The Nautilus Institute
for Security and Sustainability

FUELING DPRK ENERGY FUTURES AND ENERGY SECURITY:
2005 ENERGY BALANCE, ENGAGEMENT OPTIONS, AND FUTURE PATHS

ATTACHMENTS

WORKPAPERS, BACKGROUND DATA, AND DETAILED RESULTS

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The Nautilus Institute for Security and Sustainability, in Collaboration with the Korea Energy Economics Institute

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ATTACHMENTS 1 AND 2

WORKPAPERS, BACKGROUND DATA, AND DETAILED RESULTS:

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES FOR THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK) AND RELATED ENERGY SECTOR AND POLLUTANT EMISSIONS ANALYSES

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Detailed, Petroleum Product, and Summary Energy Balances

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ESTIMATED ENERGY BALANCE FOR THE YEAR 1990

Prepared By David Von Hippel
Date Last Modified: 3/12/2007

UNITS: TERAJOULES (TJ)	COAL & COKE	CRUDE OIL	REFINED PROD.	HYDRO/ NUCLEAR	WOOD/ BIOMASS	CHARCOAL	ELECTRICITY	**TOTAL**
ENERGY SUPPLY	1,329,590	110,742	26,604	80,447	159,327	-	(12,403)	1,694,306
Domestic Production	1,291,601	-		80,447	147,327			1,519,374
Imports	68,392	110,742	26,604		12,000			217,738
Exports	30,403						12,403	42,806
Inputs to International Marine Bunkers								-
Stock Changes								-
ENERGY TRANSFORMATION	(387,402)	(110,742)	82,864	(79,974)	(6,933)	2,080	128,062	(372,046)
Electricity Generation	(308,765)		(21,922)	(79,974)			172,800	(237,860)
Petroleum Refining		(110,742)	104,786				(593)	(6,550)
Coal Production/Preparation	(62,622)						(8,481)	(71,103)
Charcoal Production					(6,933)	2,080		(4,853)
Coke Production								-
Other Transformation								-
Own Use							(12,959)	(12,959)
Losses	(16,016)						(22,705)	(38,721)
FUELS FOR FINAL CONSUMPTION	942,187	-	109,468	473	152,393	2,080	115,659	1,322,260
ENERGY DEMAND	942,132	-	109,363	473	152,454	2,061	115,617	1,322,100
INDUSTRIAL SECTOR	643,061	-	28,493	-	5,626	-	65,392	742,573
Iron and Steel	324,615						17,388	342,003
Cement	68,139		7,571				4,356	80,065
Fertilizers	23,994		4,573				18,891	47,458
Other Chemicals	11,203						6,616	17,819
Pulp and Paper	4,026				4,026		932	8,985
Other Metals	23,720						4,126	27,846
Other Minerals	-		12,600				396	12,996
Textiles	29,385						2,497	31,882
Building Materials	61,980						189	62,169
Non-specified Industry	96,000		3,750		1,600		10,000	111,350
TRANSPORT SECTOR	-	-	37,827	-	1,818	-	11,470	51,115
Road			32,502		1,818			34,319
Rail	-		1,949				10,870	12,819
Water	-		1,253					1,253
Air			1,123					1,123
Non-Specified			1,000				600	1,600
RESIDENTIAL SECTOR	201,666	-	6,600	-	86,140	2,061	10,718	307,185
Urban	141,547		6,256			1,134	7,420	156,357
Rural	60,119		344		86,140	928	3,298	150,828
AGRICULTURAL SECTOR	9,750	-	5,005	-	44,950	-	2,572	62,277
Field Operations			2,619				907	3,526
Processing/Other	9,750		2,386		44,950		1,664	58,750
FISHERIES SECTOR	1,132	-	3,137	-	-	-	524	4,794
Large Ships	-		2,681					2,681
Collectives/Processing/Other	1,132		456				524	2,112
MILITARY SECTOR	29,825	-	16,444	-	-	-	14,008	60,277
Trucks and other Transport			6,585					6,585
Armaments			263					263
Air Force			2,648					2,648
Naval Forces			6,847					6,847
Military Manufacturing	887						48	935
Buildings and Other	28,938		100				13,960	42,998
PUBLIC/COMMERCIAL SECTORS	38,407		192		1,920		10,932	51,451
NON-SPECIFIED/OTHER SECTORS			5,900	473				6,373
NON-ENERGY USE	18,290		5,764		12,000			36,054
Electricity Gen. (Gross TWhe)	24.51		1.28	22.21				48.00

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ESTIMATED ENERGY BALANCE FOR THE YEAR 1996

Prepared By David Von Hippel
Date Last Modified: **4/4/2007**

UNITS: TERAJOULES (TJ)	COAL & COKE	CRUDE OIL	REFINED PROD.	HYDRO/ NUCLEAR	WOOD/ BIOMASS	CHARCOAL	ELECTRICITY	**TOTAL**
ENERGY SUPPLY	654,213	39,874	32,395	19,993	146,925	-	(3,473)	889,928
Domestic Production	643,476	-		19,993	134,928			798,397
Imports	11,614	39,874	39,057		12,000			102,545
Exports	876				4		3,473	4,353
Inputs to International Marine Bunkers								-
Stock Changes			6,661					6,661
ENERGY TRANSFORMATION	(244,763)	(39,874)	12,259	(19,993)	(5,096)	1,529	52,241	(243,699)
Electricity Generation	(206,369)		(25,351)	(19,993)			82,675	(169,039)
Petroleum Refining		(39,874)	39,874				(213)	(213)
Coal Production/Preparation	(30,574)						(4,141)	(34,715)
Charcoal Production					(5,096)	1,529		(3,567)
Coke Production								-
Other Transformation								-
Own Use			(2,264)				(10,124)	(12,388)
Losses	(7,820)						(15,957)	(23,777)
FUELS FOR FINAL CONSUMPTION	409,450	-	44,654	-	141,829	1,529	48,768	646,229
ENERGY DEMAND	409,392	-	44,647	-	141,857	1,532	48,792	646,221
INDUSTRIAL SECTOR	236,988	-	8,694	-	1,857	-	21,910	269,449
Iron and Steel	124,977						6,694	131,671
Cement	29,981		3,331				1,917	35,229
Fertilizers	6,515		1,129				5,130	12,774
Other Chemicals	3,697		-				2,183	5,880
Pulp and Paper	1,329				1,329		308	2,965
Other Metals	7,828						1,362	9,189
Other Minerals	832		3,326				131	4,289
Textiles	9,697						824	10,521
Building Materials	20,453						62	20,516
Non-specified Industry	31,680		908		528		3,300	36,416
TRANSPORT SECTOR	-	-	16,415	-	872	-	4,828	22,115
Road			14,235		872			15,108
Rail	-		779				4,828	5,607
Water	-		501					501
Air			899					899
Non-Specified			-				-	-
RESIDENTIAL SECTOR	106,974	-	1,946	-	102,471	1,532	6,416	219,340
Urban	77,175		1,861			843	4,781	84,660
Rural	29,799		85		102,471	690	1,635	134,679
AGRICULTURAL SECTOR	5,155	-	1,502	-	23,767	-	1,697	32,121
Field Operations			786				816	1,602
Processing/Other	5,155		716		23,767		880	30,518
FISHERIES SECTOR	509	-	998	-	-	-	236	1,743
Large Ships	-		804					804
Collectives/Processing/Other	509		193				236	939
MILITARY SECTOR	26,696	-	13,222	-	2,833	-	7,711	50,462
Trucks and other Transport			5,734					5,734
Armaments			211					211
Air Force			1,985					1,985
Naval Forces			5,198					5,198
Military Manufacturing	621		-				33	654
Buildings and Other	26,074		95		2,833		7,678	36,681
PUBLIC/COMMERCIAL SECTORS	28,555		143		2,855		5,994	37,547
NON-SPECIFIED/OTHER SECTORS			-	-				-
NON-ENERGY USE	4,515		1,729		7,200			13,444
Electricity Gen. (Gross TWhe)*	16.50		0.91	5.55				22.97

