Revision of default Net Calorific Value, Carbon Content Factor and Carbon Oxidization Factor for various fuels in 2006 IPCC GHG Inventory Guideline

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1. Overview and Background

1996 IPCC inventory guideline (1996 G/L) contains default values of Net Calorific Value, Carbon Content Factor and Carbon Oxidization Factor for various fuels to provide inventory officials relevant data when accurate country-specific data are not available.

But some of these default values in the 1996 G/L are estimated in rough manners, based on too small number of samples and/or old-fashioned measurement or under inadequate assumptions. And in 1996 G/L, no data are available for some important fuels, such as Biomass, Coal Delivered Gas and so on.

The IPCC-NGGIP Energy Expert Meeting 28-30 September 2004, Arusha, Tanzania decided to revise some default data in the 1996 G/L.

After Manila and Moscow meetings, the IPCC-NGGIP Energy Expert Meeting decided to revise all default values in the 1996 G/L except the case that reliable new data are available and that the new data are significantly different from the present values.

Recognizing that 2006 IPCC inventory guideline (2006 G/L) shall be used during the next decade, and that data availability are revolutionary improved in these years, the author tried to review all Net Calorific Value, Carbon Content Factor and Carbon Oxidization Factor for various fuels in a consistent manner, based on recent inventory data submitted by UNFCCC Annex-1 Parties as their national communication (AN-1-NC), IPCC-NGGIP Emission Factor Database(EFDB), IEA Net Calorific Values Data Base (IEA-DB) and official or scientific literature available.

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* This paper is based on the author's view and analysis under his own responsibility, and it DOES NOT reflect any official opinion addressed by RIETI, IAI or Government of Japan.

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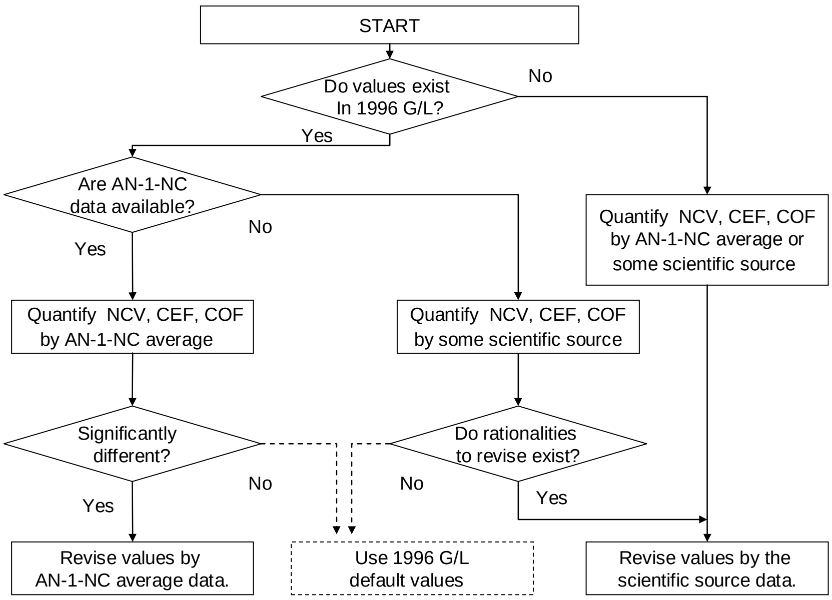
2. Methodology

2-1. Algorithm to revise default NCV, CCF and COF values

The default Net Calorific Value (NCV), Carbon Content Factor (CCF) and Carbon Oxidization Factor (COF) values for some fuel should be determined in an accurate, transparent and consistent manner. But at the same time, it is important to avoid trivial changes of these default values from the viewpoints of time-series consistency.

So the author established following decision making algorithm to revise default NCV, CCF and COF values recognizing these principles. See Chart 2-1.

Chart 2-1. Decision making algorithms for NCV, CEF and COF revision



2-1-1. No default value case

In case that no default values in the 1996 G/L, the author quantified default values with following priority.

a. AN-1-NC average data

Recognizing that only AN-1-NC provides consistent data set for NCV, CCF and COF for various fuels at present, the author used AN-1-NC country data as a basis for statistical treatment. The author prepared consistent data set for NCV, CCF and COF and estimated the default value from the average[1] of them. In case some NCV data for certain country are missing, the author made up them from corresponding data in IEA-DB.

b. EFDB and/or some scientific source data

In case that no AN-1-NC data are available, the author estimated default values from

[1] See 2-4. "Data format"

some appropriate sample data contained in EFDB[2] or actually measured data in some official or scientific literature.

2-1-2. Default value exists and AN-1-NC data available case

In case that default value already exists in the 1996 G/L and AN-1-NC data are available, the author prepared consistent country data set for NCV, CCF and COF and quantified the AN-1-NC average data. And if the AN-1-NC averaged data are significantly different[3] from the 1996 G/L value, the author revised the default value by AN-1-NC averaged data. Otherwise, the author discarded the AN-1-NC average data and kept 1996 G/L default value as it is.

2-1-3. Default value exists but no AN-1-NC data available case

In case that default value already exists in the 1996 G/L, but AN-1-NC data are not available due to too small data samples or data have no consistency with NCV, CCF and COF, the author quantified candidate data from some appropriate sample data contained in EFDB or actually measured data in some official or scientific literature.

And if there is some rationality to revise the value by expert judgement such that the candidate data are significantly different from the 1996 G/L value or 1996 G/L data have some apparent defect, the author revised the default value by the candidate data. Otherwise, the author discarded the candidate data and kept 1996 G/L default value as it is.

2-2. Data source

There exist following data sources that contain NCV, CCF and COF.

AN-1-NC: UNFCCC Annex-1 country national communication of 2002 inventory data issued in 2004. The table-1A (b) of the common reporting format contains NCV, CCF and COF in a consistent manner for more than 33 Annex-1 countries. But they contain no data for developing countries.

EFDB: IPCC-NGGIP EFDB version-1, issued in December 2003. The section 1A "Energy" contains CO2 data. EFDB contains worldwide data for NCV and CCF including developing country. But NCV and CCF data in EFDB are assembled in an independent manner and the data often lack consistency.

IEA-DB: International Energy Agency net calorific value data base for various fuels, issued in November 2004. IEA-DB contains only NCV data for world-wide countries, including developing countries. Neither CCF nor COF are available in IEA-DB.

2-3. Unit conversion and treatment of impurities

All original data are converted into uniformed common units used in 1996 G/L, such as "TJ/kt" or "tC/TJ" in Net Calorific Value (NCV) from their original units such as "TJ/l" in

[2] See 2-2. "Data source"
[3] The author judged difference with statistical t-test at 5 per cent level of significance. See 2-4.

Gross Calorific Value (GCV) or “gC/kWh”.

The conversion coefficients are subject to the standard conversion methodology and coefficients used to convert Japanese Energy Statistics by “MJ/litre” in GCV into the IEA common unit statistics by “TJ/kt” in NCV.

Most of the original data in AN-1-NC or EFDB are measured in moisture, ash, sulphur and other impurities are included basis, so default values are affected by these impurity components. This mean inventory officials should be careful NOT to apply or compare no-moisture and/or no-ash base data with these default values.

2-4. Data format

2-4-1. Importance of data and related information

Reflecting that the QA/QC are important aspect of the 2006 IPCC inventory guideline, and that some developing countries are making great efforts to determine their accurate country-specific data, the author prepared following statistical data and indicators that help their activities for accurate quantification.

2-4-2. Standard data format for quantification

- **1996 G/L Default Value:** The author show 1996 G/L default values, if available.
- **AN-1-NC data:** The author quantified UNFCCC Annex-1 national communication data average, sample number and standard deviation, if available. And the author tried t-test under a hypothesis that AN-1-NC average data are different from 1996 G/L default values at 5 per cent level of significance. If absolute “t-value” is smaller than “t (N-1, 0.95)”, the hypothesis is denied and AN-1-NC average data are NOT so significantly different from 1996 G/L default values that we should change the default values.
- **Scientific data and/or result of expert judgement:** The author quantified corresponding values from appropriate sample data contained in EFDB or actually measured data in some official or scientific literature if AN-1-NC data are not available. In some case, values are estimated by expert judgement.
- **2006 G/L Default value:** The decision making algorithm is shown in Chart 2-1.
- **95 per cent confidence interval, Upper and Lower range:** The author quantified 95 per cent confidence interval for the default value using AN-1-NC data. If AN-1-NC data are not available, the author estimated that the interval is 5 per cent[4] to the default value. And the author show maximum and minimum data in AN-1-NC to indicate possible upper and lower range of the observed data. If AN-1-NC data are not available, the author estimated that the upper and lower range data have 10 per cent of deviation to the default value. These data indicates possible ranges for an observed or estimated country-specific data to avoid latent errors in misplacements or quantification.

[4] The uncertainty ranges are given by expert judgment of IPCC-NGGIP Energy expert members.

3. Fuel Category Classification

3-1. Classification of fuels

The IPCC-NGGIP Energy Expert Meeting decided to use new fuel classification shown in table 3-1., instead of present "Solid-Liquid-Gaseous" classification in 1996 G/L.

Definitions of fuels are shown in table 1-1, "Overview", the energy part of 2006 G/L.

