0.68	1.04	0.63	0.88	0.59
G-10	1.18	0.79	1.09	0.73	1.11	0.67	0.94	0.63
G-11	1.27	0.84	1.17	0.78	1.19	0.72	1.01	0.67
G-12	1.36	0.91	1.26	0.84	1.28	0.78	1.09	0.73
G-13	1.48	0.99	1.37	0.91	1.39	0.85	1.18	0.79
G-14	1.77	1.08	1.49	0.99	1.52	0.92	1.29	0.86
G-15	1.95	1.19	1.64	1.10	1.67	1.02	1.42	0.95
G-16	2.17	1.32	1.83	1.22	1.86	1.13	1.58	1.06
G-17	2.45	1.49	2.06	1.37	2.10	1.28	1.79	1.19

References:

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xii.) Fine Ceramics Industries:

The energy requirement for the manufacturing of fine ceramics products viz. sanitary ware Tiles and porcelain items, etc varies in a broad range. The energy related issues in this sector is a complicated subject and energy requirement depends on capacity, kiln type, kiln design schedule for thermal treatment, cooling schedule, etc. which again depends on ordered quality specifications , production rate specified product and many other factors. Energy input in a particular unit also depends on the adopted heat recovery techniques. Like refractory industry, energy requirement range for a particular product is also broad and therefore it needs to be divided into various categories depending on the kiln type, capacity, production rate, firing temperature/firing schedule etc. As a matter of fact innumerable options are there and it is impossible to address all possible options. Keeping the above in view attempts have been made to consider so many categories for various production techniques in relation to different kinds of products. The values of specific energy consumption (SEC) have been taken from available literatures [34-37] and these have been incorporated in Table 17. The grade wise coal requirements for those categories have been tabulated in Table 17. In these tables only producer gas based firing has been taken in to account. The conversion efficiency, i.e., percent conversion of coal heat into producer gas heat has been considered to be 55% (i.e., thermal efficiency factor is 0.55) in all the examples shown in the table. Direct coal firing in this sector is very rare. However, that may be calculated based on the following formula.

Formula for direct coal firing:
Coal requirement in kg of coal/tons of product= (SEC_{coal} x 1000)/ GCV,
Where SEC coal is coal based specific energy consumption in kcal/kg.

For producer gas fired kilns the above mentioned formula will also be used, where coal based SEC (i.e., SEC_{coal}) in PG plant has to be considered. In that case coal based SEC in PG plant may be calculated as:

$SEC_{coal} = SEC_{kiln} / A$, where SEC_{kiln} indicates specific energy consumption in kilns through PG firing, ‘A’ is the thermal efficiency factor. The thermal efficiency factor ‘A’ may be calculated as
A = (Percent thermal energy transfer from coal to producer gas)/ 100.

Sample calculation:

SEC PG based for floor tiles 2900 kcal/kg, A=0.55

2900 /0.55 = 5272.72 kcal/kg

5272.72*1000/7150 = 737.4 kg/ton

‘SEC kiln’ has been indicated as ‘PG based SEC’ in the Table 17.

The categories mentioned in the table are broad based examples only for some common categories for which data are available. For other categories requirements will have to calculate using the above mentioned formula. Moreover, it will be prudent to take decisions for coal allocation based on operation of PG plants which are utilized to serve different kilns/ furnaces operating in a plant. The coal requirement based on producer gas plant operation has been discussed in chapter 2.

References:

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Table 17: Specific energy consumption for different categories of fine ceramics production

Sl No.	Different categories	Fuel/ SEC range	Temp	Thermal SEC, Avg value	
			oC	PG based	Coal based
				kcal/kg	kcal/kg
	Firing				
1	Floor Tile, TK, 20-30 min	PG, 2300-3500 kcal/kg	1250-1300	2900	5272.7
2	Floor Tile, RHK, 80 min	PG, 1200-1400 kcal/kg	1250-1300	1300	2363.6
	Wall tiles, TK, 20-30h	PG, 1500-2500 kcal/kg	1060-1150	2000	3636.4
4	Wall tiles, RHKK, 0.5h	PG, 500-600 kcal/kg	1060-1151	550	1000.0
5	Sanitary ware, TK, 20-30h firing time	PG, 5000-7000 kcal/kg	1220-1250	6000	10909.1
6	Sanitary ware, Conv TK , 16-24 h firing time, 10-50 tpd	PG, INDIRECT HEATING, 2500-4000kcal/ kg	1200-1280	3250	5909.1
7	Sanitary ware, Conv TK , 16-24 h firing time, 10-50 tpd	PG, 1600-2200kcal/ kg	1200-1280	1900	3454.5
8	Sanitary ware, MODERN TK-FIBRE LINED , 10-18 h firing time, 10-50 tpd	PG, 1000-1600kcal/ kg	1230-1260	1300	2363.6
9	Sanitary ware, RHK , 8-10 h firing time, 10-30 tpd	PG, , 750-1000kcal/ kg	1230-1260	875	1590.9
10	Sanitary ware, RHK , 8-12 h firing time, .8-1 tph	PG, 3500-5000 kJ/kg	1230-1260	1015	1845.5
11	Sanitary ware, SK , 12-23 h firing time, 1-15 tpc	PG, 2200-2500kcal/ kg	1180-1260	2350	4272.7
	Biscuit firing				
12	Table ware, TK, 20-30h	PG, 2500-4000 kcal/kg	800-1000	3250	5909.1
13	Table ware, RHK, 2h	PG, 1500-2500 kcal/kg	800-1000	2000	3636.4
14	Porcelain, 0.3-0.7 tph, TK	PG, 25000 kJ/kg	850-1260	5975	10863.6
	Glost firing				
15	Porcelain, conventional TK, firing time-24-30h, 2.5-10 tph	PG, 5500-7500 kcal/kg	1400	6500	11818.2
16	Porcelain, RHK, firing time-3-4h, 2.5-10 tph	PG, 1800-2500 kcal/kg	1400	2150	3909.1
17	Porcelain, SK, firing time-16-24h, 0.3-4 tpd	PG, 6000-8000 kcal/kg	1400	7000	12727.3
18	Porcelain, SK, glost fast	PG, 12500-19700 kJ/kg	1420	3850	7000.0
19	Porcelain, Fast firing with top burners, sled kiln, 2.5-4h, 1-6 tpd	PG,3000-4000 kcal/kg	1400	3500	6363.6
20	Table ware, TK, 30-40h	PG, 5000-7000 kcal/kg	1250-1350	6000	10909.1
21	Table ware, RHK, 4h	PG, 3000-4000 kcal/kg	1250-1350	3500	6363.6
	Once fired products(Tiles)				
22	Once fired tiles, TK	PG, 5400-6300, kJ/kg		1400	2545.5
23	Once fired tiles, RHK	PG, 1900-4800, kJ/kg		800	1454.5

Table 17 (contd.): Grade wise coal requirement for different categories of fine ceramics production as per Table TFC