**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ESTIMATED ENERGY BALANCE FOR THE YEAR 2000

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

UNITS: TERAJOULES (TJ)	COAL & COKE	CRUDE OIL	REFINED PROD.	HYDRO/ NUCLEAR	WOOD/ BIOMASS	CHARCOAL	ELECTRICITY	**TOTAL**
ENERGY SUPPLY	325,208	17,857	41,722	36,822	148,156	-	(82)	569,683
Domestic Production	326,129	1,278		36,822	136,145			500,374
Imports	8,397	16,579	44,730		12,012		-	81,718
Exports	9,318		3,009		1		82	12,409
Inputs to International Marine Bunkers								-
Stock Changes			-					-
ENERGY TRANSFORMATION	(50,381)	(17,857)	(1,096)	(36,822)	(4,091)	1,227	30,296	(78,724)
Electricity Generation	(30,922)		(16,949)	(36,822)			46,863	(37,830)
Petroleum Refining		(17,857)	16,867				(105)	(1,095)
Coal Production/Preparation	(15,496)						(2,099)	(17,594)
Charcoal Production					(4,091)	1,227		(2,863)
Coke Production								-
Other Transformation								-
Own Use			(1,014)				(1,900)	(2,914)
Losses	(3,963)						(12,464)	(16,427)
FUELS FOR FINAL CONSUMPTION	274,826	-	40,626	-	144,066	1,227	30,214	490,959
ENERGY DEMAND	274,761	-	40,623	-	144,052	1,227	30,138	490,800
INDUSTRIAL SECTOR	145,536	-	11,154	-	1,168	-	11,961	169,819
Iron and Steel	67,382						3,609	70,991
Cement	19,720		6,399				1,503	27,623
Fertilizers	2,070		343				1,629	4,042
Other Chemicals	2,325		-				1,373	3,699
Pulp and Paper	836				836		194	1,865
Other Metals	4,924						857	5,780
Other Minerals	869		3,478				137	4,484
Textiles	6,100						518	6,618
Building Materials	21,383						65	21,448
Non-specified Industry	19,927		934		332		2,076	23,269
TRANSPORT SECTOR	-	-	9,111	-	545	-	3,153	12,809
Road			7,220		545			7,765
Rail	-		585				3,153	3,738
Water	-		464					464
Air			843					843
Non-Specified			-				-	-
RESIDENTIAL SECTOR	85,117	-	2,869	-	109,518	1,227	2,589	201,319
Urban	59,639		2,577			637	2,239	65,092
Rural	25,478		291		109,518	590	349	136,227
AGRICULTURAL SECTOR	3,845	-	1,251	-	19,943	-	1,296	26,335
Field Operations			655				680	1,335
Processing/Other	3,845		596		19,943		615	25,000
FISHERIES SECTOR	423	-	828	-	-	-	196	1,447
Large Ships	-		668					668
Collectives/Processing/Other	423		161				196	779
MILITARY SECTOR	23,095	-	12,541	-	3,803	-	7,560	46,999
Trucks and other Transport			4,926					4,926
Armaments			172					172
Air Force			1,703					1,703
Naval Forces			5,654					5,654
Military Manufacturing	399		-				21	421
Buildings and Other	22,696		85		3,803		7,538	34,122
PUBLIC/COMMERCIAL SECTORS	15,373		77		3,075		3,383	21,908
NON-SPECIFIED/OTHER SECTORS			-	-				-
NON-ENERGY USE	1,372		2,793		6,000			10,165
Electricity Gen. (Gross TWhe)*	2.64		0.15	10.23				13.02

**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ESTIMATED ENERGY BALANCE FOR THE YEAR 2005

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

UNITS: TERAJOULES (TJ)	COAL & COKE	CRUDE OIL	REFINED PROD.	HYDRO/ NUCLEAR	WOOD/ BIOMASS	CHARCOAL	ELECTRICITY	**TOTAL**
ENERGY SUPPLY	405,139	23,547	17,217	33,351	162,363	-	(60)	641,556
Domestic Production	480,217	1,278		33,351	150,381			665,227
Imports	4,852	22,270	17,403		12,001		265	56,790
Exports	79,931		186		19		325	80,461
Inputs to International Marine Bunkers								-
Stock Changes			-					-
ENERGY TRANSFORMATION	(116,579)	(23,547)	17,427	(32,878)	(4,229)	1,269	37,406	(121,132)
Electricity Generation	(87,927)		(4,748)	(32,878)			59,588	(65,965)
Petroleum Refining		(23,547)	23,512					(35)
Coal Production/Preparation	(22,817)						(3,090)	(25,907)
Charcoal Production					(4,229)	1,269		(2,961)
Coke Production								-
Other Transformation								-
Own Use			(1,337)				(3,561)	(4,898)
Losses	(5,836)						(15,531)	(21,366)
FUELS FOR FINAL CONSUMPTION	288,559	-	34,643	473	158,133	1,269	37,346	520,424
ENERGY DEMAND	288,543	-	34,659	473	158,083	1,271	37,334	520,363
INDUSTRIAL SECTOR	149,595	-	7,758	-	369	-	14,206	171,928
Iron and Steel	51,776						2,824	54,600
Cement	23,985		3,256				1,561	28,802
Fertilizers	2,956		512				2,370	5,838
Other Chemicals	2,224						1,338	3,562
Pulp and Paper	799						188	988
Other Metals	15,655						2,773	18,428
Other Minerals	3,528		3,528				222	7,278
Textiles	6,465						559	7,024
Building Materials	20,453						64	20,517
Non-specified Industry	21,754		462		369		2,307	24,892
TRANSPORT SECTOR	-	-	9,373	-	727	-	3,587	13,687
Road			7,336		727			8,064
Rail	-		604				3,587	4,191
Water	-		489					489
Air			944					944
Non-Specified			-				-	-
RESIDENTIAL SECTOR	93,515	-	2,803	-	118,296	1,271	4,233	220,119
Urban	65,995		2,508			634	3,667	72,805
Rural	27,520		295		118,296	637	566	147,314
AGRICULTURAL SECTOR	7,800	-	919	-	24,552	-	1,460	34,731
Field Operations			481				601	1,082
Processing/Other	7,800		438		24,552		859	33,649
FISHERIES SECTOR	453	-	924	-	-	-	210	1,586
Large Ships	-		751					751
Collectives/Processing/Other	453		173				210	836
MILITARY SECTOR	21,522	-	11,813	-	4,056	-	9,026	46,416
Trucks and other Transport			4,405					4,405
Armaments			141					141
Air Force			1,615					1,615
Naval Forces			5,572					5,572
Military Manufacturing	399		-				21	421
Buildings and Other	21,122		80		4,056		9,004	34,263
PUBLIC/COMMERCIAL SECTORS	13,609		204		4,083		4,613	22,509
NON-SPECIFIED/OTHER SECTORS			-	473				473
NON-ENERGY USE	2,048		865		6,000			8,913
Electricity Gen. (Gross TWhe)*	5.23		0.17	11.15				16.55

**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

ESTIMATED ENERGY BALANCE FOR THE YEAR 1990: REFINED PRODUCTS BY PRODUCT TYPE

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

UNITS: TERAJOULES (TJ)	CRUDE OIL	GASOLINE	DIESEL	HEAVY OIL	KEROSENE & JET FUEL	LPG, REF. FUEL, NON-E	AVIATION GAS	**TOTAL**
ENERGY SUPPLY	110,742	5,272	12,954	6,220	2,159	-		137,346
Domestic Production	-							-
Imports	110,742	5,272	12,954	6,220	2,159			137,346
Exports								-
Inputs to International Marine Bunkers								-
Stock Changes								-
ENERGY TRANSFORMATION	(110,742)	25,314	19,344	16,656	8,843	11,627	1,080	(27,878)
Electricity Generation				(21,922)				(21,922)
Petroleum Refining	(110,742)	25,314	19,344	38,578	8,843	17,583	1,080	0
Coal Production/Preparation								-
Charcoal Production								-
Coke Production								-
Other Transformation								-
Own Use						(5,956)		(5,956)
Losses								-
FUELS FOR FINAL CONSUMPTION	-	30,586	32,298	22,875	11,002	11,627	1,080	109,468
ENERGY DEMAND	-	30,558	32,246	22,867	10,985	11,627	1,080	109,363
INDUSTRIAL SECTOR	-	-	3,000	21,835	-	3,658	-	28,493
Iron and Steel								-
Cement				7,571				7,571
Fertilizers				915		3,658		4,573
Other Chemicals								-
Pulp and Paper								-
Other Metals								-
Other Minerals				12,600				12,600
Textiles								-
Building Materials								
Non-specified Industry			3,000	750				3,750
TRANSPORT SECTOR	-	23,171	12,906	627	399	-	724	37,827
Road		23,171	9,331					32,502
Rail			1,949					1,949
Water			627	627				1,253
Air					399		724	1,123
Non-Specified			1,000					1,000
RESIDENTIAL SECTOR	-	-	-	-	4,491	2,108	-	6,600
Urban					4,148	2,108		6,256
Rural					344			344
AGRICULTURAL SECTOR	-	-	5,005	-	-	-	-	5,005
Field Operations			2,619					2,619
Processing/Other			2,386					2,386
FISHERIES SECTOR	-	-	2,777	360	-	-	-	3,137
Large Ships			2,547	134				2,681
Collectives/Processing/Other			230	226				456
MILITARY SECTOR	-	7,386	6,859	45	1,798	-	356	16,444
Trucks and other Transport		6,476	109					6,585
Armaments		45	218					263
Air Force		494			1,798		356	2,648
Naval Forces		371	6,432	45				6,847
Military Manufacturing								-
Buildings and Other			100					100
PUBLIC/COMMERCIAL SECTORS					96	96		192
NON-SPECIFIED/OTHER SECTORS		-	1,700		4,200			5,900
NON-ENERGY USE						5,764		5,764

SUMMARY AND COMPARISON OF RESULTS: PETROLEUM REFINING BY PRODUCT

	1990 Production Data from Jang, 1994 (Note 1)				1990 Production from Balance *(Note 2)*			
					Oil for Magnesite as Heavy		Oil for Magnesite as Crude	
Product	Production kte/yr	Conversion te/toe	Production ktoe/yr	Fraction of Total	Production ktoe/yr	Fraction of Total	Production ktoe/yr	Fraction of Total
Gasoline	950	1.07	1,017	33%	605	23%	605	26%
Diesel	1000	1.035	1,035	34%	462	17%	462	20%
Heavy Oil	650	0.96	624	20%	922	35%	621	26%
Kerosene/Jet Fuel	210	1.045	219	7%	211	8%	211	9%
Other Products	165	0.96	158	5%	446	17%	446	19%
TOTAL			3,053	100%	2,647	100%	2,346	100%

Notes:

1 *Young Sik Jang, North Korean Energy Economics, Korea Development Institute, 1994 (pp. 54, 64)*