Table 3-1. Fuel Category Classification

- *Fossil Fuel Origin*
  - *Liquid Fossil Origin*
    - *Primary fuels*
      - Crude Oil
      - Orimulsion
      - Natural Gas Liquid
    - *Secondary Fuels / Products*
      - Gasoline
        - Motor Gasoline
        - Aviation Gasoline
        - Jet Gasoline
      - Jet Kerosene
      - Other Kerosene
      - Shale Oil
      - Gas / Diesel Oil
      - Residual Fuel Oil
      - Liquefied Petroleum Gas: LPG
      - Ethane
      - Naphtha
      - Bitumen
      - Lubricants
      - Petroleum Coke
      - Refinery Feed Stocks
      - Other Oil
        - Refinery Gas
        - Paraffin Waxes
        - White Spirit & SBP
        - Other Petroleum Products
  - *Solid Fossil Origin*
    - *Primary Fuels*
      - Anthracite
      - Coking Coal
      - Other Bituminous Coal
      - Sub-Bituminous Coal
      - Lignite
      - Oil shale and Tar Sands
      - Peat
    - *Secondary Fuels / Products*
      - Brown Coal Briquettes: BKB & Patent Fuel
      - Coke
        - Coke Oven Coke and Lignite Coke
        - Gas Coke
      - Coal Derived Gases
        - Gas Works Gas
        - Coke Oven Gas
        - Blast Furnace Gas
        - Oxygen Steel Furnace Gas
  - *Gaseous Fossil Origin*
    - *Primary Fuel*
      - Natural Gas (Dry-)
  - *Other Fossil Origin*
    - *Primary Fuel*
      - Municipal Wastes (non-biomass fraction and/or its mixture)
      - Industrial Wastes

Biomass Origin
Solid Biofuels / Solid Biomass Origin
Primary Fuels
Wood/Wood Waste
Sulphite Lyes (Black Liquor)
Other Primary Solid Biomass
Secondary Fuels
Charcoal
Liquid Biofuels / Liquid Biomass Origin
Primary Fuels
Biogasoline
Biodiesels
Other Liquid Biofuels
Gas Biofuels / Gas Biomass Origin
Landfill Gas
Sludge Gas
Other Biogas
Other Biomass Origin
Municipal Waste (biomass fraction)

4. Net Calorific Value (NCV) and Carbon Content Factor (CCF)

4-1. Liquid Fossil Origin

4-1-1. Primary Fuels

a. Crude Oil

- Quantification: Table 4-1-1-1. Crude Oil

Crude Oil		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	20.0
	AN-1-NC average	42.3	20.0
	Sample number; N	30.0	30.0
	Standard Deviation	0.894	0.292
	t-value	NA	0.387
	t(N-1, 0.95)	1.699	1.699
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**42.3**	**20.0**
	95 per cent confidence interval	0.320	0.104
	Lower	40.1	18.7
	Upper	44.8	20.5

- Comments

The author found that NCV and CCF of Crude Oil have a good convergence to 42.3 TJ/kt and 20.0 tC/TJ in 30 AN-1-NC consistent samples.

In 1996 G/L, NCV of Crude Oil has been shown in a long-table format showing various country-specific data samples and no single default value has been shown, so the author determined default Crude Oil NCV as 42.3 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

b. Orimulsion

- Quantification: Table 4-1-1-2. Orimulsion

Orimulsion		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	27.5	22.0
	AN-1-NC average	27.8	21.0
	Sample number; N	5.0	5.0
	Standard Deviation	0.376	1.000
	t-value	-1.820	2.222
	t(N-1, 0.95)	2.132	2.132
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**27.5**	**21.0**
	95 per cent confidence interval	0.329	0.876
	Lower	27.5	19.6
	Upper	28.3	22.0

- Comments

In 1996 G/L, NCV and CCF of the Orimulsion are based on very small number of sample contained in the EFDB, because the Orimulsion is a unique fuel product in Venezuela.

The author found that AN-1-NC average NCV (27.8 TJ/kt) is not different from 1996 G/L default value 27.5 TJ/kt, but that AN-1-NC average CCF is significantly different.

c. Natural Gas Liquid

- Quantification: Table 4-1-1-3. Natural Gas Liquid

Natural Gas Liquid		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	17.2
	AN-1-NC average	44.2	17.5
	Sample number; N	21.0	21.0
	Standard Deviation	1.843	0.882
	t-value	NA	-1.456
	t(N-1, 0.95)	1.725	1.725
	Scientific Data, Expert Judgment	NA	NA

	2006 G/L Default Value	**44.2**	**17.2**
	95 per cent confidence interval	0.788	0.377
	Lower	40.9	16.5
	Upper	46.9	20.4

- Comments

The author found that NCV and CCF of Natural Gas Liquid have a good convergence to 44.2 TJ/kt and 17.5 tC/TJ in 21 AN-1-NC consistent samples.

In 1996 G/L, NCV of Natural Gas Liquid is not shown, so the author determined default Natural Gas Liquid NCV value as 44.2 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value 17.2 tC/TJ and AN-1-NC average data (17.5 tC/TJ).

Be careful that quality of Natural Gas Liquid differs in accordance with the regional difference of level in LPG and Ethane fraction recovery.

4-1-2. Secondary Fuels / Products #1 Fuel Products

a. Gasoline

- Quantification: Table 4-1-2-1. Gasoline

Gasoline (Motor-, Aviation-, Jet-)		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	44.8	18.9
	AN-1-NC average	44.3	19.2
	Sample number; N	33.0	33.0
	Standard Deviation	0.660	0.390
	t-value	4.178	-3.696
	t(N-1, 0.95)	1.697	1.697
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**44.3**	**19.2**
	95 per cent confidence interval	0.225	0.133
	Lower	42.5	18.7
	Upper	44.8	20.2

- Comments

Gasoline includes Motor-gasoline, Aviation-gasoline and Jet-gasoline. Only few Annex-1 country reports the value data of Aviation Gasoline and Jet Gasoline data, so the author judged those sample numbers are not sufficient at present and estimated that differences of these fuels' data with Motor Gasoline are negligibly small.

The author found that both default NCV and CCF of Gasoline in 1996 G/L (44.8 TJ/kt, 18.9 tC/TJ) are significantly different from the average of recent 33 AN-1-NC consistent samples (44.3 TJ/kt, 19.2 tC/TJ).

The author thinks that this difference is based on the substantial quality change of Gasoline due to motor vehicle fuel quality regulation for air-pollution prevention in some developed countries such as limitation of sulphur, benzene and/or lead-additive contents enforced in the midst of 1990s from the viewpoint of urban air-pollution prevention.

. And in addition, NCV and CCF of Gasoline in 1996 G/L are based on 2 or 3 samples contained in EFDB and some sample bias may affect.

b. Jet Kerosene

- Quantification: Table 4-1-2-2. Jet Kerosene

Jet Kerosene		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	44.6	19.5
	AN-1-NC average	44.1	19.7
	Sample number; N	33.0	33.0
	Standard Deviation	0.712	0.319
	t-value	4.298	-2.738
	t(N-1, 0.95)	1.697	1.697
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**44.1**	**19.7**
	95 per cent confidence interval	0.243	0.109
	Lower	42.0	19.3
	Upper	45.0	21.0

- Comments

The author found that both default NCV and CCF of Jet Kerosene in 1996 G/L (44.6 TJ/kt, 19.5 tC/TJ) are significantly different from the average of recent 33 AN-1-NC consistent samples (44.1 TJ/kt, 19.7 tC/TJ).

The author thinks that time-series difference of NCV and CCF of Jet Kerosene may be caused by steep increase of recent civil aviation that consumes Kerosene base fuels such as Jet-A-1 in comparison with Naphtha-Kerosene hybrid fuels for military use such as JP-4, and average NCV and CCF of Jet Kerosene changed in accordance of with the civil/military consumption share change.

c. Other Kerosene

- Quantification: Table 4-1-2-3. Other Kerosene

Other Kerosene		NCV	CCF
		TJ/kt	tC/TJ

	1996 G/L Default Value	44.8	19.6
	AN-1-NC average	43.8	19.7
	Sample number; N	26.0	26.0
	Standard Deviation	0.662	0.188
	t-value	7.139	-2.338
	t(N-1, 0.95)	1.708	1.708
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**43.8**	**19.7**
	95 per cent confidence interval	0.254	0.072
	Lower	42.4	19.5
	Upper	45.2	20.1

- Comments

The author found that both default NCV and CCF of Other Kerosene in 1996 G/L (44.8TJ/kt, 19.6 tC/TJ) are significantly different from the average of recent 26 AN-1-NC consistent samples (43.8 TJ/kt, 19.7 tC/TJ).

The author thinks that Jet Kerosene and Other Kerosene are produced from same fraction, so quality change of Jet Kerosene may affect the quality of Other Kerosene.

d. Shale Oil

- Quantification: Table 4-1-2-4. Shale Oil

Shale Oil		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	36.0	20.0
	AN-1-NC average	38.2	20.0
	Sample number; N	5.0	5.0
	Standard Deviation	3.115	0.696
	t-value	-1.588	0.000
	t(N-1, 0.95)	2.132	1.725
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**36.0**	**20.0**
	95 per cent confidence interval	2.730	0.610
	Lower	36.0	18.9
	Upper	44.0	21.1

- Comments

The author quantified average NCV and CCF data of Shale Oil in 5 AN-1-NC consistent samples, but results of the t-test for NCV and CCF shows no significant difference is seen in 1996 G/L default value and AN-1-NC average data.

The author thinks that sample numbers at present are too small to tackle wide dispersion of Shale Oil quality.