	Coal requirement kg of coal/ton of product																
	G-1	**G-2**	**G-3**	**G-4**	**G-5**	**G-6**	**G-7**	**G-8**	**G-9**	**G-10**	**G11**	**G12**	**G13**	**G14**	**G15**	**G16**	**G17**
1	**737.4**	769.7	805.0	843.6	886.2	933.2	985.6	1044.1	1110.0	1184.9	1270.5	1369.5	1485.3	1622.4	1787.4	1989.7	2243.7
2	330.6	345.1	360.9	378.2	397.2	418.3	441.8	468.0	497.6	531.2	569.6	613.9	665.8	727.3	801.2	891.9	1005.8
3	508.6	530.9	555.2	581.8	611.2	643.6	679.7	720.1	765.6	817.2	876.2	944.5	1024.3	1118.9	1232.7	1372.2	1547.4
4	139.9	146.0	152.7	160.0	168.1	177.0	186.9	198.0	210.5	224.7	241.0	259.7	281.7	307.7	339.0	377.4	425.5
5	1525.7	1592.6	1665.5	1745.5	1833.5	1930.8	2039.1	2160.2	2296.7	2451.5	2628.7	2833.5	3073.0	3356.6	3698.0	4116.6	4642.2
6	826.4	862.6	902.2	945.5	993.1	1045.9	1104.5	1170.1	1244.0	1327.9	1423.9	1534.8	1664.5	1818.2	2003.1	2229.8	2514.5
7	483.2	504.3	527.4	552.7	580.6	611.4	645.7	684.1	727.3	776.3	832.4	897.3	973.1	1062.9	1171.0	1303.6	1470.0
8	330.6	345.1	360.9	378.2	397.2	418.3	441.8	468.0	497.6	531.2	569.6	613.9	665.8	727.3	801.2	891.9	1005.8
9	222.5	232.2	242.9	254.5	267.4	281.6	297.4	315.0	334.9	357.5	383.4	413.2	448.1	489.5	539.3	600.3	677.0
10	258.1	269.4	281.7	295.3	310.2	326.6	344.9	365.4	388.5	414.7	444.7	479.3	519.8	567.8	625.6	696.4	785.3
11	597.6	623.8	652.3	683.6	718.1	756.2	798.6	846.1	899.5	960.2	1029.6	1109.8	1203.6	1314.7	1448.4	1612.3	1818.2
12	826.4	862.6	902.2	945.5	993.1	1045.9	1104.5	1170.1	1244.0	1327.9	1423.9	1534.8	1664.5	1818.2	2003.1	2229.8	2514.5
13	508.6	530.9	555.2	581.8	611.2	643.6	679.7	720.1	765.6	817.2	876.2	944.5	1024.3	1118.9	1232.7	1372.2	1547.4
14	1519.4	1585.9	1658.6	1738.2	1825.8	1922.8	2030.6	2151.2	2287.1	2441.3	2617.7	2821.7	3060.2	3342.7	3682.6	4099.5	4622.8
15	1652.9	1725.3	1804.3	1890.9	1986.2	2091.7	2209.0	2340.2	2488.0	2655.8	2847.8	3069.7	3329.1	3636.4	4006.2	4459.7	5029.0
16	546.7	570.7	596.8	625.5	657.0	691.9	730.7	774.1	823.0	878.4	941.9	1015.3	1101.2	1202.8	1325.1	1475.1	1663.4
17	1780.0	1858.0	1943.1	2036.4	2139.0	2252.6	2378.9	2520.3	2679.4	2860.1	3066.8	3305.8	3585.1	3916.1	4314.3	4802.7	5415.9
18	979.0	1021.9	1068.7	1120.0	1176.5	1238.9	1308.4	1386.1	1473.7	1573.0	1686.7	1818.2	1971.8	2153.8	2372.9	2641.5	2978.7
19	890.0	929.0	971.5	1018.2	1069.5	1126.3	1189.5	1260.1	1339.7	1430.0	1533.4	1652.9	1792.6	1958.0	2157.2	2401.4	2707.9
20	1525.7	1592.6	1665.5	1745.5	1833.5	1930.8	2039.1	2160.2	2296.7	2451.5	2628.7	2833.5	3073.0	3356.6	3698.0	4116.6	4642.2
21	890.0	929.0	971.5	1018.2	1069.5	1126.3	1189.5	1260.1	1339.7	1430.0	1533.4	1652.9	1792.6	1958.0	2157.2	2401.4	2707.9
22	356.0	371.6	388.6	407.3	427.8	450.5	475.8	504.1	535.9	572.0	613.4	661.2	717.0	783.2	862.9	960.5	1083.2
23	203.4	212.3	222.1	232.7	244.5	257.4	271.9	288.0	306.2	326.9	350.5	377.8	409.7	447.6	493.1	548.9	619.0

xiii.) Rolling Mill:

Most of the rolling mills in India are small and medium enterprises (SMEs); with output capacities in the range of 5 to 15 tons/ hr. Thermal energy is required for the reheating furnaces of rolling mills, which generally consume furnace oil for reheating steel billets/ ingots. As a matter of fact direct coal fired furnaces are rarely in existence. Furnace oil (FO) consumption of the reheating furnaces would be in the range of 200 to 750 liters/ hr [38]. As a substitute of furnace oil coal based producer gas may be utilized as fuel for reheating furnace. Therefore assessment of coal requirement in the respective producer gas plant should preferably be the basis for coal assessment. Assessment of normative quantities of coal in producer gas plants have been detailed in chapter 2.

As per the Indian condition in respect of furnace efficiency, the furnace oil consumption per ton of product steel can be rationally considered to be in the range of 40- 50 lit/ t of product steel. In such case CV of FO is considered to be around ~10000 kcal/lit as per Furnace oil (FO) specification sheet of Indian oil Corporation Ltd. which follows IS: 1593-1982 [39]. As per the available literature [38], if this FO is substituted by coal based gaseous fuel average coal heat required in gasification unit to replace 1 lit FO consumption is 13675 kcal). Here, around 73% of coal heat has been considered to be utilized in the re-heating furnace through gas burning. In the Indian context average coal based specific energy consumption (SEC_{coal}) per ton of steel production has been derived to be 615.38 kcal/ kg based on the average furnace oil consumption, i.e., 45 lit FO / t of product steel. Based on the above SEC_{coal} value, grade wise coal quantity for reheating furnace of rolling mill have been evaluated and those have been incorporated in Table 18.

The normative quantities of coals of different grades have been evaluated using following formula.

Formula:

Coal requirement in kg/ton of product steel= (SEC_{coal} x 1000)/ GCV

Where SEC_{coal} represents actual coal based specific energy consumption in kcal/kg.

In case of any deviation from the above mentioned SEC_{coal}, the coal quantity may be evaluated using the above mentioned formula.

When SEC of reheating furnace is obtained based on producer gas firing, then SEC coal may be derived using the following relationship:

SEC coal = SEC furnace/A,

Where ‘A’ is thermal efficiency factor of producer gas plant.

and ‘A’ = (Percent thermal energy transfer from coal to producer gas)/ 100.

i.e. if thermal efficiency of producer gas plant i.e. % coal heat being transferred to producer gas plant i.e. % coal heat being transfer to producer gas heat be 70%, then thermal efficiency factor ‘A’ = 0.7.

For producer gas fired rolling mill, the best practice guideline is to follow the methodology of assessment based on producer gas plant which has been described in chapter 2.

Sample calculation:

SEC = 615.38 kcal/kg

615.38*1000/7150 = 86.1 kg/t

Table 18: Normative requirement of coal for reheating furnaces of rolling mills

[Basis: SEC Thermal, coal based = 615.38 kcal/kg of product steel]

Coal grade	**GCV**	**coal requirement**
	kcal/ kg of coal	**kg of coal/ t of product steel**
G-1	7150	**86.1**
G-2	6850	89.8
G-3	6550	94.0
G-4	6250	98.5
G-5	5950	103.4
G-6	5650	108.9
G-7	5350	115.0
G-8	5050	121.9
G-9	4750	129.6
G-10	4450	138.3
G-11	4150	148.3
G-12	3850	159.8
G-13	3550	173.3
G-14	3250	189.3
G-15	2950	208.6
G-16	2650	232.2
G-17	2350	261.9

References:

38. *"Gasification technology for substitution of furnace oil in reheating furnaces of rolling mills", by B. V. Ravikumar, Director Cosmo Powertech Pvt. Ltd. , Email: cosmo_powertech@yahoo.co.in*
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xiv.) Brick Industry:

The process of manufacturing of brick also has not undergone much change over centuries across the world. Despite the initiation of other type building and walling materials such as earth block, concrete block, stone concrete, stone block, fly ash brick etc burnt clay bricks still occupy the dominant position in India. Specific fuel consumption, in terms of tons of fuel consumed for firing one lakh bricks is the popular way of expressing performance of brick kiln in India. The mode of expressing performance in this manner may be of interest to brick manufacturers, however it is difficult to compare performance of brick kilns on this basis, because the varying weight of fired bricks may vary from about 2 kg to 3.75 kg in India and also the difference in quality and hence calorific values of various fuels used for firing bricks.

Bricks are produced in big scale unit and several small scale units. Several kiln types are used for firing of brick throughout the India and the manufacturing processes are basically kiln based. VSVK is about 20 percent more efficient than BTK and 50 percent more efficient than clamps. Specific energy consumption per kg of bricks varies depending on the technology/ kiln type, plant capacity, firing schedule, etc. Some indicative figures on specific energy consumptions are given below [40-42].