2 *The "Oil for Magnesite as Heavy" columns in this table present production as estimated in the refined products balance, which assumes that oil used in magnesite production is heavy or residual oil. It is possible that crude oil is input to the magnesite (and/or fertilizer) production process without previous refining. If this is the case (for magnesite), the refined products balance would be as shown in the second pair of columns.*

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

ESTIMATED ENERGY BALANCE FOR THE YEAR 1996: REFINED PRODUCTS BY PRODUCT TYPE

Prepared By David Von Hippel
Date Last Modified: 3/20/2007

UNITS: TERAJOULES (TJ)	CRUDE OIL	GASOLINE	DIESEL	HEAVY OIL	KEROSENE & JET FUEL	LPG, REF. FUEL, NON-E.	AVIATION GAS	**TOTAL**
ENERGY SUPPLY	39,874	8,539	5,181	18,156	518	-	-	72,270
Domestic Production	-							-
Imports	39,874	8,539	5,181	24,818	518			78,931
Exports								-
Inputs to International Marine Bunkers								-
Stock Changes		-	-	6,661				6,661
ENERGY TRANSFORMATION	(39,874)	8,177	8,085	(10,601)	1,617	4,110	871	(27,615)
Electricity Generation				(25,351)				(25,351)
Petroleum Refining	(39,874)	8,177	8,085	14,750	1,617	6,374	871	(0)
Coal Production/Preparation								-
Charcoal Production								-
Coke Production								-
Other Transformation								-
Own Use						(2,264)		(2,264)
Losses								-
FUELS FOR FINAL CONSUMPTION	-	16,716	13,266	7,555	2,135	4,110	871	44,654
ENERGY DEMAND	-	16,694	13,287	7,555	2,128	4,110	871	44,647
INDUSTRIAL SECTOR	-	-	660	7,131	-	903	-	8,694
Iron and Steel								-
Cement				3,331				3,331
Fertilizers				226		903		1,129
Other Chemicals								-
Pulp and Paper								-
Other Metals								-
Other Minerals				3,326				3,326
Textiles								-
Building Materials								
Non-specified Industry			660	248				908
TRANSPORT SECTOR	-	10,244	5,022	251	320	-	579	16,415
Road		10,244	3,992					14,235
Rail			779					779
Water			251	251				501
Air					320		579	899
Non-Specified			-					-
RESIDENTIAL SECTOR	-	-	-	-	539	1,407	-	1,946
Urban					454	1,407		1,861
Rural					85			85
AGRICULTURAL SECTOR	-	-	1,502	-	-	-	-	1,502
Field Operations			786					786
Processing/Other			716					716
FISHERIES SECTOR	-	-	856	142	-	-	-	998
Large Ships			764	40				804
Collectives/Processing/Other			92	102				193
MILITARY SECTOR	-	6,451	5,248	32	1,199	-	292	13,222
Trucks and other Transport		5,639	95					5,734
Armaments		36	174					211
Air Force		494			1,199		292	1,985
Naval Forces		281	4,884	32				5,198
Military Manufacturing								-
Buildings and Other			95					95
PUBLIC/COMMERCIAL SECTORS					71	71		143
NON-SPECIFIED/OTHER SECTORS			-		-			-
NON-ENERGY USE						1,729		1,729

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

ESTIMATED ENERGY BALANCE FOR THE YEAR 2000
REFINED PRODUCTS BY PRODUCT TYPE

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

UNITS: TERAJOULES (TJ)	CRUDE OIL	GASOLINE	DIESEL	HEAVY OIL	KEROSENE & JET FUEL	LPG, REF. FUEL, NON-E.	AVIATION GAS	**TOTAL**
ENERGY SUPPLY	17,857	6,082	8,854	20,164	1,382	5,240	-	59,578
Domestic Production	1,278							1,278
Imports	16,579	6,082	8,854	22,989	1,382	5,424		61,309
Exports				2,825		183		3,009
Inputs to International Marine Bunkers								-
Stock Changes		-		-	-			-
ENERGY TRANSFORMATION	(17,857)	3,369	3,629	(9,527)	734	1	699	(18,952)
Electricity Generation				(16,177)		(771)		(16,949)
Petroleum Refining	(17,857)	3,369	3,629	6,650	734	1,786	699	(990)
Coal Production/Preparation								-
Charcoal Production								-
Coke Production								-
Other Transformation								-
Own Use						(1,014)		(1,014)
Losses								-
FUELS FOR FINAL CONSUMPTION	-	9,451	12,484	10,636	2,116	5,241	699	40,626
ENERGY DEMAND	-	9,413	12,506	10,640	2,125	5,241	699	40,623
INDUSTRIAL SECTOR	-	-	623	10,257	-	274	-	11,154
Iron and Steel								-
Cement				6,399				6,399
Fertilizers				69		274		343
Other Chemicals								-
Pulp and Paper								-
Other Metals								-
Other Minerals				3,478				3,478
Textiles								-
Building Materials								
Non-specified Industry			623	311				934
TRANSPORT SECTOR	-	3,738	4,298	232	379	-	463	9,111
Road		3,738	3,482					7,220
Rail			585					585
Water			232	232				464
Air					379		463	843
Non-Specified			-					-
RESIDENTIAL SECTOR	-	-	-	-	734	2,135	-	2,869
Urban					443	2,135		2,577
Rural					291			291
AGRICULTURAL SECTOR	-	-	1,251	-	-	-	-	1,251
Field Operations			655					655
Processing/Other			596					596
FISHERIES SECTOR	-	-	710	118	-	-	-	828
Large Ships			634	33				668
Collectives/Processing/Other			76	85				161
MILITARY SECTOR	-	5,675	5,623	34	974	-	235	12,541
Trucks and other Transport		4,845	81					4,926
Armaments		30	143					172
Air Force		494			974		235	1,703
Naval Forces		306	5,315	34				5,654
Military Manufacturing								-
Buildings and Other			85					85
PUBLIC/COMMERCIAL SECTORS					38	38		77
NON-SPECIFIED/OTHER SECTORS			-					-
NON-ENERGY USE						2,793		2,793

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

ESTIMATED ENERGY BALANCE FOR THE YEAR 2005
REFINED PRODUCTS BY PRODUCT TYPE

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

UNITS: TERAJOULES (TJ)	CRUDE OIL	GASOLINE	DIESEL	HEAVY OIL	KEROSENE & JET FUEL	LPG, REF. FUEL, NON-E.	AVIATION GAS	**TOTAL**
ENERGY SUPPLY	23,547	3,686	7,625	2,503	2,288	1,115	-	40,764
Domestic Production	1,278							1,278
Imports	22,270	3,686	7,625	2,503	2,288	1,301		39,672
Exports				-		186		186
Inputs to International Marine Bunkers								-
Stock Changes								-
ENERGY TRANSFORMATION	(23,547)	4,811	4,783	4,898	965	1,422	548	(6,121)
Electricity Generation				(3,857)		(891)		(4,748)
Petroleum Refining	(23,547)	4,811	4,783	8,755	965	3,650	548	(35)
Coal Production/Preparation								-
Charcoal Production								-
Coke Production								-
Other Transformation								-
Own Use						(1,337)		(1,337)
Losses								-
FUELS FOR FINAL CONSUMPTION	-	8,497	12,408	7,401	3,253	2,537	548	34,643
ENERGY DEMAND	-	8,498	12,396	7,419	3,262	2,537	548	34,659
INDUSTRIAL SECTOR	-	-	336	7,013	-	410	-	7,758
Iron and Steel								-
Cement				3,256				3,256
Fertilizers				102		410		512
Other Chemicals								-
Pulp and Paper								-
Other Metals								-
Other Minerals				3,528				3,528
Textiles								-
Building Materials								
Non-specified Industry			336	126				462
TRANSPORT SECTOR	-	3,346	4,839	244	618	-	326	9,373
Road		3,346	3,991					7,336
Rail			604					604
Water			244	244				489
Air					618		326	944
Non-Specified			-					-
RESIDENTIAL SECTOR	-	-	-	-	1,694	1,110	-	2,803
Urban					1,399	1,110		2,508
Rural					295			295
AGRICULTURAL SECTOR	-	-	919	-	-	-	-	919
Field Operations			481					481
Collectives/Processing/Other			438					438
FISHERIES SECTOR	-	-	796	128	-	-	-	924
Large Ships			713	38				751
Processing/Other			82	91				173
MILITARY SECTOR	-	5,152	5,506	34	899	-	222	11,813
Trucks and other Transport		4,332	73					4,405
Armaments		24	117					141
Air Force		494			899		222	1,615
Naval Forces		302	5,237	34				5,572
Military Manufacturing								-
Buildings and Other			80					80
PUBLIC/COMMERCIAL SECTORS					51	153		204
NON-SPECIFIED/OTHER SECTORS			-					-
NON-ENERGY USE						865		865