Shale Oil is often used in Economy In Transition countries. Some country uses Oil Shale itself for fuel, in such case see “Oil Shale”.

e. Gas / Diesel Oil

- Quantification: Table 4-1-2-5. Gas / Diesel Oil

Gas / Diesel Oil		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	43.3	20.2
	AN-1-NC average	43.0	20.1
	Sample number; N	33.0	33.0
	Standard Deviation	0.497	0.137
	t-value	4.004	3.447
	t(N-1, 0.95)	1.697	1.697
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**43.0**	**20.1**
	95 per cent confidence interval	0.170	0.047
	Lower	41.4	19.7
	Upper	43.3	20.3

- Comments

The author found that both default NCV and CCF of Gas / Diesel Oil in 1996 G/L (43.3 TJ/kt, 20.2 tC/TJ) are significantly different from the average of recent 33 AN-1-NC consistent samples (43.0 TJ/kt, 20.1 tC/TJ).

The author thinks that this difference is based on the substantial quality change of Gas / Diesel Oil due to motor vehicle fuel quality regulation for air-pollution prevention in some developed countries.

f. Residual Fuel Oil

- Quantification: Table 4-1-2-6. Residual Fuel Oil

Residual Fuel Oil		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	40.2	21.1
	AN-1-NC average	40.4	21.0
	Sample number; N	33.0	33.0
	Standard Deviation	0.487	0.208
	t-value	-2.921	1.629

	t(N-1, 0.95)	1.697	1.697
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**40.4**	**21.1**
	95 per cent confidence interval	0.166	0.071
	Lower	39.8	20.3
	Upper	41.7	21.5

- Comments

The author found that NCV and CCF of Residual Fuel Oil have a good convergence to 40.4 TJ/kt and 21.0 tC/TJ in 33 AN-1-NC consistent samples.

The result of t-test for NCV shows a significant difference between 1996 G/L default value and AN-1-NC average data, but t-test for CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

g. Liquefied Petroleum Gas / LPG

- Quantification: Table 4-1-2-7. Liquefied Petroleum Gas

Liquefied Petroleum Gas		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	47.3	17.2
	AN-1-NC average	47.0	17.4
	Sample number; N	30.0	30.0
	Standard Deviation	1.218	0.278
	t-value	1.592	-3.440
	t(N-1, 0.95)	1.699	1.699
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**47.3**	**17.4**
	95 per cent confidence interval	0.436	0.099
	Lower	44.8	17.1
	Upper	52.2	18.0

- Comments

Liquefied Petroleum Gas is consisted by Propane (46.7 TJ/kt and 17.5 tC/TJ in theoretical value), Butane (46.3 TJ/kt, 17.9 tC/TJ) and small portion of impurity gas such as Ethane (47.8 TJ/kt, 16.7 tC/TJ).

The author found that NCV and CCF of Liquefied Petroleum Gas have a good convergence to 47.0 TJ/kt and 17.4 tC/TJ in 30 AN-1-NC consistent samples.

The result of t-test for NCV shows no significant difference is seen in 1996 G/L default value and AN-1-NC average data, but t-test for CCF shows a significant difference.

h. Ethane

- Quantification: Table 4-1-2-8. Ethane

Ethane		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	47.5	16.8
	AN-1-NC average	46.4	17.4
	Sample number; N	14.0	14.0
	Standard Deviation	1.932	1.541
	t-value	2.201	-1.356
	t(N-1, 0.95)	1.771	1.771
	Scientific Data, Expert Judgment	47.8	16.7
	2006 G/L Default Value	**47.8**	**16.7**
	95 per cent confidence interval	1.012	0.807
	Lower	40.2	16.2
	Upper	47.5	22.0

- Comments

Theoretical NCV and CCF value of Ethane are 47.8 TJ/kt and 16.7 tC/TJ.

On the other hand, the author found that average NCV and CCF of “Ethane” in 13 AN-1-NC consistent samples are 46.4 TJ/kt and 17.4 tC/TJ. The AN-1-NC average data of “Ethane” is rather closer to Propane (46.7 TJ/kt and 17.5 tC/TJ in theoretical value).

In order to avoid confusion, the author set default NCV and CCF value of Ethane in accordance with theoretical value by expert judgement.

4-1-3. Secondary Fuels / Products #2 Other Liquid Fossil Origin Products

a. Naphtha

- Quantification: Table 4-1-3-1. Naphtha

Naphtha		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	45.0	20.0
	AN-1-NC average	44.5	19.8
	Sample number; N	23.0	23.0
	Standard Deviation	1.078	0.460
	t-value	2.161	1.792
	t(N-1, 0.95)	1.717	1.717
	Scientific Data, Expert Judgment	NA	NA

	2006 G/L Default Value	**44.5**	**19.8**
	95 per cent confidence interval	0.440	0.188
	Lower	41.8	18.1
	Upper	46.5	20.2

- Comments

The author found that both default NCV and CCF of Naphtha in 1996 G/L (45.0 TJ/kt, 20.0 tC/TJ) are significantly different from the average of recent 23 AN-1-NC consistent samples (44.5 TJ/kt, 19.8 tC/TJ).

The author estimates that default Naphtha CCF value in 1996 G/L is determined by just applying Crude Oil CCF value (20.0 tC/TJ). But in most case, Naphtha is made from lighter fraction of Crude Oil distillation.

b. Bitumen

- Quantification: Table 4-1-3-2. Bitumen

Bitumen		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	40.2	22.0
	AN-1-NC average	39.8	22.1
	Sample number; N	27.0	27.0
	Standard Deviation	1.373	1.262
	t-value	1.472	-0.580
	t(N-1, 0.95)	1.706	1.706
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**40.2**	**22.0**
	95 per cent confidence interval	0.518	0.476
	Lower	33.5	20.0
	Upper	41.2	28.1

- Comments

The author quantified average NCV and CCF data of Bitumen in 27 AN-1-NC consistent samples, but results of the t-test for NCV and CCF shows no significant difference is seen in 1996 G/L default value and AN-1-NC average data.

c. Lubricants

- Quantification: Table 4-1-3-3. Lubricants

Lubricants		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	40.2	20.0

	AN-1-NC average	39.9	20.1
	Sample number; N	26.0	26.0
	Standard Deviation	1.406	0.229
	t-value	0.960	-1.275
	t(N-1, 0.95)	1.708	1.708
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**40.2**	**20.0**
	95 per cent confidence interval	0.540	0.088
	Lower	33.5	19.9
	Upper	42.3	21.2

- Comments

The author quantified average NCV and CCF data of Lubricants in 26 AN-1-NC consistent samples, but results of the t-test for NCV and CCF shows no significant difference is seen in 1996 G/L default value and AN-1-NC average data.

d. Petroleum Coke

- Quantification: Table 4-1-3-4. Petroleum Coke

Petroleum Coke		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	31.0	27.5
	AN-1-NC average	32.5	26.7
	Sample number; N	26.0	26.0
	Standard Deviation	2.832	1.961
	t-value	-2.669	2.114
	t(N-1, 0.95)	1.708	1.708
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**32.5**	**26.7**
	95 per cent confidence interval	1.089	0.754
	Lower	29.7	20.2
	Upper	41.9	28.1

- Comments

The author found that both default NCV and CCF of Petroleum Coke in 1996 G/L (31.0 TJ/kt, 27.5 tC/TJ) are significantly different from the average of recent 26 AN-1-NC consistent samples (32.5 TJ/kt, 26.7 tC/TJ).

Petroleum Coke is consisted by “Green / Raw Coke” and “Calcinated Coke”, and “Calcinated Coke” has a slightly lower NCV and higher CCF. So the author thinks that quality of Petroleum Coke shall be affected by combination ratio of these Cokes.

Moreover, the author thinks that quality of Petroleum Coke is affected by the catalytic cracking process technology of residual oil that has been revolutionary developed and improved in 1990s.

e. Refinery Feedstock

- Quantification: Table 4-1-3-5. Refinery Feedstock

Refinery Feedstock		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	44.8	20.0
	AN-1-NC average	43.0	19.9
	Sample number; N	21.0	21.0
	Standard Deviation	3.098	0.498
	t-value	2.716	1.306
	t(N-1, 0.95)	1.725	1.725
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**43.0**	**20.0**
	95 per cent confidence interval	1.325	0.213
	Lower	30.6	18.2
	Upper	46.4	20.5

- Comments

The author quantified average NCV and CCF of Refinery Feedstock as 43.0 TJ/kt and 19.9 tC/TJ in 21 AN-1-NC consistent samples.

The result of t-test for NCV shows a significant difference between 1996 G/L default value and AN-1-NC average data, but t-test for CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

f. Refinery Gas

- Quantification: Table 4-1-3-6. Refinery Gas

Refinery Gas		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	18.2
	AN-1-NC average	NA	NA
	Scientific Data, Expert Judgment	49.5	15.7
	2006 G/L Default Value	**49.5**	**15.7**
	95 per cent confidence interval	2.476	0.786
	Lower	44.6	14.2

	Upper	54.5	17.3

- **Comments**

In 1996 G/L, default NCV of Refinery Gas is not shown. And default CCF value in 1996 G/L is questionable because the CCF value surpluses theoretical value of Butane (17.9 tC/TJ) though major components of Refinery Gas are Methane (14.9 tC/TJ), Ethane (16.7 tC/TJ), Hydrogen sulphide, Hydrogen and impurity hydrocarbon gases.