Type of Kiln	Specific Fuel consumption (MJ/kg)
VSBK	0.76-1.14
BTK	1.1-1.6
TUNNEL	1.2-2.5
CLAMP	1.2-1.75
Zig-Zag	0.8-1.1

Table 19: Normative requirement of coal for Brick Industry

Type	VSVK	BTK	Tunnel	Clamp	Zig-Zag
SEC (thermal) → MJ/kg	**0.95**	**1.35**	**1.85**	**1.47**	**0.95**
Coal Req. →	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**
Grade ↓					
G-1	**31.64**	44.96	61.61	48.95	31.64
G-2	33.02	46.92	64.30	51.09	33.02
G-3	34.53	49.07	67.25	53.44	34.53
G-4	36.19	51.43	70.48	56.00	36.19
G-5	38.02	54.02	74.03	58.82	38.02
G-6	40.03	56.89	77.96	61.95	40.03
G-7	42.28	60.08	82.33	65.42	42.28
G-8	44.79	63.65	87.22	69.31	44.79
G-9	47.62	67.67	92.73	73.68	47.62
G-10	50.83	72.23	98.98	78.65	50.83
G-11	54.50	77.45	106.14	84.34	54.50
G-12	58.75	83.49	114.41	90.91	58.75
G-13	63.72	90.54	124.08	98.59	63.72
G-14	69.60	98.90	135.53	107.69	69.60
G-15	76.67	108.96	149.31	118.64	76.67
G-16	85.35	121.29	166.22	132.08	85.35
G-17	96.25	136.78	187.44	148.94	96.25

The normative requirement of coal for brick industry may be calculated using the following formula:

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in MJ/kg*1000/4.2 = SEC in kcal/kg

0.95*1000/4.2= 226.19 kcal/kg

226.19*1000/7150= 31.64 kg/ton

References:

40. *Manual & Information's Brochure, Article on Brick.*
41. *Inter Disciplinary Programme in Energy System, IIT, Bombay.*
42. *Energy Conservation & Pollution Control in Brick, TERI.*

xv.) SSF Unit:

The primitive process of soft coke making is replaced by a mechanized process for conversion of conventional coals to domestic coke. The process not only minimizes air pollution but also recovers the valuable by-product tar. The product from this process burns with less smoke and is called as special smokeless fuel (SSF). Inferior grade of weakly caking coal (caking index 8-14), washery grade IV, coking coal middling are the raw material used for Special Smokeless Fuel .The coal requirement for one tone of SSF production is in the range 1.2-1.85 ton [43] .
There are three grades of SSF.

Table 20: Draft standards for solid smokeless fuel

Characteristics		**Required for**		
		Gr1	Gr 2	Gr. 3
VM (wt %)	Min	6	6	6
	Max	12	12	12
Moisture		6	6	6
Total Inert material (Ash) wt%		Up to 30	Over 30 and up to 40	Over 40 and up to 50
CV kcal/kg		>5510	4510-5510	3500-4500

The approximate CV of washery grade (IV) is 5640 kcal/kg; Semi coking coal 6020-6885 kcal/kg and Coking coal middling is 4000-4500 kcal/kg. For grade 1, SSF prepared from washery grade (IV) and Semi coking coal, the requirement of coal for one tonne of SSF production is in the range 1.2-1.4 tonne and for Grade 2 and Grade 3 SSF prepared from coking coal middling, the requirement of coal for one tonne of SSF production is 1.4-1.85 ton.

Table 21: Normative requirement of coal for SSF Industry

t/t		
1.2-1.85	Weakly-/Semi- Coking Coal (coking index 8-14), Washery Grade IV, Coking coal middling	

Ref: 43. Evaluation of coal Briquettes and SSF as domestic Fuels: A systems approach Tata Energy Research Institute.

xvi.) Food processing Industry:

Due to the wide range of processes and products, benchmarking of energy usage in the food industry is difficult. The different food products are pickle, fruit juice, sauce, vinegar, jelly, gluton, fiber, glucose, dextrose, milk powder, milk products etc. Depending on variety of products and thermal energy consumption the total products are divided in five groups Pickle, sauce, jelly, vinegar, kasundi etc in one group, Concentrated fruit juice in one group, vegetable and other food products like gluton, glucose, dectrose etc in one group, milk products like butter, cheese in one group and milk powder in other group. From Industry visit it is found that the thermal energy consumption of concentrated fruit choose is very high compared to ordinary fruit juice, pickle, sauce, jelly etc. Because of this concentrated fruit juice is kept in group B. Similarly thermal energy consumption of milk powder is very high compare to other milk products like cheese, ghee, butter etc. The milk powder is kept in other group than milk products. The unit operation which consumes thermal energy for food processing are drying, extraction, fermentation, neutralization, hydrolysis, cooking, crystralization, pasteurization, steaming etc. The thermal energy consumption varies widely. For pickle, sauce, vinegar, fruit juice, kasundi etc. the average thermal energy requirement is 1470 kJ/kg and for concentrated fruit juice it is 4800 kJ/kg. For vegetable and other food products like gluton, glucose, dextrose, starch, germ etc the average figure of required thermal energy is 3570 kJ/kg. For milk products thermal energy varies widely. For milk products like butter, cheese etc the average thermal energy consumption is 2000 kJ/kg, whereas for milk powder the average thermal energy requirement is 9000 kJ/kg [44, 45].

The following table (Table 22) shows the normative quantity for different categories under this sector. Average thermal specific energy consumption figures considered for this evaluation has also been mentioned in the table.

Table 22: Normative requirement of coal for food processing industry

Category	A	B	C	D	E
SEC Thermal kJ/kg →	**1470**	**4800**	**3570**	**2000**	**9000**
Coal Req. →	**kg/t**	**kg/t**	**kg/t**	**kg/t**	**kg/t**
Grade ↓					
G-1	**48.95**	159.84	118.88	66.60	299.70
G-2	51.09	166.84	124.09	69.52	312.83
G-3	53.44	174.48	129.77	72.70	327.15
G-4	56.00	182.86	136.00	76.19	342.86
G-5	58.82	192.08	142.86	80.03	360.14
G-6	61.95	202.28	150.44	84.28	379.27
G-7	65.42	213.62	158.88	89.01	400.53
G-8	69.31	226.31	168.32	94.30	424.33
G-9	73.68	240.60	178.95	100.25	451.13
G-10	78.65	256.82	191.01	107.01	481.54
G-11	84.34	275.39	204.82	114.74	516.35
G-12	90.91	296.85	220.78	123.69	556.59
G-13	98.59	321.93	239.44	134.14	603.62
G-14	107.69	351.65	261.54	146.52	659.34
G-15	118.64	387.41	288.14	161.42	726.39
G-16	132.08	431.27	320.75	179.69	808.63
G-17	148.94	486.32	361.70	202.63	911.85

A-PICKLE, FRUIT JUICE. KASUNDI, JELLIES, SAUCE, VINEGAR ETC
B-Concentrated fruit juice
C-Vegetable and other food products (gluto, fibre, starch, germ, liquid glucose, dextrose, mono-hydrate etc)
D-Milk products (Butter, cheese, concentrated milk etc)
E-Milk powder

However, based on the technology based SEC consumption figure this may be calculated using the following equation.

The normative requirement of coal for food processing industry may be calculated using the following formula:

Coal requirement in kg/ton = SEC (kcal/kg)*1000/ GCV

SEC in KJ per kg/4.2 = SEC in kcal/kg

1470/4.2= 350 kcal/kg

350*1000/7150= 48.95 kg/ton

Finally, considering the technology dependent or raw material dependent SEC variation etc, it is recommended to consider boiler operational data for assessment of normative quantity of coal for an industry. The methodology has been included in chapter 2.

Reference:

44. Theoretical Energy Calculation for food processing under South African condition, School of Bio-resources, Engineering & Environmental Hydrology, of Kwazulu, South Africa.
45. Comparison of Energy usage data in Dairy Processing, FOPREH database.

Chapter: 2

In this Chapter three basic units have been considered:

i) Steam Generation in Boiler/ Coal based boilers

ii) Coal based producer gas

iii) Hot Air Generator.

Coal based boiler may serve one of the three purposes viz., electricity generation, steam generation for process heat in several industries and combined heat cum power generation. Therefore boiler application is not only limited to power generation but also it serves lots of industrial sectors through the supply of process steam as a source of thermal energy required for respective industrial processes.

Similarly, coal based producer gas plants serves many industries like glass, refectories, fine ceramics, lime calcinations, etc. In these industries producer gas plants are commonly considered to be the basic unit of utilization of coal to yield producer gasses for kiln firing.