NAUTILUS INSTITUTE

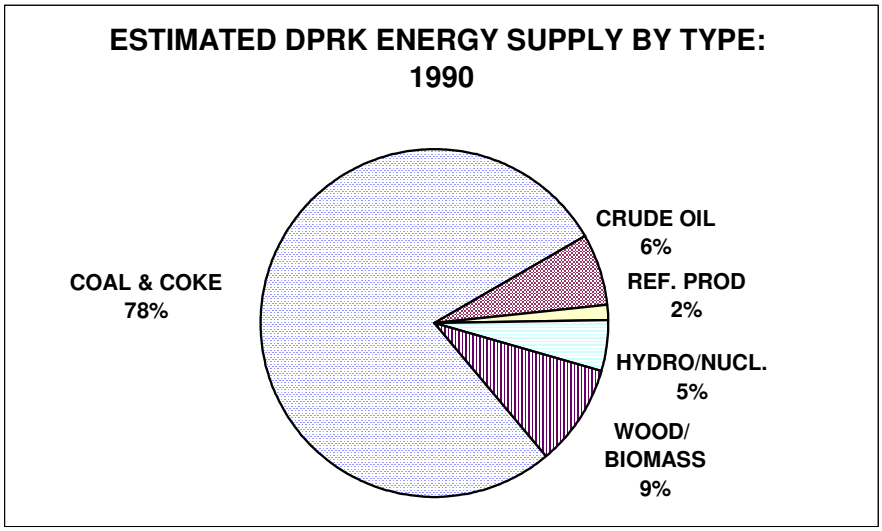
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

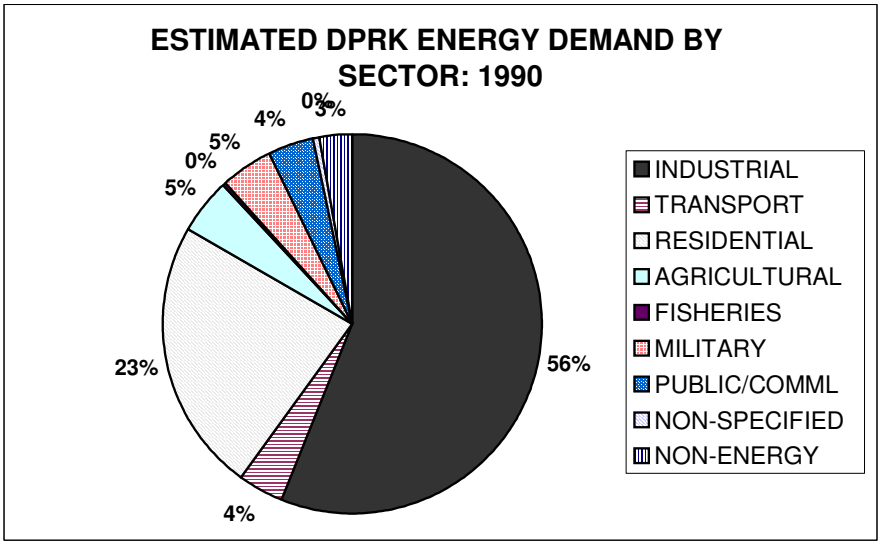
2006 UPDATE

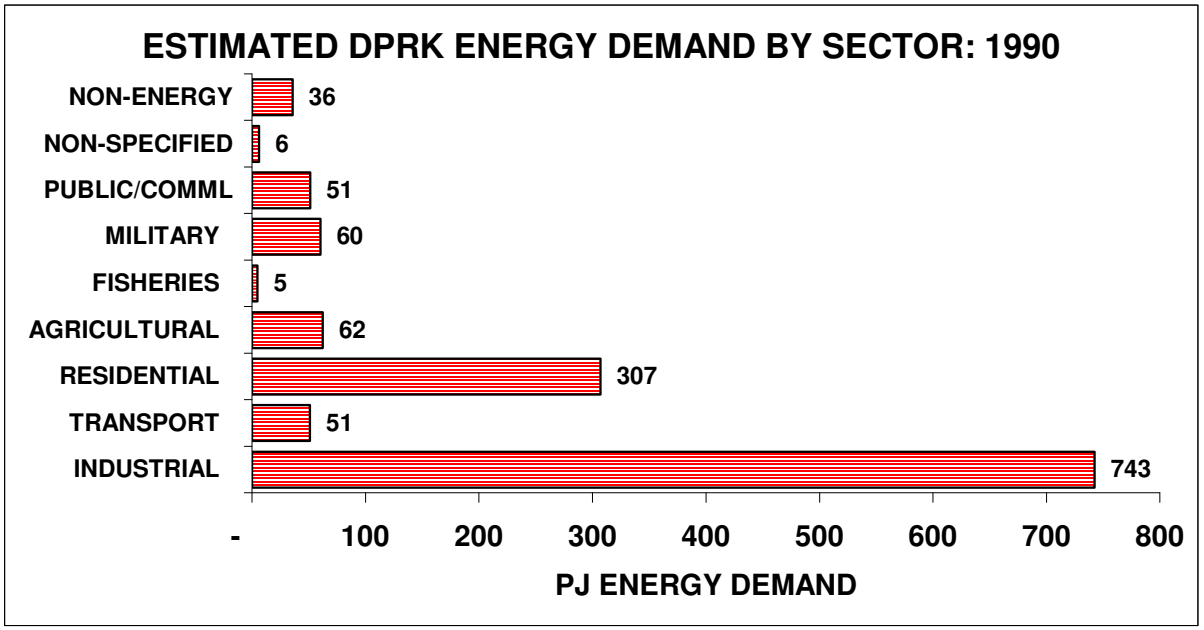
ESTIMATED SUMMARY ENERGY BALANCE FOR 1990

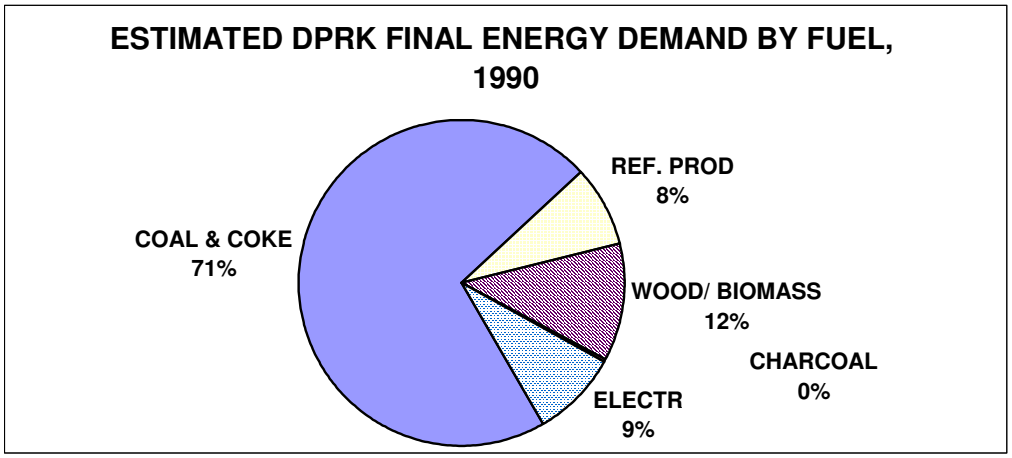
Prepared By David Von Hippel
Date Last Modified: 3/8/2007

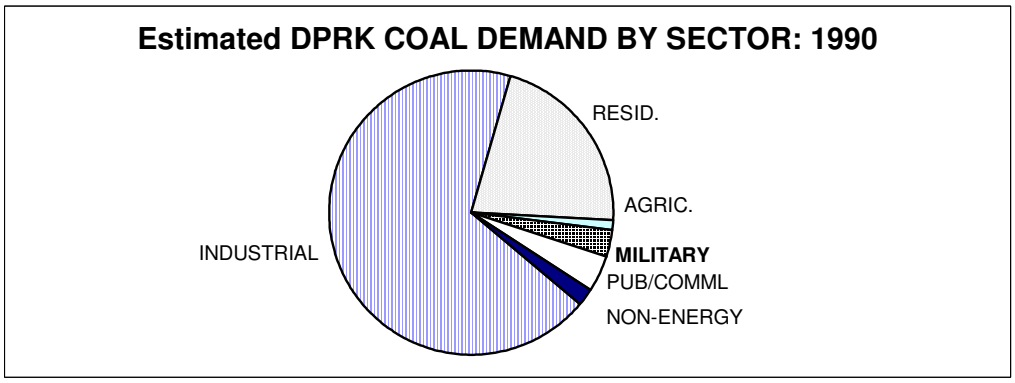
UNITS: PETAJOULES (PJ)	COAL & COKE	CRUDE OIL	REF. PROD	HYDRO/NUCL.	WOOD/ BIOMASS	CHAR-COAL	ELEC.	**TOTAL**
ENERGY SUPPLY	1,330	111	27	80	159	-	(12)	1,694
Domestic Production	1,292	-		80	147			1,519
Imports	68	111	27		12			218
Exports	30						12	43
Stock Changes								
ENERGY TRANSF.	(394)	(111)	89	(80)	(7)	2	128	(372)
Electricity Generation	(315)		(16)	(80)			173	(238)
Petroleum Refining		(111)	105				(1)	(7)
Coal Prod./Prep.	(63)						(8)	(71)
Charcoal Production					(7)	2		(5)
Own Use							(13)	(13)
Losses	(16)						(23)	(39)
FUELS FOR FINAL CONS.	936	-	116	0	152	2	116	1,322
ENERGY DEMAND	942	-	109	0	152	2	116	1,322
INDUSTRIAL	643	-	28	-	6	-	65	743
TRANSPORT	-	-	38	-	2	-	11	51
RESIDENTIAL	202	-	7	-	86	2	11	307
AGRICULTURAL	10	-	5	-	45	-	3	62
FISHERIES	1	-	3	-	-	-	1	5
MILITARY	30	-	16	-	-	-	14	60
PUBLIC/COMML	38	-	0	-	2	-	11	51
NON-SPECIFIED			6	0				6
NON-ENERGY	18		6		12			36
Elect. Gen. (Gr. TWhe)	24.51		1.28	22.21				48.00