No AN-1-NC data are available for Refinery Gas, so the author determined default NCV and CCF value in accordance with default value of Japanese Energy Statistics based on actual measurement of 10 refinery samples in 1996. Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

g. Other Petroleum Products

- **Quantification: Table 4-1-3-7. Other Petroleum Products**

Other Oil Products / Paraffin Wax, White Spirit & SBP, Others		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	40.2	20.0
	AN-1-NC average	40.9	20.0
	Sample number; N	23.0	23.0
	Standard Deviation	2.537	0.160
	t-value	-1.352	-0.162
	t(N-1, 0.95)	1.717	1.717
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**40.2**	**20.0**
	95 per cent confidence interval	1.037	0.066
	Lower	33.7	19.6
	Upper	48.2	20.5

- **Comments**

Other Petroleum Products includes Paraffin Wax, White Spirit & SBP, and others.

Only few Annex-1 country reports the data of each products, and in some case all of their value were exactly same as default value of 1996 G/L, so the author judged those detailed sample numbers are not sufficient at present.

The author quantified average NCV and CCF data of Other Petroleum Products in 23 AN-1-NC consistent samples, but results of the t-test for NCV and CCF shows no significant difference is seen in 1996 G/L default value and AN-1-NC average data.

4-2. Solid Fossil Origin

4-2-1. Primary Fuels

a. Anthracite

- Quantification: Table 4-2-1-1. Anthracite

Anthracite		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	26.8
	AN-1-NC average	26.7	26.6
	Sample number; N	14.0	14.0
	Standard Deviation	2.445	0.408
	t-value	NA	1.577
	t(N-1, 0.95)	1.771	1.771
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**26.7**	**26.8**
	95 per cent confidence interval	1.281	0.214
	Lower	21.6	25.3
	Upper	32.2	26.9

- Comments

The author quantified NCV and CCF of Anthracite as 26.7 TJ/kt and 26.6 tC/TJ in 14 AN-1-NC consistent samples.

In 1996 G/L, NCV of Anthracite has been shown in a long-table format showing various country-specific data samples and no single default value has been shown, so the author determined default Anthracite NCV value as 26.7 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

b. Coking Coal

- Quantification: Table 4-2-1-2. Coking Coal

Coking Coal		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	25.8
	AN-1-NC average	28.2	25.6
	Sample number; N	24.0	24.0
	Standard Deviation	2.089	0.994
	t-value	NA	0.765
	t(N-1, 0.95)	1.714	1.714

	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**28.2**	**25.8**
	95 per cent confidence interval	0.836	0.398
	Lower	21.6	24.0
	Upper	31.0	29.5

- Comments

The author quantified NCV and CCF of Coking Coal as 28.2 TJ/kt and 25.6 tC/TJ in 24 AN-1-NC consistent samples.

In 1996 G/L, NCV of Coking Coal has been shown in a long-table format showing various country-specific data samples and no single default value has been shown, so the author determined default Coking Coal NCV value as 28.2 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

Coal is relatively diversified in its NCV and CCF quality in AN-1-NC due to their variety of moisture, ash and sulphur content when compared with crude oil or natural gas. But Coking Coal has a good convergence because Coke Oven Coke's quality is affected by Coking Coal and industrial specifications of Coke Oven Coke for steelmaking process are quite similar in countries.

c. Other Bituminous Coal

- Quantification: Table 4-2-1-3. Other Bituminous Coal

Other Bituminous Coal		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	25.8
	AN-1-NC average	25.8	25.8
	Sample number; N	30.0	30.0
	Standard Deviation	2.364	0.689
	t-value	NA	0.230
	t(N-1, 0.95)	1.699	1.699
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**25.8**	**25.8**
	95 per cent confidence interval	0.846	0.247
	Lower	19.9	23.5
	Upper	30.5	27.6

- Comments

The author quantified NCV and CCF of Other Bituminous Coal as 25.8 TJ/kt and 25.8 tC/TJ in 30 AN-1-NC consistent samples.

In 1996 G/L, NCV of Other Bituminous Coal has been shown in a long-table format showing various country-specific data samples and no single default value has been shown, so the author determined default NCV value as 25.8 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

d. Sub-Bituminous Coal

- Quantification: Table 4-2-1-4. Sub-Bituminous Coal

Sub-Bituminous Coal		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	26.2
	AN-1-NC average	18.9	26.3
	Sample number; N	16.0	16.0
	Standard Deviation	3.608	0.504
	t-value	NA	-0.836
	t(N-1, 0.95)	1.753	1.753
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**18.9**	**26.2**
	95 per cent confidence interval	1.768	0.247
	Lower	11.5	25.5
	Upper	26.0	27.6

- Comments

The author quantified NCV and CCF of Sub-Bituminous Coal as 18.9 TJ/kt and 26.2 tC/TJ in 16 AN-1-NC consistent samples.

In 1996 G/L, NCV of Sub-Bituminous Coal has been shown in a long-table format showing various country-specific data samples and no single default value has been shown, so the author determined default NCV value as 18.9 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

e. Lignite

- Quantification: Table 4-2-1-5. Lignite

Lignite		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	27.6
	AN-1-NC average	11.9	27.9
	Sample number; N	24.0	24.0
	Standard Deviation	4.460	1.723

	t-value	NA	-0.889
	t(N-1, 0.95)	1.714	1.714
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**11.9**	**27.6**
	95 per cent confidence interval	1.784	0.689
	Lower	5.5	24.7
	Upper	21.6	34.0

- Comments

The author quantified NCV and CCF of Lignite as 11.9 TJ/kt and 27.9 tC/TJ in 24 AN-1-NC consistent samples.

In 1996 G/L, NCV of Lignite has been shown in a long-table format showing various country-specific data samples and no single default value has been shown, so the author determined default Lignite NCV value as 11.9 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

f. Oil Shale and Tar Sands

- Quantification: Table 4-2-1-6. Oil Shale and Tar Sands

Oil Shale and Tar Sands		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	9.40	29.1
	AN-1-NC average	8.92	29.1
	Sample number; N	5.0	5.0
	Standard Deviation	0.854	0.000
	t-value	1.267	NA
	t(N-1, 0.95)	2.132	2.132
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**9.40**	**29.1**
	95 per cent confidence interval	0.748	1.455
	Lower	7.3	26.2
	Upper	9.6	32.0

- Comments

The author quantified NCV and CCF of Oil Shale and Tar Sands as 8.92 TJ/kt and 29.1 tC/TJ in 5 AN-1-NC consistent samples.

The result of t-test for NCV shows no significant difference between 1996 G/L default value and AN-1-NC average data.

On the other hand, all 5 Annex-1 countries in AN-1-NC used default CCF in 1996

G/L, so the author could not quantify standard deviation, t-value, confidence interval and Upper/Lower range from AN-1-NC sample data.

So the author determined to use 1996 G/L default CCF value and estimated that confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) by expert judgement.

g. Peat

- Quantification: Table 4-2-1-7. Peat

Peat		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	28.9
	AN-1-NC average	9.76	28.9
	Sample number; N	13.0	13.0
	Standard Deviation	1.415	0.257
	t-value	NA	-0.420
	t(N-1, 0.95)	1.782	1.782
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**9.76**	**28.9**
	95 per cent confidence interval	0.769	0.140
	Lower	7.8	28.3
	Upper	12.5	29.6

- Comments

The author quantified NCV and CCF of Peat as 9.76 TJ/kt and 28.9 tC/TJ in 13 AN-1-NC consistent samples.

In 1996 G/L, there is no NCV of Peat, so the author determined default Peat NCV value as 9.76 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

4-2-2. Secondary Fuels / Products #1 Solid and Liquid Products

a. Brown Coal Briquette (BKB) and Patent Fuel

- Quantification: Table 4-2-2-1. Brown Coal Briquette (BKB) and Patent Fuel

BKB and Patent fuel		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	25.8
	AN-1-NC average	20.7	26.6
	Sample number; N	19.0	19.0
	Standard Deviation	4.230	1.491

	t-value	NA	-2.419
	t(N-1, 0.95)	1.734	1.734
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**20.7**	**26.6**
	95 per cent confidence interval	1.902	0.670
	Lower	15.1	25.2
	Upper	32.0	30.4

- Comments

Brown Coal Briquette (BKB) and Patent Fuel are typical coal derived fuels.

In AN-1-NC and some other literature, they are reported and/or quantified in a merged manner though Brown Coal Briquette (BKB) and Patent Fuel have quite different quality.

The author quantified NCV and CCF of Brown Coal Briquette (BKB) and Patent Fuel as 20.7 TJ/kt and 26.6 tC/TJ in 19 AN-1-NC consistent samples.

In 1996 G/L, there is no NCV of Brown Coal Briquette (BKB) or Patent Fuel, so the author determined default NCV value as 20.7 TJ/kt.

The author found that CCF of Brown Coal Briquette (BKB) and Patent Fuel in 1996 G/L (25.8 tC/TJ) are significantly different from the average of recent 19 AN-1-NC consistent samples (26.6 tC/TJ).

Be careful that Brown Coal Briquette (BKB) and Patent Fuel have rather different quality. The author estimated NCV based on IEA-DB that Brown Coal Briquette (BKB) as 19.7 TJ/kt and Patent Fuel as 28.4 TJ/kt, but no corresponding CCF.