Hot air generator of another basic unit applicable for tea industries, drying of food grains etc., where coal is actually consumed to generate hot air. This hot air acts as the source of heat for several industrial processes as mentioned above.

This chapter is very much important because any one of those three basic units is practically the coal consuming units. Therefore product based assessments, considering the product manufacturing equipment (or furnaces), should not be the primary mode of estimation of normative quantity of coal, particularly in those cases where alternative assessment is possible through consideration of basic units.

The basic unit based assessment is preferred because of following reasons:

a.) It considers the actual coal utilization units of a plant instead of the units which utilize energy through steam, hot air or producer gas firing. Therefore assessments based on actual coal consuming units appear to be more reliable, authentic and realistic (because of this fact these three units have been designated here as the basic units).

b.) Product manufacturing may take the help of fuels other than coal as a source of thermal energy, e.g., natural gas, LPG, furnace oil etc., may be used instead of coal based producer gas.

c.) Sometimes variation in specific energy consumption (SEC) in respect of a particular product/ or technology/ technique is large due to various reason. It happens even with best available technology (BAT) in the market. Therefore assessment based on product type/ production technology/ production process, etc. may sometimes be far away from the reality.

d.) There are plants, where actual SEC does not fall within the normal range of specific energy consumption. This may be due to the product specialty, in terms of size, shape, product design, ordered specification and desired special property development. Such outliers SEC figures are observed very often for which generalized assessment as focused in chapter 1 of this report is not applicable.

e.) Example tables given in chapter1 for different industrial sectors are true for certain efficiency factor mentioned there. For some other efficiency factors the numbers in the table will change. In case of change of efficiency factor it has to be calculated based on the formula mentioned in respective sectors. However, consideration of basic unit may consider number of efficiency factors (may be variation of other parameter also) in a single example-table. Therefore base example table are broad based in case of basic units.

f.) From the basic unit based examples-tables it is easier to realize the variation depending on the efficiency factor(s).

g.) Given a system, technology as well as a product type, SEC in several industries may vary because it is reported on finished product and quantity of finished product in a lot depends on the rejections. Percent rejection is a variable in many industries it depends on the acceptable allowance in ordered specification, consistency in raw material quality, selection of proper time temperature schedule, kiln performance, human errors, unforeseen reasons etc. Therefore if the coal quantity assessment be switched over to basic unit based approach such uncertain factors may be avoided.

h.) Co-fuel application (e.g., ‘producer gas in combination with natural gas’ or ‘biomass in combination with coal’) is very much common in many industries. In such cases contribution of coal to meet total process-energy requirement is uncertain and therefore is very difficult to calculate the normative coal requirement unless the estimation methodology be based on basic unit(s) consuming coals.

i.) Change in product pattern in an industrial set up in a year is also a factor of uncertainty. Because sometimes clear picture of current year’s production pattern may not be predictable from past few years' statistics. Therefore coal allocation through product/ process based approach is complicated for such multi product set up. In such cases, the determination of normative coal requirement may be simplified if basic unit based approach is followed.

j.) In some sector, large variations of product quality vis-à-vis production strategies are possible for a single product type and it is virtually impossible to handle all those on case to case basis. Hundreds of subcategories for the products under a certain industrial sector may be possible, indications of which have been given in several example-tables of chapter 1. It is not at all possible to include everything followed in India in example-tables and that level of detailing is not also available in published literature/ document. It may be simplified if attempts are made to get the estimate on normative coal requirement through consideration of basic unit(s) to the extent possible.

k.) Inadequacies and gaps are often there in published SEC data to cover up all the product/ technology/ process based sub categorization for many sectors. Incompleteness in SEC data (e.g., conditions / relevant details not mentioned) is sometimes very much evident in the literature documents. Under this scenario it will be prudent to prefer basic unit based approach for assessment of coal requirement for the industrial sectors.

l.) In industrial production practices there is possibility of out sourcing of process steam, producer gas, etc. Therefore in case of procuring the process heat-supply from other nearby industries the production based assessment (of coal requirement) for product manufacturing unit has got no meaning.

Keeping all in view this report emphasizes on preferring the basic unit-based approach for assessment of normative coal quantity where it can be assessed through both way approach.

In the following sections the above mentioned basic units have been addressed. The basic units may also be treated as independent unit on case to case basis. Apart from delivering process steam different kinds of boilers may be linked to electricity production. Again as per the defined activities of this project producer gas plant was also considered to be the discrete plant.

The production capacity - production-technology- production technique based assessment (as described in Chapter 1 for different sectors) are also important for cross checking purpose and also for some unique cases when industrial criteria suitably fits with the example table/ estimation methodology.

i) Steam Generation in Boiler:

Many industries use boiler to generate process steam only. The industries falling under this category are Fertilisers, Chemicals and Pharmaceuticals, Paper, Cotton/Textiles, Jute, Rayon, Rubber, Leather works, Match Factories, Food Processing, Vegetable Oil, Sugar, etc. The industries falling under this category use boilers of different type and make including Fluidised Bed Boilers.
While evaluating the grade wise requirement of coal the following formula may be used.

Coal requirement (kg/hr) = $Q^* (H-h_w) / (BE * GCV)$

Q= Quantity .of steam entering into generator (kg/hr)
H= Enthalpy of steam of required temperature & pressure (kcal/kg) (From Steam Table)
h_w = Enthalpy of feed water (kcal/kg)
BE = Efficiency of boiler (%)
GCV = Gross Calorific Value of Coal (kcal/kg)
Enthalpy of steam at 5.1 kg/cm^2 at 152^{o}C = 631.4 kcal/ kg
Enthalpy of steam at 10.2 kg/cm^2 at 180^{o}C = 638 kcal/ kg
Enthalpy of steam at 15.3 kg/cm^2 at 198^{o}C = 641 kcal/ kg
Enthalpy of steam at 20.4 kg/cm^2 at 212^{o}C = 643 kcal/ kg
Enthalpy of feed water = 30 kcal/ kg

Examples of deriving coal requirement for boilers for process steam only
The coal requirement figures for boilers producing process steam only have been summarized in the following Tables as examples. The examples deal with different saturated pressure and temperature and depict coal requirement per annum for one T/hr of process steam production considering 300 days' operation. Examples of worked out values of different examples (as shown in the table) may be used as ready reference. But, it is always preferred to evaluate the normative requirement using formula as stated above and inputs received from particular industry.

Table 23: Normative requirement of coal for steam production

	Coal required per annum for One t/hr of process steam production, B.E. = 65%				
Sat. Pr,	**5.1 kg/sq cm**	**7.5 kg/sq cm**	**10.2 kg/sq cm**	**15.3 kg/sq cm**	**20.4 kg/sq cm**
Temp.	**152^{0}C**	**167^{0}C**	**180^{0}C**	**198^{0}C**	**212^{0}C**
Enthalpy kcal/kg	**654.46**	**658.65**	**661.26**	**664.81**	**666.55**
Grade					
G 1	**968**	974	978	984	986
G 2	1010	1017	1021	1027	1030
G 3	1056	1063	1068	1074	1077
G 4	1107	1114	1119	1125	1128
G 5	1163	1171	1175	1182	1185
G 6	1225	1233	1238	1245	1248
G 7	1293	1302	1307	1315	1318
G 8	1370	1379	1385	1393	1397
G 9	1457	1466	1472	1481	1485
G 10	1555	1565	1572	1581	1585
G 11	1667	1678	1685	1695	1699
G 12	1797	1809	1817	1827	1832
G 13	1949	1962	1970	1981	1987
G 14	2129	2143	2152	2164	2170
G 15	2345	2361	2371	2384	2391
G 16	2611	2628	2639	2654	2661
G 17	2944	2964	2976	2993	3001

Sample calculation:

Coal requirement (kg/hr) = Q* (H-h_w) / (BE *GCV)

Q= Quantity .of steam entering into generator (kg/hr)
H= Enthalpy of steam of required temperature & pressure (kcal/kg) (From Steam Table)
h_w = Enthalpy of feed water (kcal/kg)
BE = Efficiency of boiler (%)
GCV = Gross Calorific Value of Coal (kcal/kg)