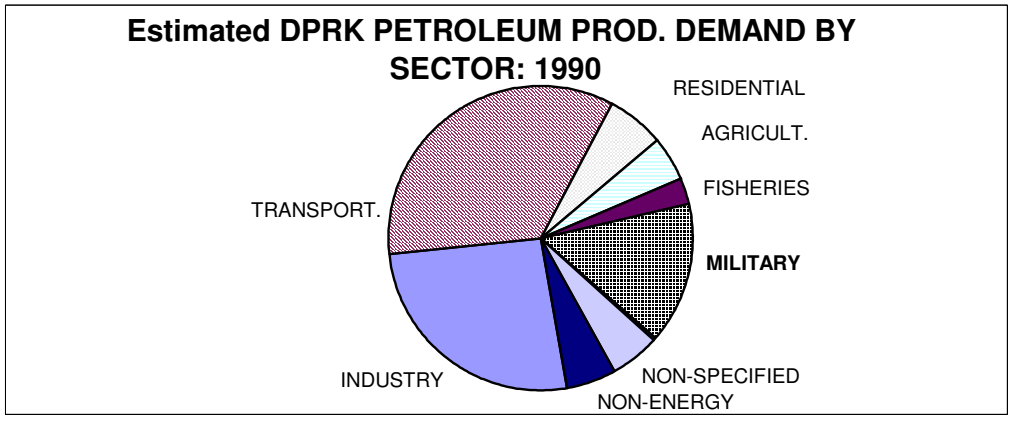

ESTIMATED DPRK ENERGY SUPPLY BY TYPE: 1990
CRUDE OIL 6%
REF. PROD 2%
HYDRO/NUCL. 5%
WOOD/ BIOMASS 9%
COAL & COKE 78%

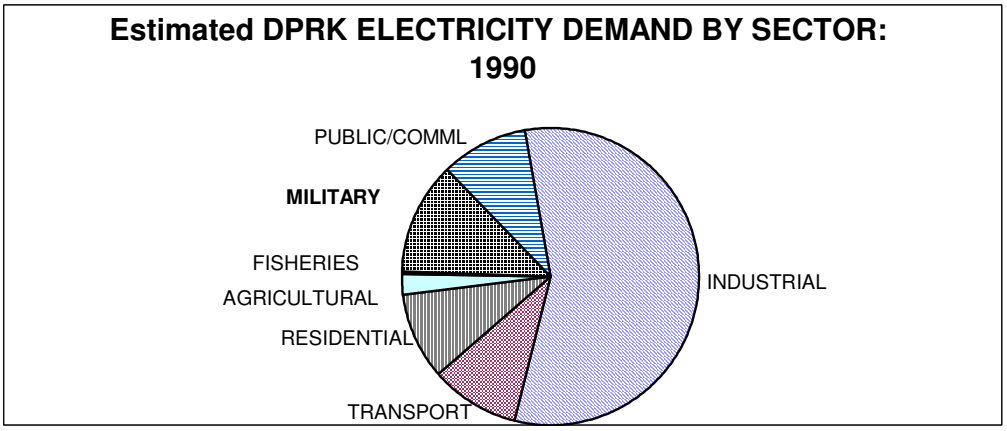

ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 1990
56%
4%
23%
5%
0%
5%
4%
0%
3%
INDUSTRIAL
TRANSPORT
RESIDENTIAL
AGRICULTURAL
FISHERIES
MILITARY
PUBLIC/COMML
NON-SPECIFIED
NON-ENERGY


ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 1990
NON-ENERGY 36
NON-SPECIFIED 6
PUBLIC/COMML 51
MILITARY 60
FISHERIES 5
AGRICULTURAL 62
RESIDENTIAL 307
TRANSPORT 51
INDUSTRIAL 743
- 100 200 300 400 500 600 700 800
PJ ENERGY DEMAND


ESTIMATED DPRK FINAL ENERGY DEMAND BY FUEL, 1990
REF. PROD 8%
COAL & COKE 71%
WOOD/ BIOMASS 12%
CHARCOAL 0%
ELECTR 9%


Estimated DPRK COAL DEMAND BY SECTOR: 1990
RESID.
AGRIC.
INDUSTRIAL
MILITARY
PUB/COMML
NON-ENERGY


Estimated DPRK PETROLEUM PROD. DEMAND BY SECTOR: 1990
RESIDENTIAL
AGRICULT.
FISHERIES
TRANSPORT.
MILITARY
INDUSTRY
NON-SPECIFIED
NON-ENERGY


Estimated DPRK ELECTRICITY DEMAND BY SECTOR: 1990
PUBLIC/COMML
MILITARY
FISHERIES
AGRICULTURAL
INDUSTRIAL
RESIDENTIAL
TRANSPORT

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

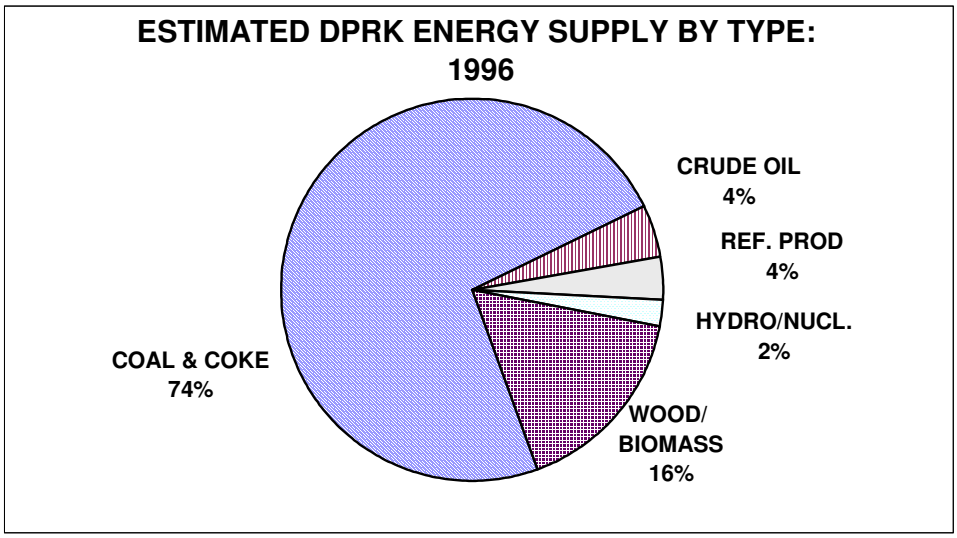
2006 UPDATE

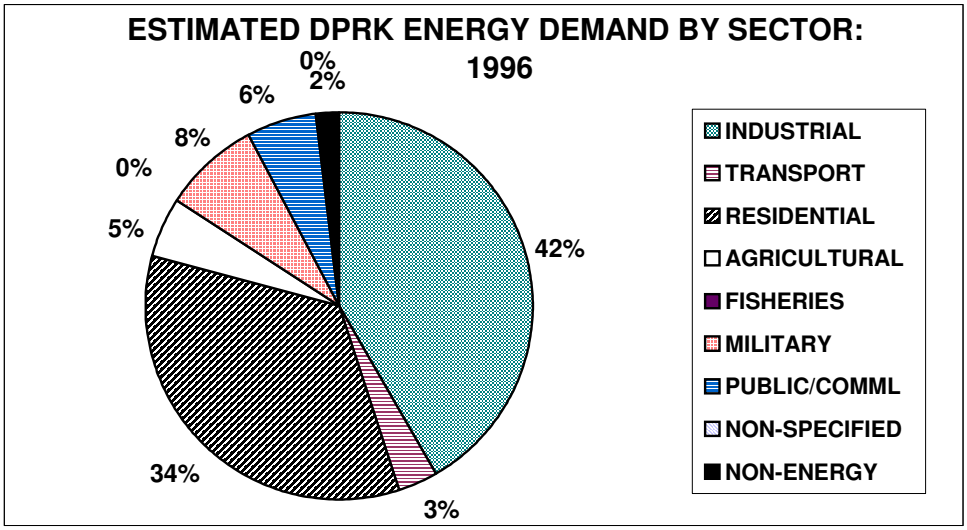
ESTIMATED SUMMARY ENERGY BALANCE FOR 1996