So in case that it is not so hard to identify quantities of them and it is not so hard to know country specific NCV and/or CCF values of them, the author recommends quantifying them in a separate manner.

b. Coke / Coke Oven Coke and Lignite Coke, Gas Coke

- Quantification: Table 4-2-2-2. Coke Oven Coke and Lignite Coke, Gas Coke

Coke Oven Coke and Lignite Coke, Gas Coke		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	29.5
	AN-1-NC average	28.2	29.1
	Sample number; N	27.0	27.0
	Standard Deviation	1.197	1.493
	t-value	NA	1.430
	t(N-1, 0.95)	1.706	1.706
	Scientific Data, Expert Judgment	NA	NA

	2006 G/L Default Value	**28.2**	**29.5**
	95 per cent confidence interval	0.451	0.563
	Lower	25.1	23.7
	Upper	30.2	32.6

- Comments

Coke includes Coke Oven Coke, Lignite Coke and Gas Coke. All of these Cokes are produced by coal carbonization, and qualities of these Cokes are quite similar, more than 90 per cent of their component is solid carbon.

The author quantified NCV and CCF of Coke Oven Coke as 28.2 TJ/kt and 29.1 tC/TJ in 27 AN-1-NC consistent samples.

In 1996 G/L, no default NCV of Coke Oven Coke or other Cokes have been shown, so the author determined default NCV value as 28.2 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

c. Coal Tar

- Quantification: Table 4-2-2-3. Coal Tar

Coal Tar		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	28.0	NA
	AN-1-NC average	NA	NA
	Scientific Data, Expert Judgment	28.0	22.0
	2006 G/L Default Value	**28.0**	**22.0**
	95 per cent confidence interval	1.400	1.100
	Lower	25.2	19.8
	Upper	30.8	24.2

- Comments

In 1996 G/L, only default NCV value is shown. Because no AN-1-NC data are available for Coal Tar, and the author could not find any adequate data for NCV in EFDB or some literature, the author determined to keep 1996 G/L default NCV value for “Coal Oils and Tars derived from Coking Coals” (28.0 TJ/kt).

But in 1996 G/L, no default CCF value of Coal Tar is shown, so the author estimated default Coal Tar CCF value in accordance with Bitumen (22.0 tC/TJ) by expert judgement, based on the fact that major component for both Coal Tar and Bitumen are aromatic hydrocarbons such as Benzene (22.9 tC/TJ in theoretical value).

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

4-2-3. Secondary Fuels / Products #2 Gaseous Products

a. Coke Oven Gas, Gas Works Gas

- Quantification: Table 4-2-3-1. Coke Oven Gas, Gas Works Gas

Coke Oven Gas, Gas Works Gas		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	13.0
	AN-1-NC average	NA	NA
	Scientific Data, Expert Judgment	38.7	12.1
	2006 G/L Default Value	**38.7**	**12.1**
	95 per cent confidence interval	1.150	0.405
	Lower	37.5	11.7
	Upper	39.8	12.5

- Comments

Both Coke Oven Gas and Gas Works Gas are coal carbonization by-product and have similar quality.

In 1996 G/L, default NCV of Coke Oven Gas is not shown. And default CCF value in 1996 G/L is questionable because Coke Oven Gas is consisted by more than 50 per cent of Hydrogen and 30 per cent of Methane (14.8 tC/TJ).

No AN-1-NC data are available for Coke Oven Gas, so the author determined default NCV and CCF value in accordance with sample data by JFE Steel Co. and British Steel Co. based on actual measurement and chemical component analysis. Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

b. Blast Furnace Gas

- Quantification: Table 4-2-3-2. Blast Furnace Gas

Blast Furnace Gas		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	66.0
	AN-1-NC average	NA	NA
	Scientific Data, Expert Judgment	2.47	70.8
	2006 G/L Default Value	**2.47**	**70.8**
	95 per cent confidence interval	0.124	3.540
	Lower	2.2	63.7
	Upper	2.7	77.9

- Comments

In 1996 G/L, default NCV of Blast Furnace Gas (BFG) is not shown. And default CCF value in 1996 G/L has a problem that the value shows only "Total Carbon" base emission factor and lacks important information such as "Combustible Carbon" base emission factor.

No AN-1-NC data are available for BFG, so the author determined default NCV and CCF value in accordance with sample data by JFE Steel Co. and British Steel Co. based on actual measurement and chemical component analysis.

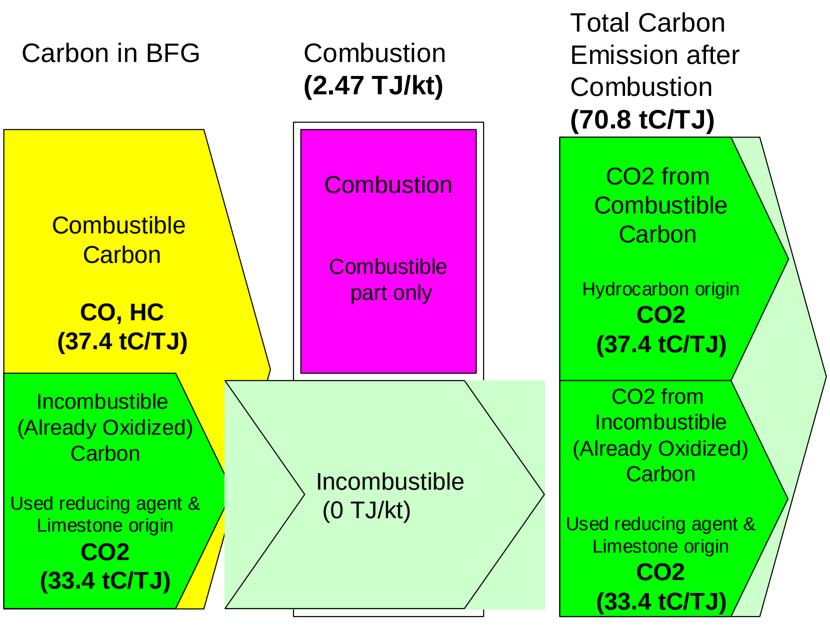
Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

The default NCV value of BFG (2.47 TJ/kt) is relatively very low because more than 50 per cent of BFG is air origin Nitrogen and 20 per cent is Carbon Dioxide already oxidized in the Blast Furnace process.

The default CCF value of BFG (70.8 tC/TJ) shows "Total Carbon" base emission factor that counts total carbon emitted after BFG combustion including already-oxidized carbon dioxide in the Blast Furnace process. "Combustible Carbon" base emission factor of BFG that excludes already-oxidized carbon dioxide in the Blast Furnace process is estimated to be 37.4 tC/TJ. Hence, "Already-Oxidized Carbon" base emission factor for fugitive emission is estimated to be 33.4 tC/TJ (= 70.8 – 37.4 tC/TJ).

Inventory experts should be careful for latent carbon double-counting for BFG with reducing agents and limestone used in Blast Furnace; carbon contained in BFG is a part of originally contained carbon in reducing agents and limestone used in Blast Furnace.

Chart 4-1. Carbon content of BFG



c. **Oxygen Steel Furnace Gas**

- Quantification: Table 4-2-3-3. Oxygen Steel Furnace Gas

Oxygen Steel Furnace Gas		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	NA
	AN-1-NC average	NA	NA
	Scientific Data, Expert Judgment	7.06	49.6
	2006 G/L Default Value	7.06	49.6
	95 per cent confidence interval	0.190	0.169
	Lower	6.9	49.4
	Upper	7.3	49.7

- Comments

In 1996 G/L, no default NCV or CCF of Oxygen Steel Furnace Gas (OSFG) is shown.

No AN-1-NC data are available for BFG, so the author determined default NCV and CCF value in accordance with sample data by JFE Steel Co. and British Steel Co. based on actual measurement and chemical component analysis.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

The default NCV value of OSFG (7.06 TJ/kt) is relatively very low because more than 70 per cent of OSFG is Carbon Monoxide and about 15 per cent is Carbon Dioxide already-oxidized in the Oxygen Steel Furnace process.

The default CCF value of OSFG (49.6 tC/TJ) shows "Total Carbon" base emission factor that counts total carbon emitted after OSFG combustion including already-oxidized carbon dioxide in the Oxygen Steel Furnace process. "Combustible Carbon" base emission factor of OSFG that excludes already-oxidized carbon dioxide in the Blast Furnace process is estimated to be 40.7 tC/TJ. Hence, "Already-Oxidized Carbon" base emission factor for fugitive emission is estimated to be 8.85 tC/TJ (= 49.6 – 40.7 tC/TJ).

Inventory experts should be careful for latent carbon double-counting for OSFG and reducing agents used in Blast Furnace such as Coke Oven Coke; carbon contained in OSFG is originally contained reducing agents used in Blast Furnace[5].

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[5] Almost all carbon contained in OSFG comes from non-organic carbon dissolved in pig-iron. But its origin is reducing agents used in Blast Furnace to make pig-iron.

The author neglects inter-exchange of limestone or dolomite origin carbon and reducing agent origin carbon in Oxygen Steel Furnace in order to avoid unnecessary complexity.

4-3. Gaseous Fossil Origin

4-3-1. Primary Fuels

a. Natural Gas (Dry-)

- Quantification: Table 4-3-1-1. Natural Gas (Dry-)

Natural Gas (Dry-)		NCV	CCF
		TJ/kt	tC/TJ
	1996 G/L Default Value	NA	15.3
	AN-1-NC average	48.0	15.3
	Sample number; N	10.0	10.0
	Standard Deviation	1.041	0.275
	t-value	NA	-0.173
	t(N-1, 0.95)	1.812	1.697
	Scientific Data, Expert Judgment	NA	NA
	2006 G/L Default Value	**48.0**	**15.3**
	95 per cent confidence interval	0.645	0.170
	Lower	46.5	15.0
	Upper	50.4	16.1

- Comments

The author quantified NCV and CCF of Natural Gas as 48.0 TJ/kt and 15.3 tC/TJ in 10 AN-1-NC consistent samples.