Enthalpy of steam (H) at 5.1 kg/cm^2 at 152^{o}C = 654.46 kcal/ kg
Enthalpy of feed water (hw) = 29.85 kcal/ kg
Enthalpy change = (H-hw) kcal/ kg
So, Coal requirement (kg/hr) for 1ton/hr of process steam production= **Q* (H-h_w) / (BE *GCV)**
=1000*(654.45-29.85)/ (0.65*7150)
=134.41
Ton of coal required per annum= 134.41*24*300/1000 = 968

Table 24: Normative requirement of coal for steam production

Coal required per annum for One T/hr of process steam production, B.E. = 70%

	Coal required per annum for One t/hr of process steam production, B.E. = 70%				
Sat. Pr,	**5.1 kg/sq cm**	**7.5 kg/sq cm**	**10.2 kg/sq cm**	**15.3 kg/sq cm**	**20.4 Kg/sq cm**
Temp.	**152^{0}C**	**167^{0}C**	**180^{0}C**	**198^{0}C**	**212^{0}C**
Enthalpy kcal/kg	**654.46**	**658.65**	**661.26**	**664.81**	**666.55**
Grade					
G 1	899	905	908	913	916
G 2	938	944	948	953	956
G 3	981	987	992	997	1000
G 4	1028	1035	1039	1045	1048
G 5	1080	1087	1092	1098	1101
G 6	1137	1145	1149	1156	1159
G 7	1201	1209	1214	1221	1224
G 8	1272	1281	1286	1293	1297
G 9	1353	1362	1367	1375	1379
G 10	1444	1453	1459	1468	1472
G 11	1548	1558	1565	1574	1578
G 12	1669	1680	1687	1696	1701
G 13	1810	1822	1829	1840	1845
G 14	1977	1990	1998	2010	2015
G 15	2178	2192	2202	2214	2220
G 16	2424	2441	2451	2464	2471
G 17	2734	2752	2764	2779	2787

Table 25: Normative requirement of coal for steam production

	Coal required per annum for One t/hr of process steam production, B.E. = 75%				
Sat. Pr,	**5.1 kg/sq cm**	**7.5 kg/sq cm**	**10.2 kg/sq cm**	**15.3 kg/sq cm**	**20.4 kg/sq cm**
Temp.	**152^0C**	**167^0C**	**180^0C**	**198^0C**	**212^0C**
Enthalpy kcal/kg	**654.46**	**658.65**	**661.26**	**664.81**	**666.55**
Grade					
G 1	839	844	848	853	855
G 2	875	881	885	890	892
G 3	915	922	925	931	933
G 4	959	966	970	975	978
G 5	1008	1015	1019	1024	1027
G 6	1061	1068	1073	1079	1082
G 7	1121	1128	1133	1139	1142
G 8	1187	1195	1200	1207	1210
G 9	1262	1271	1276	1283	1287
G 10	1347	1356	1362	1370	1374
G 11	1445	1455	1461	1469	1473
G 12	1557	1568	1574	1583	1588
G 13	1689	1700	1707	1717	1722
G 14	1845	1857	1865	1876	1881
G 15	2033	2046	2055	2066	2072
G 16	2263	2278	2287	2300	2306
G 17	2552	2569	2579	2594	2601

Table 26: Normative requirement of coal for steam production

	Coal required per annum for One t/hr of process steam production, B.E. = 80%				
Sat. Pr,	**5.1 kg/sq cm**	**7.5 kg/sq cm**	**10.2 kg/sq cm**	**15.3 kg/sq cm**	**20.4 kg/sq cm**
Temp.	**152^0C**	**167^0C**	**180^0C**	**198^0C**	**212^0C**
Grade					
Enthalpy kcal/kg	**654.46**	**658.65**	**661.26**	**664.81**	**666.55**
G 1	786	791	795	799	801
G 2	821	826	830	834	837
G 3	858	864	868	872	875
G 4	899	905	909	914	917
G 5	945	951	955	960	963
G 6	995	1002	1006	1011	1014
G 7	1051	1058	1062	1068	1071
G 8	1113	1121	1125	1132	1135
G 9	1183	1191	1196	1203	1206
G 10	1263	1272	1277	1284	1288
G 11	1355	1364	1369	1377	1381
G 12	1460	1470	1476	1484	1488
G 13	1583	1594	1601	1610	1614
G 14	1730	1741	1749	1758	1763
G 15	1906	1918	1926	1937	1942
G 16	2121	2136	2144	2156	2162
G 17	2392	2408	2418	2432	2438

Table 27: Normative requirement of coal for steam production

	Coal required per annum for One t/hr of process steam production, B.E. = 85%				
Sat. Pr,	**5.1 kg/sq cm**	**7.5 kg/sq cm**	**10.2 kg/sq cm**	**15.3 kg/sq cm**	**20.4 kg/sq cm**
Temp.	**152^{0}C**	**167^{0}C**	**180^{0}C**	**198^{0}C**	**212^{0}C**
Enthalpy kcal/kg	**654.46**	**658.65**	**661.26**	**664.81**	**666.55**
Grade					
G 1	740	745	748	752	754
G 2	772	778	781	785	787
G 3	808	813	817	821	823
G 4	847	852	856	861	863
G 5	889	895	899	904	906
G 6	936	943	947	952	955
G 7	989	996	1000	1005	1008
G 8	1048	1055	1059	1065	1068
G 9	1114	1121	1126	1132	1135
G 10	1189	1197	1202	1209	1212
G 11	1275	1283	1289	1296	1300
G 12	1374	1383	1389	1397	1401
G 13	1490	1500	1507	1515	1519
G 14	1628	1639	1646	1655	1659
G 15	1793	1805	1813	1823	1828
G 16	1997	2010	2018	2030	2035
G 17	2251	2266	2276	2289	2295

ii) Normative requirement of coal for Producer Gas plant:

CV of producer gas normally varies from 1000 - 1300 kcal/ Nm^3 [46]. In Indian context, it may be raised maximum up to 1400kcal/ Nm^3. The available documents [46, 47] depict that the heat transferred to producer gas from coal is in the range of 69-76% of coal heat. Considering the performance of producer gas plant in India and inferior grade of coal feeding in producer gas plant as per the information received through industrial visit and expert opinions it may be reasonably opined that the percentage of heat which is transferred from coal to producer gas (i.e. thermal efficiency) may normally vary between 50 and 70%. Specific coal consumption in producer gas plant may be fixed depending on the coal grade, CV of resulted producer gas and the thermal efficiency factor. Accordingly, the figures have been tabulated in Table 28 to decide the specific coal requirement in producer gas (PG) plants. In the table, thermal efficiency has been considered up to 80% although it is very difficult to attain. It may also to be noted that the figures in the table are only examples. If input parameters be outside the domain of the table then the coal requirement will have to be calculated using formula mentioned below.

Coal requirement in producer gas plant may be calculated as :

Coal requirement in kg per m^3 of gas generated (F) =

CV OF PRODUCER GAS IN KCAL PER NM^3/ (COAL CV * EFFICIENCY FACTOR),

Where efficiency factor = efficiency in percent / 100

If monthly gas generation data is known (say ‘P’ m^3),

then the total coal requirement = (F x P)/ 1000 ton

In the units where producer gas plant is the basic unit which actually utilizes coal to produce secondary fuel i.e., producer gas for kiln/ furnace firing, the assessment of coal requirement is recommended to be done on the basis of producer gas plant data.

The producer gas plants use lump coal of size 8-70mm. The coal fines in supply and those generated during coal sizing are rejected. The normative requirement coal mentioned in Table 28 actually means the quantity of coal of specified size range. It is to be taken in to the consideration that the fines are not utilizable in PG Plant.