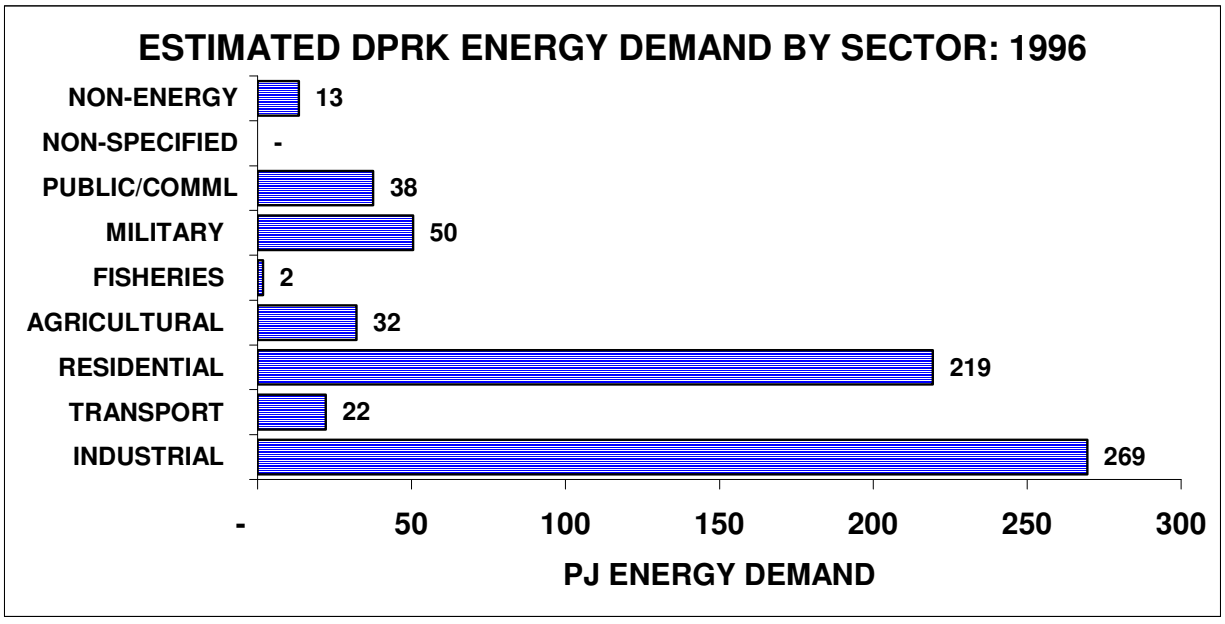
Prepared By David Von Hippel
Date Last Modified: 4/4/2007

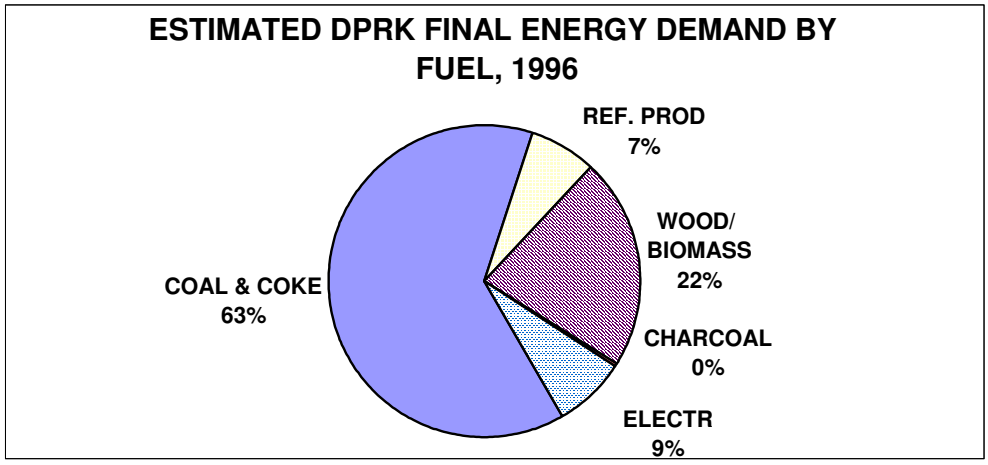
UNITS: PETAJOULES (PJ)	COAL & COKE	CRUDE OIL	REF. PROD	HYDRO/ NUCL.	WOOD/ BIOMASS	CHAR-COAL	ELEC.	**TOTAL**
ENERGY SUPPLY	654	40	32	20	147	-	(3)	890
Domestic Production	643	-	-	20	135	-	-	798
Imports	12	40	39	-	12	-	-	103
Exports	1	-	-	-	0	-	3	4
Stock Changes	-	-	7	-	-	-	-	7
ENERGY TRANSF.	(245)	(40)	12	(20)	(5)	2	52	(244)
Electricity Generation	(206)	-	(25)	(20)	-	-	83	(169)
Petroleum Refining	-	(40)	40	-	-	-	(0)	(0)
Coal Prod./Prep.	(31)	-	-	-	-	-	(4)	(35)
Charcoal Production	-	-	-	-	(5)	2	-	(4)
Own Use	-	-	(2)	-	-	-	(10)	(12)
Losses	(8)	-	-	-	-	-	(16)	(24)
FUELS FOR FINAL CONS.	409	-	45	-	142	2	49	646
ENERGY DEMAND	409	-	45	-	142	2	49	646
INDUSTRIAL	237	-	9	-	2	-	22	269
TRANSPORT	-	-	16	-	1	-	5	22
RESIDENTIAL	107	-	2	-	102	2	6	219
AGRICULTURAL	5	-	2	-	24	-	2	32
FISHERIES	1	-	1	-	-	-	0	2
MILITARY	27	-	13	-	3	-	8	50
PUBLIC/COMML	29	-	0	-	3	-	6	38
NON-SPECIFIED			-					-
NON-ENERGY	5		2		7			13
								-
Elect. Gen. (Gr. TWhe)*	16.50	-	0.91	5.55	-	-	-	22.97

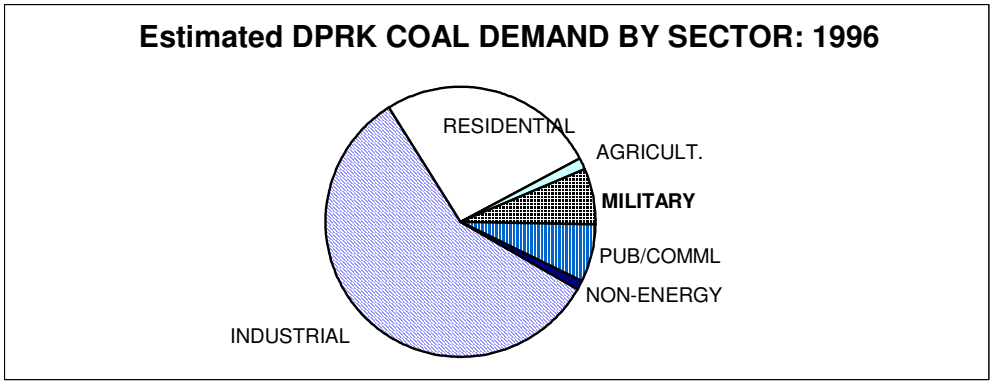
**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

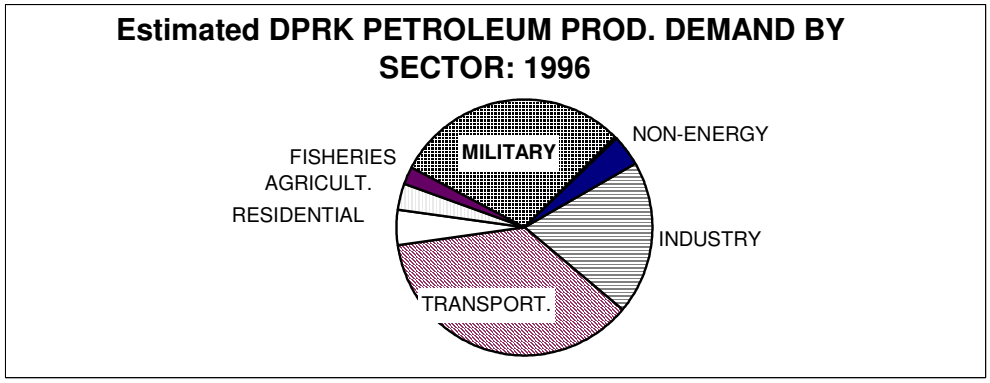

ESTIMATED DPRK ENERGY SUPPLY BY TYPE:
1996
CRUDE OIL
4%
REF. PROD
4%
HYDRO/NUCL.
2%
WOOD/
BIOMASS
16%
COAL & COKE
74%

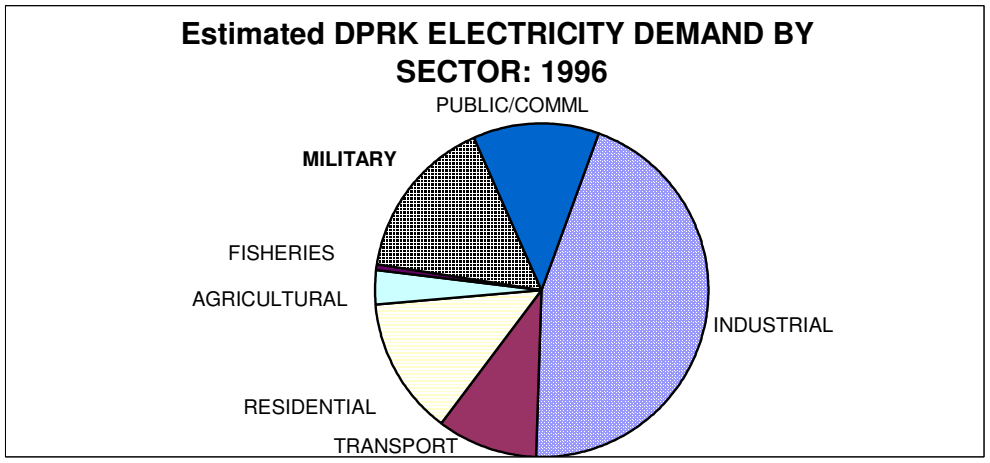

ESTIMATED DPRK ENERGY DEMAND BY SECTOR:
1996
0%
2%
6%
8%
0%
5%
42%
34%
3%
INDUSTRIAL
TRANSPORT
RESIDENTIAL
AGRICULTURAL
FISHERIES
MILITARY
PUBLIC/COMML
NON-SPECIFIED
NON-ENERGY


ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 1996
NON-ENERGY
13
NON-SPECIFIED
-
PUBLIC/COMML
38
MILITARY
50
FISHERIES
2
AGRICULTURAL
32
RESIDENTIAL
219
TRANSPORT
22
INDUSTRIAL
269
-
50
100
150
200
250
300
PJ ENERGY DEMAND


ESTIMATED DPRK FINAL ENERGY DEMAND BY FUEL, 1996
REF. PROD 7%
WOOD/ BIOMASS 22%
CHARCOAL 0%
ELECTR 9%
COAL & COKE 63%


Estimated DPRK COAL DEMAND BY SECTOR: 1996
RESIDENTIAL
AGRICULT.
MILITARY
PUB/COMML
NON-ENERGY
INDUSTRIAL


Estimated DPRK PETROLEUM PROD. DEMAND BY SECTOR: 1996
NON-ENERGY
FISHERIES
MILITARY
AGRICULT.
RESIDENTIAL
INDUSTRY
TRANSPORT.