In 1996 G/L, no default NCV of Natural Gas have been shown, so the author determined default NCV value as 48.0 TJ/kt.

The result of t-test in CCF shows that no significant difference are seen in 1996 G/L default value and AN-1-NC average data.

4-4. Other Fossil Origin / Waste Fuels

4-4-1. Primary Fuels

a. Municipal Waste (non-biomass fraction and its mixture), Industrial Waste

- Comments

In 1996 G/L, neither NCV nor CCF default values for Municipal Waste and Industrial Waste have been shown. And no AN-1-NC data are available.

The author found CCF sample data in EFDB, but found no NCV data in EFDB or some adequate literature.

The Waste fuels often have a wide variety of their components in accordance with social, economical and climate conditions of countries, especially their moisture and incombustible content such as sand, glass, ceramics, metal have so widely varied that NCV have large divergence. But combustible parts of Waste fuels are often consisted by large part of plastics and small part of biomass mixture, so CCFs are supposed to have a convergence to some extent.

The author estimated only CCF value (34.1 tC/TJ) for Municipal Waste (non-biomass fraction) and CCF value (46.4 tC/TJ) for Industrial Waste based on EFDB sample data[6] and filled "NA" for NCV values. These CCF values are larger than any kind of fossil origin primary fuels because the original EFDB value assumes "Wet-base" wastes that contain certain part of moisture.

Hence, NCV for non-biomass fraction of Waste shall be quantified by inventory officials of counties by themselves.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

Inventory experts should be careful that these values are applicable only for non-biomass fraction and its mixture; pure biomass fraction of wastes such as separately collected waste paper and waste wood from other garbage should be quantified as "Municipal waste (biomass fraction)".

b. Waste Oil

- Comments

In 1996 G/L, neither NCV nor CCF default values for Waste Oil have been shown. And no AN-1-NC data are available.

The author estimated NCV and CCF of Waste Oil in accordance with the value of Lubricants (40.2 TJ/kt, 20.0 tC/TJ) by expert judgement, based on the fact that major source of Waste Oil is used Lubricants.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

4-5. Solid Biomass Origin

4-5-1. Primary Fuels

a. Wood/Wood Waste

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Wood/Wood Waste. And no AN-1-NC data are available.

The author estimated NCV and CCF (15.6 TJ/kg, 30.7 tC/TJ) for Wood/Wood Waste

[6]* At present, there are no distinction between fossil fuel origin carbon and biomass origin carbon in EFDB sample data, so the author just applied CCF for Municipal Waste (non-renewable fraction and its mixture). Inventory officials should be careful for the latent double-counting.

based on sample data in EFDB.

The values for Wood/Wood Waste are estimated from small number of sample data, so the confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

b. Sulphite Lyes (Black Liquar)

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Sulphite Lyes (Black Liquar). And no AN-1-NC data are available.

The author estimated NCV (11.8 TJ/kt) from recent Japanese Energy Statistics data and estimated CCF (30.7 tC/TJ) from Wood/Wood Waste data by expert judgement, because Sulphite Lyes (Black Liquar) is a dense Lignin solution recovered from Kraft Pulp production process, with moisture content 25 to 32 per cent.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

c. Other Solid Biomass

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Other Solid Biomass.

The author estimated that NCV and CCF of Other Solid Biomass are same as “Solid Biomass” in AN-1-NC data.

The author found 7 sample data in AN-1-NC, average NCV and CCF are 11.6 TJ/kt and 27.4 tC/TJ. Their standard deviations are 3.992 for NCV and 2.996 for CCF.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

4-5-2. Secondary Fuels / Products

a. Charcoal

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Charcoal. And no AN-1-NC data are available.

The author estimated NCV (29.5 TJ/kt) from sample data in EFDB, and estimated CCF (30.7 tC/TJ) from Wood/Wood Waste data because Charcoal is produced carbonization of Wood and its major component is solid Carbon (30.5 tC/TJ).

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

4-6. Liquid and Gas Biomass Origin

4-6-1. Liquid Biomass

a. Biogasoline, Biodiesels

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Biogasoline and/or Biodiesels. And no AN-1-NC data are available.

The author estimated NCV and CCF for Biogasoline and Biodiesels from theoretical value of Ethanol by its enthalpy of formation (27.0 TJ/kt, 19.3 tC/TJ).

Biogasoline and Biodiesel are often mixture of conventional Gasoline or Gas / Diesel Oil and Ethanol or other bio-origin liquids, so activity data for these bio-origin fuels should be quantified only for the mass of Ethanol or other bio-origin liquids.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

b. Other Liquid Biomass

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Other Liquid Biomass.

The author estimated that NCV and CCF of Other Liquid Biomass are same as "Liquid Biomass" in AN-1-NC data.

The author found 10 sample data in AN-1-NC, average NCV and CCF are 27.4 TJ/kt and 21.7 tC/TJ, and standard deviations are 6.339 and 3.456.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

The author show theoretical NCV and CCF for Methanol are 20.1 TJ/kt and 18.6 tC/TJ, and theoretical NCV and CCF for Ethanol are 27.0 TJ/kt and 19.3 tC/TJ by their enthalpy of formation.

4-6-2. Gas Biomass

a. Landfill Gas, Sludge Gas, Other Biogas

- Comments

In 1996 G/L, no default NCV value has been shown for Gas Biomass, and default CCF of Bio-methane (30.6 tC/TJ) is questionable because the value includes carbon dioxide emission during the methane fermentation process.

The author estimated NCV and CCF for Landfill Gas, Sludge Gas and Other Biogas from theoretical value of Methane by its enthalpy of formation (50.4 TJ/kt, 14.9 tC/TJ[7]).

Biogas are often mixture of Carbon Dioxide formed by fermentation process and

[7] The present default CCF for Gas Biomass (Methane, 30.6 tC/TJ) includes double-counting carbon parts with methane fermentation process CO2 emission. The author thinks that such fermentation process emission shall be counted to the industrial process sector or waste sector. For example, present way shall cause serious double counting problem when we suppose a case of Methane recovery from waste water processing facility or land-filling deposit; CO2 emissions associated with methane fermentation in these facility or deposit are already counted in Waste sector "6A or 6B".

Methane, so activity data for these Biogas should be quantified only for the mass of Methane.

4-7. Other Biomass Origin

4-7-1. Primary Fuels

a. Municipal Waste (biomass origin)

- Comments

In 1996 G/L, neither NCV nor CCF has been shown for Municipal waste (biomass origin). And no AN-1-NC data are available.

The author estimated NCV (11.6 TJ/kt) and CCF (27.4 tC/TJ) from “Other Solid Biomass” data, because this category assumes pure biomass fraction of waste consisted from paper, wood and their derived products, such as separately collected waste paper and waste wood from other garbage.

Confidence intervals (5 per cent) and Lower/Upper ranges (plus / minus 10 per cent) are estimated by expert judgement.

5. Carbon Oxidization Factor: COF

5-1. Default COF

In 1996 G/L, default COF of fossil origin fuels has been determined from 0.98 to 0.995.

The IPCC-NGGIP Moscow Energy Expert Meeting in July 2005 has decided to set all COF as 1.00 because the revised COF contributes very small portion for uncertainty.

Hereafter the author explains the process of COF revision.

Inventory officials should be careful that default COF for all fuels should be 1.00, or just quantify Carbon Dioxide emission by multiplying activity data in NCV, CCF and 44/12.

5-2. Fossil Origin

The author quantified COF in similar ways with NCV and CCF, using AN-1-NC sample data as a basis.

The author found that some Annex-1 country just uses the default value or more likely value, but others use 1.000 and assume perfect oxidization. In case of Japan, hydrocarbon or soot emissions from certain scale of facilities and motor vehicles are severely regulated by air-pollution prevention lows and so many facilities and major portion of motor-vehicles equip after treatment systems such as boiler soot separator and recirculation system or three-way catalytic converter system, so carbon oxidization factor in Japan can be estimated to be 1.000 by fair reason.

Reflecting that consistency of default NCV, CCF and COF are very important, the author quantified average, Lower and Upper range of COF for each fuel based on AN-1-NC data.

The author estimated COF for fossil origin fuels that no COF data available in AN-1-NC, based on analogical estimates from similar existing fuels that COF data are available; for example, COF of Blast Furnace Gas is estimated based on the value of Natural Gas (Dry-).

In such cases that COF values are estimated by expert judgement above, the author filled in “NA” in the Upper and Lower column to indicate that the value shall contain unknown level of uncertainty. This mean, the uncertainty level exceeds 10 per cent.

5-3. Biomass Origin

The author estimated COF for biomass origin fuels based on similar existing fuels; for example, COF of Charcoal is estimated to be the same level of Coke Oven Coke.

In cases that COF values are estimated by such expert judgement, the author filled in “NA” in the Coefficient of Variation, Upper and Lower column to indicate that the value shall contain unknown level of uncertainty. This mean, the uncertainty level exceeds 10 per cent.

6. Summary of Quantification Results

6-1. Quantification Results

The author attaches Annex tables for NCV, CCF, and COF; Table 6-1 to 6-3.