Sample calculation:

Coal requirement in kg per m^3 of gas generated (F) =

1000 (7150 * 0.50) = 0.28 kg/ m^3 of gas generated

Table 28: Normative requirement of coal by Producer gas plant

coal grades	Coal CV kcal/kg	CV of PG kcal/kg	Coal requirement, kg/ m^3 of gas generated						
			on % coal heat transformed to producer gas heat (efficiency factor)						
			50%	55%	60%	65%	70%	75%	80%
G-1	7150	1000	**0.28**	0.25	0.23	0.22	0.20	0.19	0.17
G-2	6850		0.29	0.27	0.24	0.22	0.21	0.19	0.18
G-3	6550		0.31	0.28	0.25	0.23	0.22	0.20	0.19
G-4	6250		0.32	0.29	0.27	0.25	0.23	0.21	0.20
G-5	5950		0.34	0.31	0.28	0.26	0.24	0.22	0.21
G-6	5650		0.35	0.32	0.29	0.27	0.25	0.24	0.22
G-7	5350		0.37	0.34	0.31	0.29	0.27	0.25	0.23
G-8	5050		0.40	0.36	0.33	0.30	0.28	0.26	0.25
G-9	4750		0.42	0.38	0.35	0.32	0.30	0.28	0.26
G-10	4450		0.45	0.41	0.37	0.35	0.32	0.30	0.28
G11	4150		0.48	0.44	0.40	0.37	0.34	0.32	0.30
G12	3850		0.52	0.47	0.43	0.40	0.37	0.35	0.32
G13	3550		0.56	0.51	0.47	0.43	0.40	0.38	0.35
G14	3250		0.62	0.56	0.51	0.47	0.44	0.41	0.38
G-15	2950		0.68	0.62	0.56	0.52	0.48	0.45	0.42
G-16	2650		0.75	0.69	0.63	0.58	0.54	0.50	0.47
G-17	2350		0.85	0.77	0.71	0.65	0.61	0.57	0.53
G-1	7150	1150	0.32	0.29	0.27	0.25	0.23	0.21	0.20
G-2	6850		0.34	0.31	0.28	0.26	0.24	0.22	0.21
G-3	6550		0.35	0.32	0.29	0.27	0.25	0.23	0.22
G-4	6250		0.37	0.33	0.31	0.28	0.26	0.25	0.23
G-5	5950		0.39	0.35	0.32	0.30	0.28	0.26	0.24
G-6	5650		0.41	0.37	0.34	0.31	0.29	0.27	0.25
G-7	5350		0.43	0.39	0.36	0.33	0.31	0.29	0.27
G-8	5050		0.46	0.41	0.38	0.35	0.33	0.30	0.28
G-9	4750		0.48	0.44	0.40	0.37	0.35	0.32	0.30
G-10	4450		0.52	0.47	0.43	0.40	0.37	0.34	0.32
G11	4150		0.55	0.50	0.46	0.43	0.40	0.37	0.35
G12	3850		0.60	0.54	0.50	0.46	0.43	0.40	0.37
G13	3550		0.65	0.59	0.54	0.50	0.46	0.43	0.40
G14	3250		0.71	0.64	0.59	0.54	0.51	0.47	0.44
G-15	2950		0.78	0.71	0.65	0.60	0.56	0.52	0.49
G-16	2650		0.87	0.79	0.72	0.67	0.62	0.58	0.54
G-17	2350		0.98	0.89	0.82	0.75	0.70	0.65	0.61

G-1	7150	1300	0.36	0.33	0.30	0.28	0.26	0.24	0.23
G-2	6850		0.38	0.35	0.32	0.29	0.27	0.25	0.24
G-3	6550		0.40	0.36	0.33	0.31	0.28	0.26	0.25
G-4	6250		0.42	0.38	0.35	0.32	0.30	0.28	0.26
G-5	5950		0.44	0.40	0.36	0.34	0.31	0.29	0.27
G-6	5650		0.46	0.42	0.38	0.35	0.33	0.31	0.29
G-7	5350		0.49	0.44	0.40	0.37	0.35	0.32	0.30
G-8	5050		0.51	0.47	0.43	0.40	0.37	0.34	0.32
G-9	4750		0.55	0.50	0.46	0.42	0.39	0.36	0.34
G-10	4450		0.58	0.53	0.49	0.45	0.42	0.39	0.37
G11	4150		0.63	0.57	0.52	0.48	0.45	0.42	0.39
G-12	3850		0.68	0.61	0.56	0.52	0.48	0.45	0.42
G-13	3550		0.73	0.67	0.61	0.56	0.52	0.49	0.46
G-14	3250		0.80	0.73	0.67	0.62	0.57	0.53	0.50
G-15	2950		0.88	0.80	0.73	0.68	0.63	0.59	0.55
G-16	2650		0.98	0.89	0.82	0.75	0.70	0.65	0.61
G-17	2350		1.11	1.01	0.92	0.85	0.79	0.74	0.69

References;

46. B. V. Ravi Kumar, Gasification technology for substitution of furnace oil in reheating furnaces of rolling mills, Director Cosmo Powertech Pvt. Ltd. , Email: cosmo_powertech@yahoo.co.in

47. Comprehensive industrial documents for producer gas plants and biomass gasifier, CPCB, Central Pollution Control board, (MoEF), New Delhi, website: www.cpcb.nic.in, email: cpcb@nic.in

iii) Hot Air Generator:

Hot air generators supply air heated to elevated temperature by mixing it with products of combustion from a burner. The hot air generator consists of an inner refractory lined combustion chamber, venture section where hot products of combustion mix with dilution air and outlet section. Hot air at wide range of temperature and pressures is produced for applications like foundry sand drying, drying & processing of ores and minerals, food processing, tea drying, seed drying, paint drying etc. There are two types of hot air generator – directly fired and indirectly fired. Indirect fired hot air generator has temperature limitation up to 400^{o}C. Indirect fired hot air generators do not have any refractory and all internal parts like combustion chambers, heat exchangers are highly reliable with low thermal inertia and have virtually no maintenance. Indirect fired are used for the application where clean hot process air is recovered for the drying such as food processing, paint, chemicals etc. Hot air generators are fully automatic and run on coal, gas oil, biomass etc. They are ideal source of obtaining hot process air for drying, ovens, spray drying and other similar applications. Direct fired are used for the applications where contamination by carbon particles or combustion products do not matter for the products to be dried (Maximum temperature – 800^{o}C) [48-50].

Table 29: Normative requirement of coal for Hot Air Generator (HAG)

Basis: Heat Output- $30*10^4$ Kcal/hr, Volume of Hot air- $39000m^3$/hr, Efficiency -90%					
HAG efficiency	**40**	**50**	**60**	**70**	**80**
	$kg/1000m^3$	$kg/1000m^3$	$kg/1000m^3$	$kg/1000m^3$	$kg/1000m^3$
G-1	**2.69**	2.15	1.79	1.54	1.34
G-2	2.81	2.25	1.87	1.60	1.40
G-3	2.94	2.35	1.96	1.68	1.47
G-4	3.08	2.46	2.05	1.76	1.54
G-5	3.23	2.59	2.15	1.85	1.62
G-6	3.40	2.72	2.27	1.94	1.70
G-7	3.59	2.88	2.40	2.05	1.80
G-8	3.81	3.05	2.54	2.18	1.90
G-9	4.05	3.24	2.70	2.31	2.02
G-10	4.32	3.46	2.88	2.47	2.16
G-11	4.63	3.71	3.09	2.65	2.32
G-12	5.00	4.00	3.33	2.85	2.50
G-13	5.42	4.33	3.61	3.10	2.71
G-14	5.92	4.73	3.94	3.38	2.96
G-15	6.52	5.22	4.35	3.73	3.26
G-16	7.26	5.81	4.84	4.15	3.63
G-17	8.18	6.55	5.46	4.68	4.09

Calculation of Hot air generator:

Kg of coal/100 m^3 = (output heat in kcal/hr*1000/ (Efficiency of HAG*GCV in kcal/kg* vol of hot air)

= $30*10^4*10^3/0.4*7150*39000$

=2.69

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Concluding Remarks:

- Specific energy consumption (SEC) of different industries/ product categories is the basis of this estimation.
- Information on specific energy consumption was basically collected from published literature, different reports, and industrial organizations. Expert opinions taken in some specific cases.
- Relevant energy information related SEC was also collected through several industrial visits.
- Targeted product specification, raw material type and quality of the raw material may vary on case to case basis and accordingly adjustments in final temperature, firing cycle/ schedule are done which leads to variation in SEC. Therefore, given a new set up and technology and the best available technology (BAT) variation in SEC is quite obvious.
- Further variation in SEC takes place due to age of the equipment of thermal treatment, multiple fuel use, fuel economization strategies, design modifications, adopted heat recovery techniques, electrical boosting (as in the case of glass tank furnaces), production capacity variation, different dimensions of heat treatment equipment (furnace/ converter/ boiler, etc.), material of construction, quality of refractory used in furnace construction, type of insulation and many other factors.
- In this report estimation of normative coal requirement have been made on current GCV based coal grading system, where the range within each grade is 300 kcal/kg.
- Apart from direct coal fired furnaces / kilns, coal consumption in other production units actually takes place to generate producer gas (PG), steam from boiler, hot flue gas from hot air generator etc. Therefore most desired mode of estimation of coal requirement has to be based on norms fixed for basic units like boiler, PG plant, hot air generator, etc.
- In the sectors like tea textile, paper, refractory, glass, fine ceramics, etc., different kinds of sub kinds of sub-categories have been considered which are product-based, raw material-based, technology based and even technique-based on case to case basis. all such selected sub-categories are indicative of common production practices
- Different tables have been incorporated in this report as per the above sub-categories for estimation from production-data of the plants (i.e., considering the production of final product items). All those tables are very important for cross checking purposes in case the estimations are done through basic units like PG plant, boiler and hot air generator.