Estimated DPRK ELECTRICITY DEMAND BY SECTOR: 1996
PUBLIC/COMML
MILITARY
FISHERIES
AGRICULTURAL
INDUSTRIAL
RESIDENTIAL
TRANSPORT

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

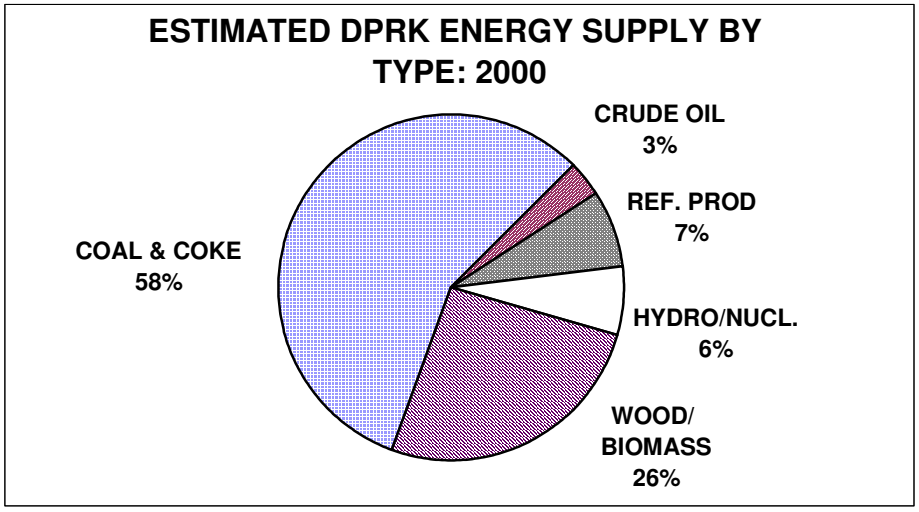
2006 UPDATE

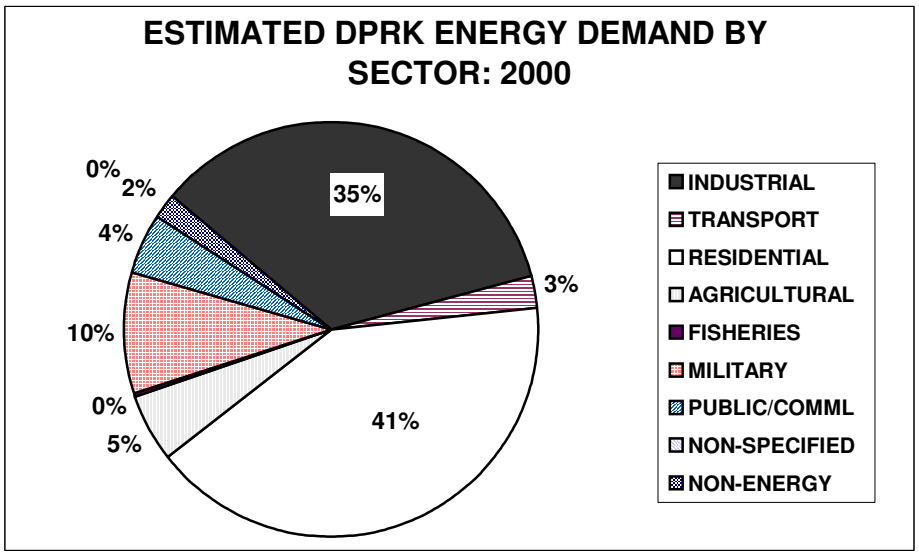
ESTIMATED SUMMARY ENERGY BALANCE FOR 2000

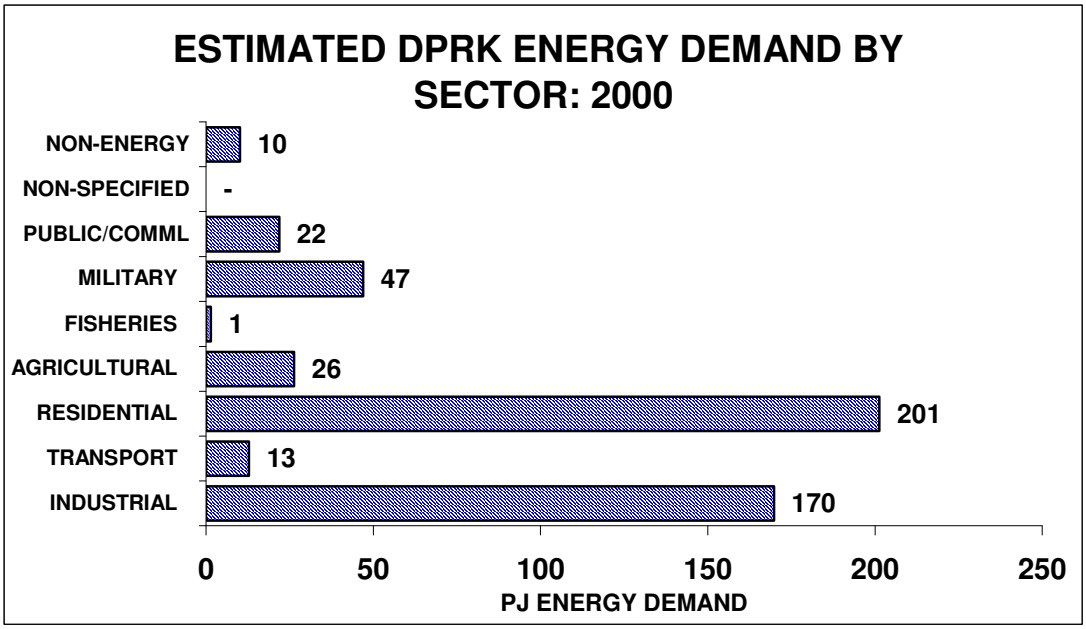
Prepared By David Von Hippel
Date Last Modified: 4/4/2007

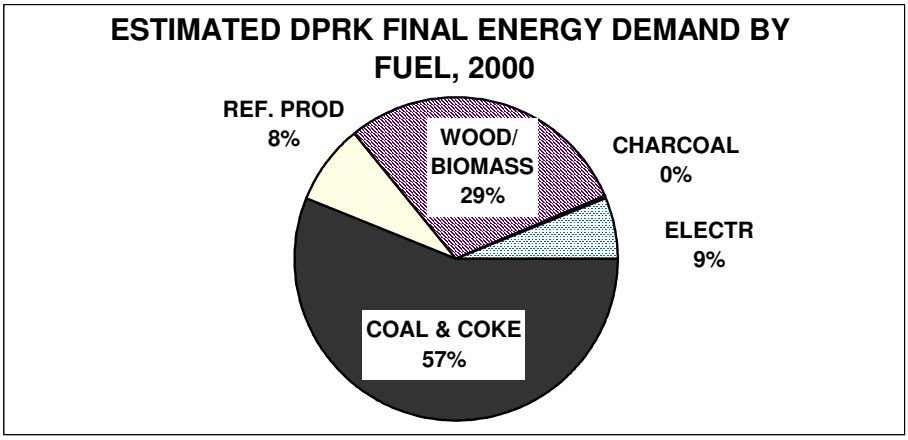
UNITS: PETAJOULES (PJ)	COAL & COKE	CRUDE OIL	REF. PROD	HYDRO/ NUCL.	WOOD/ BIOMASS	CHAR-COAL	ELEC.	**TOTAL**
ENERGY SUPPLY	325	18	42	37	148	-	(0)	570
Domestic Production	326	1	-	37	136	-	-	500
Imports	8	17	45	-	12	-	-	82
Exports	9	-	3	-	0	-	0	12
Stock Changes	-	-	-	-	-	-	-	-
ENERGY TRANSF.	(50)	(18)	(1)	(37)	(4)	1	30	(79)
Electricity Generation	(31)	-	(17)	(37)	-	-	47	(38)
Petroleum Refining	-	(18)	17	-	-	-	(0)	(1)
Coal Prod./Prep.	(15)	-	-	-	-	-	(2)	(18)
Charcoal Production	-	-	-	-	(4)	1	-	(3)
Own Use	-	-	(1)	-	-	-	(2)	(3)
Losses	(4)	-	-	-	-	-	(12)	(16)
FUELS FOR FINAL CONS.	275	-	41	-	144	1	30	491
ENERGY DEMAND	275	-	41	-	144	1	30	491
INDUSTRIAL	146	-	11	-	1	-	12	170
TRANSPORT	-	-	9	-	1	-	3	13
RESIDENTIAL	85	-	3	-	110	1	3	201
AGRICULTURAL	4	-	1	-	20	-	1	26
FISHERIES	0	-	1	-	-	-	0	1
MILITARY	23	-	13	-	4	-	8	47
PUBLIC/COMML	15	-	0	-	3	-	3	22
NON-SPECIFIED			-					-
NON-ENERGY	1		3		6			10
Elect. Gen. (Gr. TWhe)*	2.64	-	0.15	10.23	-	-	-	13.02