Be careful that COF table is shown just for reference and should NOT be quoted for use in inventory quantification.

6-2. NCV and CCF Correlation

The author checked NCV and CCF correlations. See Figure 6-1 and Figure 6-2.

As explained in 4-2-3, coal delivered gas such as BFG shows large anomaly because they contain already-oxidized carbon dioxide. The author excluded these coal delivered gas and grouped fuel type by high- and Low- hydrogen, moisture, ash and sulphur content in Figure 6-2.

Table 6-1. Net Calorific Value (NCV)							
	Values	PR/	NCV	TJ/kt			
Fuel type		Prima	Default N	Lower	Upper	Revi	Note
English Description							
Crude Oil		Yes	42.3	40.1	44.8	NW	
Orimulsion		Yes	27.5	27.5	28.3	- -	
Natural Gas Liquids		Yes	44.2	40.9	46.9	NW	
Gasoline	Motor Gasoline	No	44.3	42.5	44.8	RV.	
	Aviation Gasoline	No	44.3	42.5	44.8	-	
	Jet Gasoline	No	44.3	42.5	44.8	-	
Jet Kerosene		No	44.1	42.0	45.0	RV.	
Other Kerosene		No	43.8	42.4	45.2	RV.	
Shale Oil		No	36.0	36.0	44.0	- -	
Gas/Diesel Oil		No	43.0	41.4	43.3	RV.	
Residual Fuel Oil		No	40.4	39.8	41.7	RV.	
Liquefied Petroleum Gases		No	47.3	44.8	52.2	- -	
Ethane		No	46.4	40.2	47.5	RV.	
Naphtha		No	44.5	41.8	46.5	RV.	
Bitumen		No	40.2	33.5	41.2	- -	
Lubricants		No	40.2	33.5	42.3	- -	
Petroleum Coke		No	32.5	29.7	41.9	RV.	
Refinery Feedstocks		No	43.0	30.6	46.4	RV.	
Other Oil	Refinery Gas	No	49.5	NA	NA	NW	Estimated from Japanese sample data
	Paraffin Waxes	No	40.2	33.7	48.2	- -	
	White Spirit & SBP	No	40.2	33.7	48.2	- -	
	Other Petroleum Products	No	40.2	33.7	48.2	- -	
Anthracite		Yes	26.7	21.6	32.2	NW	
Coking Coal		Yes	28.2	21.6	31.0	NW	
Other Bituminous Coal		Yes	25.8	19.9	30.5	NW	
Sub-Bituminous Coal		Yes	18.9	11.5	26.0	NW	
Lignite		Yes	11.9	5.5	21.6	NW	
Oil Shale and Tar Sands		Yes	9.40	7.27	9.60	- -	
Peat		Yes	9.76	7.79	12.5	NW	
Brown Coal Briquettes		No	20.7	15.1	32.0	NW	
Patent Fuel		No	20.7	15.1	32.0	NW	
Coke	Coke Oven Coke and Lignit	No	28.2	25.1	30.2	NW	
	Gas Coke	No	28.2	25.1	30.2	NW	
Coal Tar		No	28.0	NA	NA	RV.	Estimated from EFDB data
Derived G	Gas Works Gas	No	38.7	NA	NA	NW	Estimated from Coke Oven Gas value
	Coke Oven Gas	No	38.7	NA	NA	NW	Estimated from Japan & UK sample data
	Blast Furnace Gas	No	2.47	NA	NA	NW	Estimated from Japan & UK sample data
	Oxygen Steel Furnace Gas	No	7.06	NA	NA	NW	Estimated from Japan & UK sample data
Natural Gas		Yes	48.0	46.5	50.4	NW	
Municipal Wastes (non-biomass and bi		Yes	x			x	
Industrial Wastes		Yes	x			x	
Waste Oil		No	40.2	NA	NA	NW	Estimated from Lubricants value
Solid Biofu	Wood/Wood Waste	Yes	15.6	NA	NA	NW	Estimated from EFDB data
	Sulphite lyes (Black Liquor)	Yes	11.8	NA	NA	NW	Estimated from Japanese sample data
	Other Primary Solid Biomas	Yes	11.6	NA	NA	NW	Estimated from Solid Biomass value
	Charcoal	No	29.5	NA	NA	NW	Estimated from EFDB data
Liquid Biof	Biogasoline	Yes	27.0	NA	NA	NW	Estimated from Ethanol theoretical value
	Biodiesels	Yes	27.0	NA	NA	NW	Estimated from Ethanol theoretical value
	Other Liquid Biofuels	Yes	27.4	NA	NA	NW	Estimated from Liquid Biomass value
Gas Bioma	Landfill Gas	Yes	50.4	NA	NA	NW	Estimated from Methane theoretical value
	Sludge Gas	Yes	50.4	NA	NA	NW	Estimated from Methane theoretical value
	Other Biogas	Yes	50.4	NA	NA	NW	Estimated from Methane theoretical value
Other non	Municipal Wastes (renewable	Yes	11.6	NA	NA	NW	Estimated from Solid Biomass value

Table 6-2. Carbon Content Factor (CCF)

	Values	PR/	CCF	tC/TJ			
Fuel type		Prima	Default (	Lower	Upper	Revi	Note
English Description							
Crude Oil		Yes	**20.0**	18.7	20.5	--	
Orimulsion		Yes	**21.0**	19.6	22.0	RV.	
Natural Gas Liquids		Yes	**17.2**	16.5	20.4	--	
Gasoline	Motor Gasoline	No	**19.2**	18.7	20.2	RV.	
	Aviation Gasoline	No	**19.2**	18.7	20.2	RV.	
	Jet Gasoline	No	**19.2**	18.7	20.2	RV.	
Jet Kerosene		No	**19.7**	19.3	21.0	RV.	
Other Kerosene		No	**19.7**	19.5	20.1	RV.	
Shale Oil		No	**20.0**	18.9	21.1	--	
Gas/Diesel Oil		No	**20.1**	19.7	20.3	RV.	
Residual Fuel Oil		No	**21.1**	20.3	21.5	--	
Liquefied Petroleum Gases		No	**17.4**	17.1	18.0	RV.	
Ethane		No	**16.8**	16.2	22.0	--	
Naphtha		No	**19.8**	18.1	20.2	RV.	
Bitumen		No	**22.0**	20.0	28.1	--	
Lubricants		No	**20.0**	19.9	21.2	--	
Petroleum Coke		No	**26.7**	20.2	28.1	RV.	
Refinery Feedstocks		No	**20.0**	18.2	20.5	--	
Other Oil	Refinery Gas	No	**15.7**	NA	NA	RV.	Estimated from Japanese sample data
	Paraffin Waxes	No	**20.0**	19.6	20.5	--	
	White Spirit & SBP	No	**20.0**	19.6	20.5	--	
	Other Petroleum Products	No	**20.0**	19.6	20.5	--	
Anthracite		Yes	**26.8**	25.3	26.9	--	
Coking Coal		Yes	**25.8**	24.0	29.5	--	
Other Bituminous Coal		Yes	**25.8**	23.5	27.6	--	
Sub-Bituminous Coal		Yes	**26.2**	25.5	27.6	--	
Lignite		Yes	**27.6**	24.7	34.0	--	
Oil Shale and Tar Sands		Yes	**29.1**	NA	NA	RV.	Estimated from too small number of data
Peat		Yes	**28.9**	28.32	29.6	--	
Brown Coal Briquettes		No	**26.6**	25.2	30.4	RV.	
Patent Fuel		No	**26.6**	25.2	30.4	RV.	
Coke	Coke Oven Coke and Lignit	No	**29.5**	23.7	32.6	--	
	Gas Coke	No	**29.5**	23.7	32.6	--	
Coal Tar		No	**22.0**	NA	NA	NW	Estimated from Bitumen value
Derived G	Gas Works Gas	No	**12.1**	NA	NA	NW	Estimated from Coke Oven Gas value
	Coke Oven Gas	No	**12.1**	NA	NA	RV.	Estimated from Japan & UK sample data
	Blast Furnace Gas	No	**70.8**	NA	NA	RV.	Estimated from Japan & UK sample data
	Oxygen Steel Furnace Gas	No	**49.6**	NA	NA	NW	Estimated from Japan & UK sample data
Natural Gas		Yes	**15.3**	15.0	16.1	--	
Municipal Wastes (non-biomass and bi		Yes	**34.1**	NA	NA	NW	Estimated from EFDB data
Industrial Wastes		Yes	**46.4**	NA	NA	NW	Estimated from EFDB data
Waste Oil		No	**20.0**	NA	NA	NW	Estimated from Lubricants value
Solid Biofu	Wood/Wood Waste	Yes	**30.7**	NA	NA	NW	Estimated from EFDB data
	Sulphite lyes (Black Liquor)	Yes	**30.7**	NA	NA	NW	Estimated from Wood, Wood Waste value
	Other Primary Solid Biomas	Yes	**27.4**	NA	NA	NW	Estimated from Solid Biomass value
	Charcoal	No	**30.7**	NA	NA	RV.	Estimated from Wood, Wood Waste value
Liquid Biof	Biogasoline	Yes	**19.3**	NA	NA	NW	Estimated from Ethanol value
	Biodiesels	Yes	**19.3**	NA	NA	NW	Estimated from Ethanol value
	Other Liquid Biofuels	Yes	**21.7**	NA	NA	NW	Estimated from Liquid Biomass value
Gas Bioma	Landfill Gas	Yes	**14.9**	NA	NA	NW	Estimated from Methane theoretical value
	Sludge Gas	Yes	**14.9**	NA	NA	NW	Estimated from Methane theoretical value
	Other Biogas	Yes	**14.9**	NA	NA	NW	Estimated from Methane theoretical value
Other non	Municipal Wastes (renewabl	Yes	**27.4**	NA	NA	NW	Estimated from Solid Biomass value