- SEC based approach is required in case of those industries where coal is used directly as mentioned in section 6.0 ('Approach') in page no. 7.
- This report finally recommends allocation of coal quantity based on basic units like, PG plant, Boiler and hot air generator, wherever applicable as mentioned in section 6.0 ('Approach') in page no. 7.
- This report as a whole is a very extensive guideline with lots of examples and elaborations. This report also includes guideline for collection of desired information and calculation methodologies.

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Annexure-I

List of industries covered in this report

1. Fertilizers
2. Paper and Pulp
3. Textile
4. Petro Chemicals
5. Chloro- Alkali industries
6. Rubber Industries
7. Coal requirement for Coke making Industries
8. Glass Industries
9. Refractories
10. Lime Calcinations
11. Manufacturing of Tea
12. Fine Ceramics Industry
13. Producer Gas Plants
14. Rolling Mill
15. Brick Industry
16. SSF Unit
17. Food Processing
18. Steam Generation in Boiler

Annexure-II

Required Information

Coal for Fertilizer Industry

		Inputs
1	Annual Production in Ton	
2.	SEC (Thermal) in kcal/kg	
3.	Required information for boiler as mentioned in Annexure-XIV	

Annexure-III

Coal for Paper and Pulp Industry

		Inputs
1.	Type of Paper	
2.	Source of Raw Material	
3.	Annual Production in Ton	
4.	SEC (Thermal) in kcal/kg	
5.	Required information for boiler as mentioned in Annexure-XIV	

Annexure-IV

Coal for Textile Industry

	Inputs	**Inputs**
1.	Name of Textile Products	
2.	Annual Production in Ton	
3.	SEC (Thermal) in kcal/kg	
4.	Required information for boiler as mentioned in Annexure-XIV	

Annexure-V

Coal for Petrochemicals Industry

		Inputs
1.	Annual Production in Ton	
2.	SEC (Thermal) in kcal/kg	
3.	Required information for boiler as mentioned in Annexure-XIV	

Annexure-VI

Coal for Chloro-alkali Industry

		Inputs
1.	Category of Chloro-alkali Industry	
2.	Name of Process	
3.	Annual Production in Ton	
4.	SEC (Thermal) in kcal/kg	
5.	Required information for boiler as mentioned in Annexure-XIV	

Annexure-VII

Coal for Rubber Industry

		Inputs
1.	Name of Rubber Products	
2.	Annual Production in Ton	
3.	SEC (Thermal) in kcal/kg	
4.	Required information for boiler as mentioned in Annexure-XIV	

Annexure-VIII

COAL FOR COKE MAKING INDUSTRIES

		Assumed Inputs
1	Coke Oven Type (Non Recovery old beehive, Non recovery improved type, pusher type, Stamp charging, Recovery type, Soft coke)	
2	Oven dimension(in inch) for Recovery by product type)	
3	Coal feed rate (ton/oven/batch)	
4	Coking time (hrs)	
5	Number of ovens in operation	
6	Number of ovens installed	

Illustrative example to assess coal requirement in Coke making Industries

Considering following feedback from the a consumer

		Assumed Inputs
1	Coke Oven Type (Non Recovery old beehive, Non recovery improved type, pusher type, Stamp charging, Recovery type, Soft coke)	**Non Recovery**
2	Oven dimension(in inch) for Recovery by product type)	**NA**
3	Coal feed rate (ton/oven/batch)	**9**
4	Coking time (hrs)	**48**
5	Number of ovens in operation	**10**
6	Number of ovens installed	**20**

Cal: Coal/oven/month (t) = 24*30*9/48 = 135.

Points No 5 & 6 are sought from the consumer to assess the total coal requirement based on the actual number of ovens which are in working condition.

Annexure-IX

Glass Industry

1	Number of glass tank furnaces using coal/ PG and respective melting capacity (tonne/day)	
2	Actual glass draw (tonne/day) yearly average figure = P	
3	Product Type (container-coloured and colour less, float glass, sheet glass, borosil glass etc.)	
4	Fuel Used (Coal/Producer Gas)	
5.	Sp. Energy consumption (Thermal) for melting & refining, i.e. SEC (in melter or furnace), kcal/kg	
6	Mention about PG fired annealing lehr (if any): number of such Lehr and capacity (Q) (tonne/day) of each.	
7.	Thermal efficiency of PG plant, i.e., Percent coal heat value transferred to PG, in case of producer gas fired furnaces/ lehrs (A)	
8.	Required information for producer as mentioned in Annexure-XV	

Illustrative example to assess coal requirement in GLASS Industry

		Assumed Inputs
1	Number of glass tank furnaces using coal/ PG and respective melting capacity (tonne/day)	One, 25 TPD
2	Actual glass draw (tonne/day) yearly average figure = P	20 TPD
3	Product Type (container-coloured and colour less, float glass, sheet glass, borosil glass etc.)	Container glass
4	Fuel Used (Coal/Producer Gas)	PG
5.	Sp. Energy consumption (Thermal) for melting & refining, i.e. SEC (in melter or furnace), kcal/kg	2000 kcal/kg *
6	Mention about PG fired annealing lehr (if any): number of such Lehr and capacity (Q) (tonne/day) of each.	One, 10 TPD
7.	Thermal efficiency of PG plant, i.e., Percent coal heat value transferred to PG, in case of producer gas fired furnaces/ lehrs (A)	55%

- *If SEC (in melter or furnace) it has to be converted to kcal/ kg unit*

a) Coal requirement for 20 TPD glass tank furnace (PG fired), 20 TPD draw:

$SEC_{\text{Coal based}}$ = (SEC_{furnace} x 100)/ A = (2000x 100)/ 55 = (2000/ 0.55) ----- (i)

[This equation (i) applicable when furnaces/ kilns are fired with producer gas]

Say, coal supply = G1 and corresponding GCV= 7150 kcal/kg

P= production (i.e., draw) in tons/day = 20TPD

Coal requirement per day (X1) = P x [{SEC $_{Coal\ based}$ x 1000} /GCV of coal]……… (.ii.)

= 20 x [{(2000/ 0.55) x 1000} /7150]

= 20 x 508.6 = 10171.65 kg = 10.172 TPD

b) Coal consumption for PG fired annealing Lehr, 10TPD

SEC $_{Coal\ based}$ = (SEC $_{Lehr}$ x 100)/ A = (450x 100)/ 55 = (450/ 0.55) ……… (iii.)

[This equation (iii) applicable for producer gas fired Lehr]

Now, the quantity of annealed product per day using producer gas as fuel (Q) = 10 TPD,

Therefore, Coal requirement per day (X2) = Q x [{SEC $_{Coal\ based}$ x 1000} /GCV of coal]……… (iv)

Coal requirement per day = 10 x [{(450/ 0.55} x 1000} /7150]

= 10 x 114.431 = 1144.31 kg = 1.144 TPD

In case of direct coal fired unit, when the value of SEC $_{Coal\ based}$ is provided that may be used directly in equation (ii) or in equation (iv).

c) Total coal requirement = X1 + X2= 10.172 + 1.144 = 11. 316 TPD = 11. 32 TPD

N. B. - Similar calculations have to be done for each furnace / lehr when multiple furnaces / lehrs are in use in glass factory (to consider coal / producer gas fired units only). Sum of coal requirement in all such units will be the total coal requirement of a particular glass factory

Annexure-X

FOR RAW MATERIAL CALCINATION/ REFRACTORIES / LIME CALCINATION/ FINE CERAMICS FOR EACH UNITS USING COAL OR COAL BASED PRODUCER GAS

Please do not furnish information about kilns using fuels other than coal/ producer gas

A	Firing/ calcination	Assumed Inputs
1	Type of kilns(DD kiln, Tunnel kiln, Chamber kiln, etc.) and number of kilns in each type & Kiln capacity	
2	Product Type and corresponding kiln type- mention each combination	
3	Mention fuel used (Coal/ Producer Gas) for each product type – Kiln type combination	
4	Firing temperature(s) of kilns (^oC) for each product type- kiln type combinations	
5	Cycle period (days) for each case (if applicable)	
6	Kiln wise annual Production for different product type – Kiln type combination (actual) (t)	
7.	SEC* of kiln for each category formed based on product type – Kiln type combination, fuel used, temperature, cycle period etc. and give average annual production for each of those categories. Add annexure if needed.	
8.	Thermal efficiency of PG plant, i.e., Percent coal heat value transferred to PG, in case of producer gas fired furnaces/ kilns (A)	
9.	Required information for producer as mentioned in Annexure-XV	

*SEC= Specific energy consumption in kcal/kg

Example of calculation from assumed input:

Say, the extract of the inputs of a particular kiln (unit) of an industry is as follows:

Product type- kiln type combinations: High Alumina - Tunnel kiln.

Firing Temperature = 1450 ^oC

Firing cycle: not defined / not applicable

Fuel: Producer gas

Annual production (P) = 10000 t

SEC_{kiln} = 1275 kcal/kg

Thermal efficiency of PG plant = A = 55%

$SEC_{Coal\ based}$ = (SEC_{kiln} x 100)/ A = (1275x 100)/ 55 = (1275/ 0.55) ----- (i)

[This equation (i) applicable when furnaces/ kilns are fired with producer gas]

Coal supply = G1 and corresponding GCV= 7150 kcal/kg

Annual Coal requirement = P x [{$SEC_{Coal\ based}$ x 1000} /7150] ---- (ii)
= 10000 x [{(1275/ 0.55) x 1000} /7150]
= 10000 x 324.2 kg
= 3242 t

In case of direct coal fired units, when the value of $SEC_{Coal\ based}$ is provided that may be used directly in equation (ii). In that case equation (i) is not applicable.

N. B.-

- ***Similar calculations have to be done for each category of production practices using different furnaces / kilns. Sum of coal requirement in all such kilns will be the total coal requirement of a particular factory.***

- ***The calculation shown above is common for* ‘raw material calcination’, ‘refractories’ , ‘lime calcination’ and ‘fine ceramics’**

- ***Refractory industries may also have Raw Material calcination-kilns which may use coal or coal derived producer gas as fuel.***

Annexure-XI

MANUFACTURING OF TEA

		Inputs
1	Tea Grade (CTC/ Orthodox/ Dual)	
2	Annual production of CTC Grade, t	
3	Annual production of Orthodox Grade , t	
4	SEC (thermal) in kcal/kg	
5.	Required information for Hot Air Generator as mentioned in Annexure-XVI	

Annexure-XII

COAL FOR RE HEATING FURNACE OF ROLLING MILLS

		Inputs
1	Annual production , t	
2.	Sp. Energy consumption (Thermal) in reheating furnace, $SEC_{\text{Coal based}}$, in kcal/kg	

EXAMPLE CALCULATION:

COAL REQUIREMENT FOR RE HEATING FURNACE (ROLLING MILLS)

Assumed inputs

		Inputs
1	Annual production , t	**1000t**
2.	Sp. Energy consumption (Thermal) in reheating furnace based on coal, $SEC_{\text{Coal based}}$, in kcal/kg	**615. 37**
3.	Required information for producer as mentioned in Annexure-XV	

Say, Coal supply => G1 grade and corresponding GCV= 7150 kcal/kg

P= production in tons/day = 100TPD

Coal requirement per day (X1) = P x [{$SEC_{\text{Coal based}}$ x 1000} /GCV of coal]……… (.ii.)
= 100 x [(615.37 x 1000) /7150]
= 100 x 86.1 = 8610 kg per day = 8.61 TPD

Annexure-XIII

Coal for Brick Industry

		Inputs
1.	Type of kiln (VSVK, BTK, Tunnel, clamp, Zig-zag etc.	
2.	Annual Production in Ton	
3.	SEC (thermal) in kcal/kg	

Coal for Special Smokeless Fuel (SSF)

1.	Grade of SSF	
2.	Annual Production in Ton	
3.	SEC (thermal) in kcal/kg	

COAL FOR FOOD PROCESSING

1.	**Category of Food Product**	**Inputs**
a.	Pickle, Fruit Juice, Kasundi, Jellies, Sauce, vinegar etc.	
b.	Concentrated Fruit Juice	
c.	Vegetable and other Food Products (Glucon, Fibire, Starch, Germ, Liquid Glucose, dextrose, Mono-hydrate etc.)	
d.	Milk products (Butter, Cheese, Concentrated Milk etc.)	
e.	Milk Powder	
2.	Annual Production in Ton	
3.	SEC (thermal) in kcal/kg [categorywise]	
4.	Required information for boiler/hot air generator as mentioned in Annexure-XIV	

Annexure-XIV

COAL FOR PROCESS STEAM

		Inputs
1	Quantity .of steam (kg/hr)	
2	Temperature(^oC) & Pressure (kg/cm square) of steam	
3	Enthalpy of steam of required temperature & pressure (kcal/kg) (From Steam Table)	
4	Enthalpy of feed water to Boiler (kcal/kg)	
5	Details of Boiler and Make	
6	Thermal Efficiency of boiler (%)	
7	Gross Calorific Value of desired coal(GCV) kcal/kg	
8	Average Days of operation in a year	

Assumed Inputs

COAL FOR PROCESS STEAM

		Inputs
1	Quantity .of steam entering into generator (kg/hr) **Q**	
2	Temperature(^oC) , Pressure (kg/cm square) of steam	
3	Enthalpy of steam of required temperature & pressure (kcal/kg) (From Steam Table **H**	
4	Enthalpy of feed water to Boiler (kcal/kg) $\mathbf{h_w}$	
5	Details of Boiler and Make	
6	Thermal Efficiency of boiler (%)	

For a particular grade of coal the GCV value can be estimated as suggested in the text and the coal requirement can be estimated from the following formula.

Coal requirement (kg/hr) = $Q^* (H-h_w) / (BE\ ^*GCV)$

Annexure-XV

COAL FOR PRODUCER GAS PLANT

		Inputs
1	CV of producer gas, kcal/ Nm^3	
2	Percentage of coal heat to be transferred to producer gas heat (thermal efficiency)	
3	Hourly production capacity of producer Gas, Nm^3 / hr	
4	Average Days of operation in a year	

Illustrative example to assess coal requirement in Producer Gas Plant

		Assumed Inputs
1	CV of producer gas , kcal/ Nm^3	**1300**
2	Percentage of coal heat to be transferred to producer gas heat (thermal efficiency factor)- e.g., 50%/ 55%/ 60%/ 70%, etc.	**70%**
3	Hourly production capacity of producer Gas, Nm^3 / hr , **Q** Nm^3 / hr	**16000** Nm^3 / hr
4	Average Days of operation in a year	**300 days**

Illustrative example based on consumer inputs:
Daily generation of producer gas = Q x 24 = 'P' Nm^3
Say, the grade of coal supply: G1 i.e., GCV = 7150

Coal requirement in kg per m^3 of gas generated (F) =

CV OF PRODUCER GAS IN KCAL PER NM^3/ (COAL CV * EFFICIENCY FACTOR),

Where efficiency factor = (Thermal efficiency in percent / 100) = 70/ 100
= 0.7
Therefore Coal requirement per m^3 of gas generated (F) = 1300 / (7150 *0.7)
= 0.26 kg
Daily requirement of Coal = 0.26 x P = 0.26 x Q x 24 kg/ day

Annual requirement = 0.26 x Q x24x 300 kg/ year
= (0.26 x Q x 24x 300)/ 1000 tons per year
= (0.26 x 16000 x 24 x300/1000) tons per year
= 29952 t/ year

Annexure-XVI

Coal for Hot Air Generator (HAG)

		Inputs
1.	Efficiency of Hot Air Generator	
2.	Output Heat value of hot air, kcal/hr.	
3.	Volume of hot air, m^3/hr.	

Coal Required (kg) for 1000m^3 Hot Air

$$= \frac{\text{Output heat of hot air in kcal/hr x 1000}}{\text{Efficiency of HAG x GCV in kcal/kg x volume of hot air } m^3}$$