Table 6-3. Carbon Oxidization Factor(COF) / ONLY FOR REFERENCE, DO NOT CITE NOR QUOTE

	Values	PR/	COF	-			
Fuel type		Prima	Carbon (	Lower	Upper	Revi	Note
English Description							
Crude Oil		Yes	0.992	0.990	1.000	RV.	
Orimulsion		Yes	0.992	0.990	1.000	RV.	
Natural Gas Liquids		Yes	0.993	0.990	1.000	RV.	
Gasoline	Motor Gasoline	No	0.992	0.990	1.000	RV.	
	Aviation Gasoline	No	0.992	0.990	1.000	RV.	
	Jet Gasoline	No	0.992	0.990	1.000	RV.	
Jet Kerosene		No	0.992	0.990	1.000	RV.	
Other Kerosene		No	0.992	0.990	1.000	RV.	
Shale Oil		No	0.991	0.980	1.000	--	
Gas/Diesel Oil		No	0.992	0.990	1.000	RV.	
Residual Fuel Oil		No	0.992	0.980	1.000	RV.	
Liquefied Petroleum Gases		No	0.993	0.990	1.000	RV.	
Ethane		No	0.993	0.990	1.000	RV.	
Naphtha		No	0.993	0.990	1.000	RV.	
Bitumen		No	0.993	0.990	1.000	RV.	
Lubricants		No	0.993	0.990	1.000	RV.	
Petroleum Coke		No	0.993	0.980	1.000	RV.	
Refinery Feedstocks		No	0.992	0.990	1.000	RV.	
Other Oil	Refinery Gas	No	0.996	NA	NA	NW	Estimated from Natural Gas value
	Paraffin Waxes	No	0.992	0.990	1.000	RV.	
	White Spirit & SBP	No	0.992	0.990	1.000	RV.	
	Other Petroleum Products	No	0.992	0.990	1.000	RV.	
Anthracite		Yes	0.985	0.980	1.000	RV.	
Coking Coal		Yes	0.984	0.980	1.000	RV.	
Other Bituminous Coal		Yes	0.985	0.980	1.000	RV.	
Sub-Bituminous Coal		Yes	0.983	0.980	1.000	RV.	
Lignite		Yes	0.984	0.980	1.000	RV.	
Oil Shale and Tar Sands		Yes	0.986	0.980	1.000	RV.	
Peat		Yes	0.985	0.950	1.000	--	
Brown Coal Briquettes		No	0.986	0.970	1.000	RV.	
Patent Fuel		No	0.986	0.970	1.000	RV.	
Coke	Coke Oven Coke and Lignit	No	0.984	0.970	1.000	RV.	
	Gas Coke	No	0.984	0.970	1.000	RV.	
Coal Tar		No	0.993	NA	NA	NW	Estimated from Bitumen value
Derived Ga	Gas Works Gas	No	0.996	NA	NA	NW	Estimated from Natural Gas value
	Coke Oven Gas	No	0.996	NA	NA	NW	Estimated from Natural Gas value
	Blast Furnace Gas	No	0.996	NA	NA	NW	Estimated from Natural Gas value
	Oxygen Steel Furnace Gas	No	0.996	NA	NA	NW	Estimated from Natural Gas value
Natural Gas		Yes	0.996	0.995	1.000	RV.	
Municipal Wastes (non-biomass and bio		Yes	0.975	NA	NA	NW	Estimated from Solid Biomass value
Industrial Wastes		Yes	0.975	NA	NA	NW	Estimated from Solid Biomass value
Waste Oil		No	0.993	NA	NA	NW	Estimated from Lubricants value
Solid Biofu	Wood/Wood Waste	Yes	0.975	NA	NA	NW	Estimated from Solid Biomass value
	Sulphite lyes (Black Liquor)	Yes	0.975	NA	NA	NW	Estimated from Solid Biomass value
	Other Primary Solid Biomas	Yes	0.975	NA	NA	NW	Estimated from Solid Biomass value
	Charcoal	No	0.984	0.970	1.000	NW	Estimated from Coke Oven Coke value
Liquid Biof	Biogasoline	Yes	0.986	NA	NA	NW	Estimated from Liquid Biomass value
	Biodiesels	Yes	0.986	NA	NA	NW	Estimated from Liquid Biomass value
	Other Liquid Biofuels	Yes	0.986	NA	NA	NW	Estimated from Liquid Biomass value
Gas Bioma	Landfill Gas	Yes	0.990	NA	NA	NW	Estimated from Gas Biomass value
	Sludge Gas	Yes	0.990	NA	NA	NW	Estimated from Gas Biomass value
	Other Biogas	Yes	0.990	NA	NA	NW	Estimated from Gas Biomass value
Other non	Municipal Wastes (renewabl	Yes	0.975	NA	NA	NW	Estimated from Solid Biomass value

Figure 6-1: NCV – CCF Correlation / All Fuels

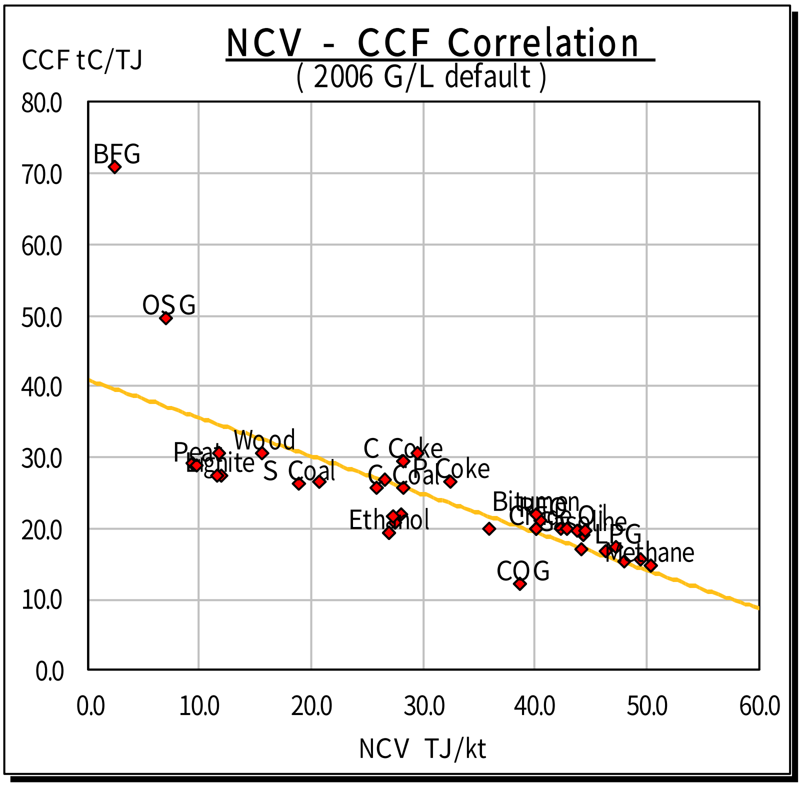
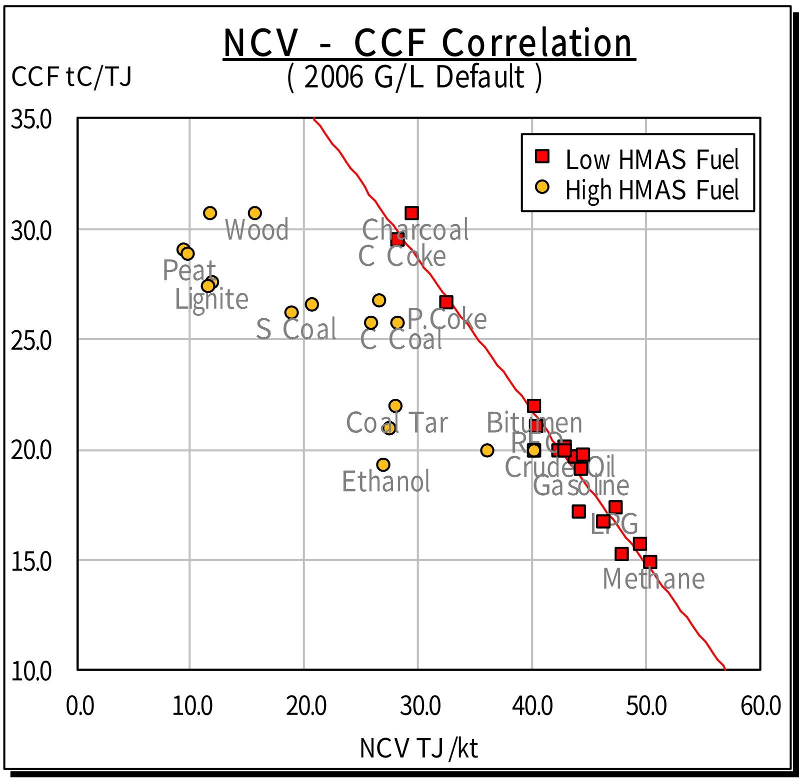


Figure 6-2: NCV – CCF Correlation / Low- and High- Hydrogen, Moisture, Ash and Sulphur Fuel



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