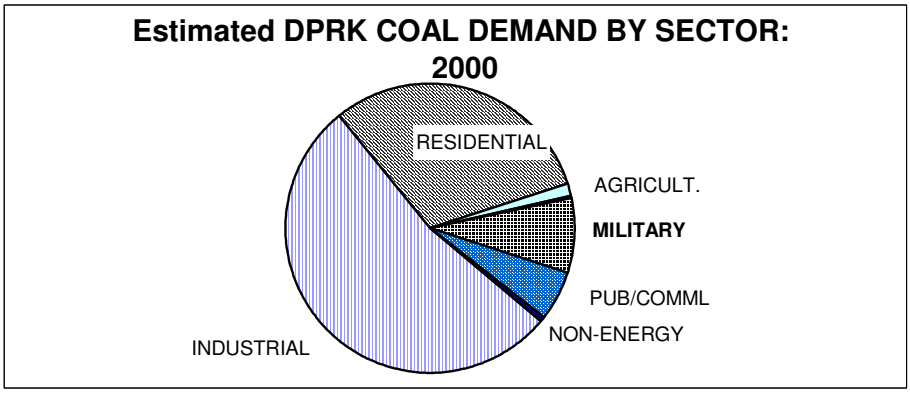
**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

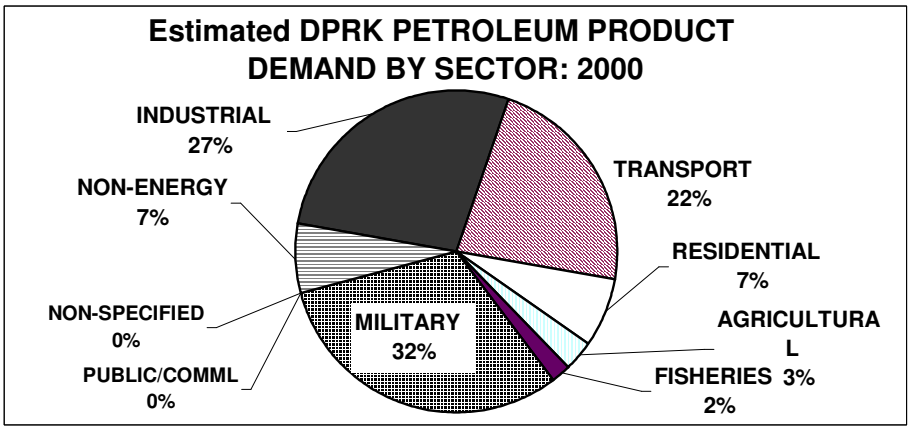

ESTIMATED DPRK ENERGY SUPPLY BY TYPE: 2000
CRUDE OIL 3%
REF. PROD 7%
HYDRO/NUCL. 6%
WOOD/ BIOMASS 26%
COAL & COKE 58%

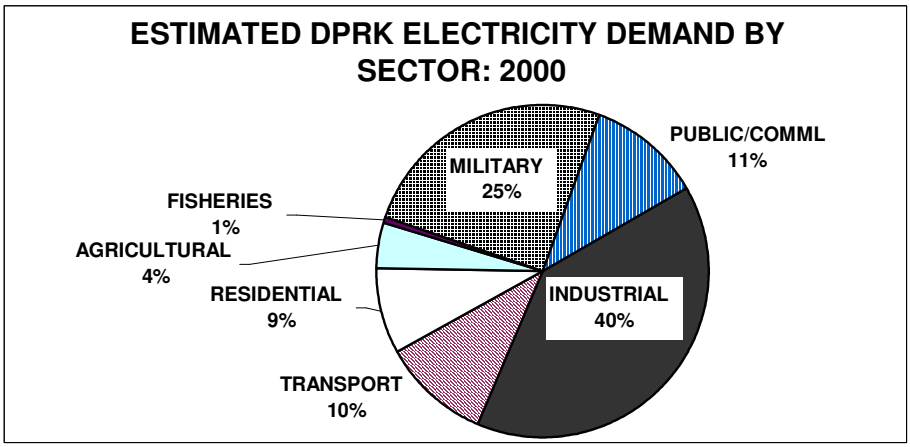

ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 2000
35%
3%
41%
5%
0%
10%
4%
2%
0%
INDUSTRIAL
TRANSPORT
RESIDENTIAL
AGRICULTURAL
FISHERIES
MILITARY
PUBLIC/COMML
NON-SPECIFIED
NON-ENERGY


ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 2000
NON-ENERGY 10
NON-SPECIFIED -
PUBLIC/COMML 22
MILITARY 47
FISHERIES 1
AGRICULTURAL 26
RESIDENTIAL 201
TRANSPORT 13
INDUSTRIAL 170
0
50
100
150
200
250
PJ ENERGY DEMAND


ESTIMATED DPRK FINAL ENERGY DEMAND BY FUEL, 2000
REF. PROD 8%
WOOD/ BIOMASS 29%
CHARCOAL 0%
ELECTR 9%
COAL & COKE 57%


Estimated DPRK COAL DEMAND BY SECTOR: 2000
RESIDENTIAL
AGRICULT.
MILITARY
PUB/COMML
NON-ENERGY
INDUSTRIAL


Estimated DPRK PETROLEUM PRODUCT DEMAND BY SECTOR: 2000
INDUSTRIAL 27%
NON-ENERGY 7%
NON-SPECIFIED 0%
PUBLIC/COMML 0%
MILITARY 32%
TRANSPORT 22%
RESIDENTIAL 7%
AGRICULTURAL 3%
FISHERIES 2%


ESTIMATED DPRK ELECTRICITY DEMAND BY SECTOR: 2000
MILITARY 25%
PUBLIC/COMML 11%
FISHERIES 1%
AGRICULTURAL 4%
RESIDENTIAL 9%
INDUSTRIAL 40%
TRANSPORT 10%

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

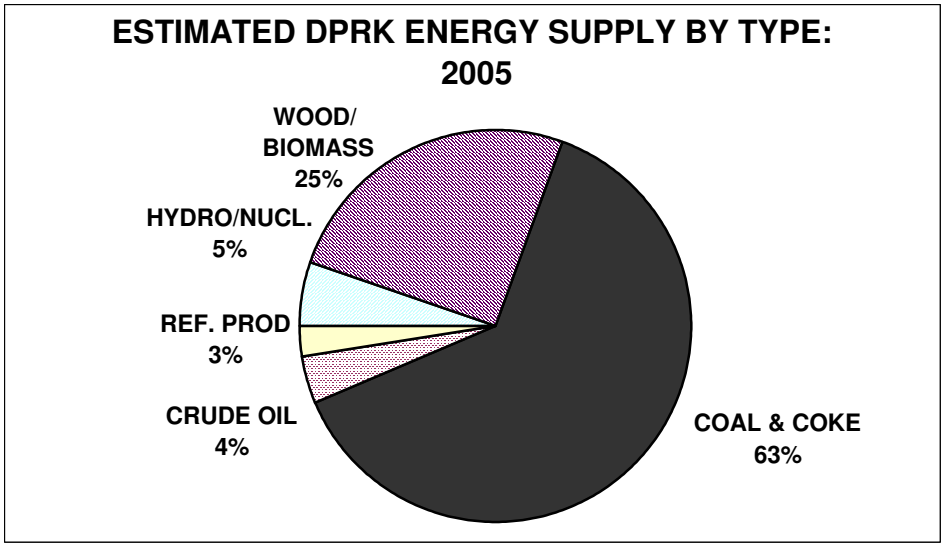
2006 UPDATE

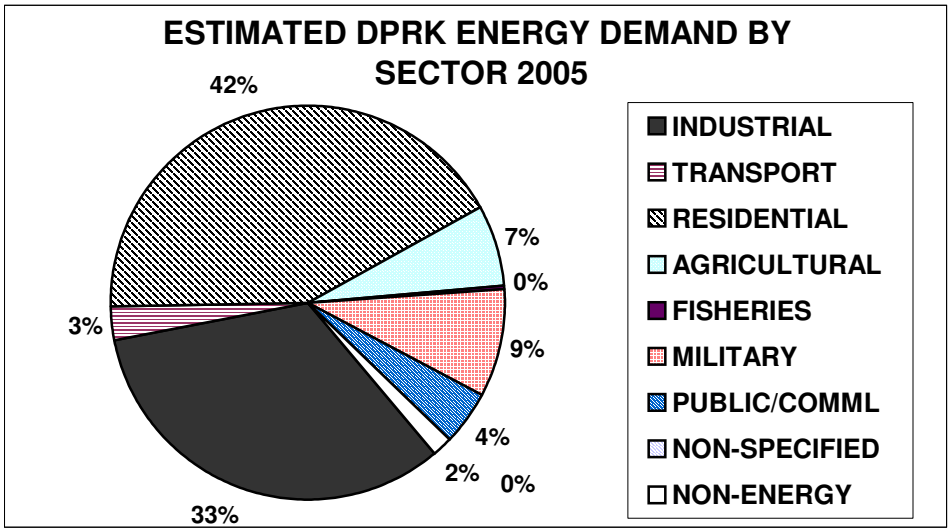
ESTIMATED SUMMARY ENERGY BALANCE FOR 2005

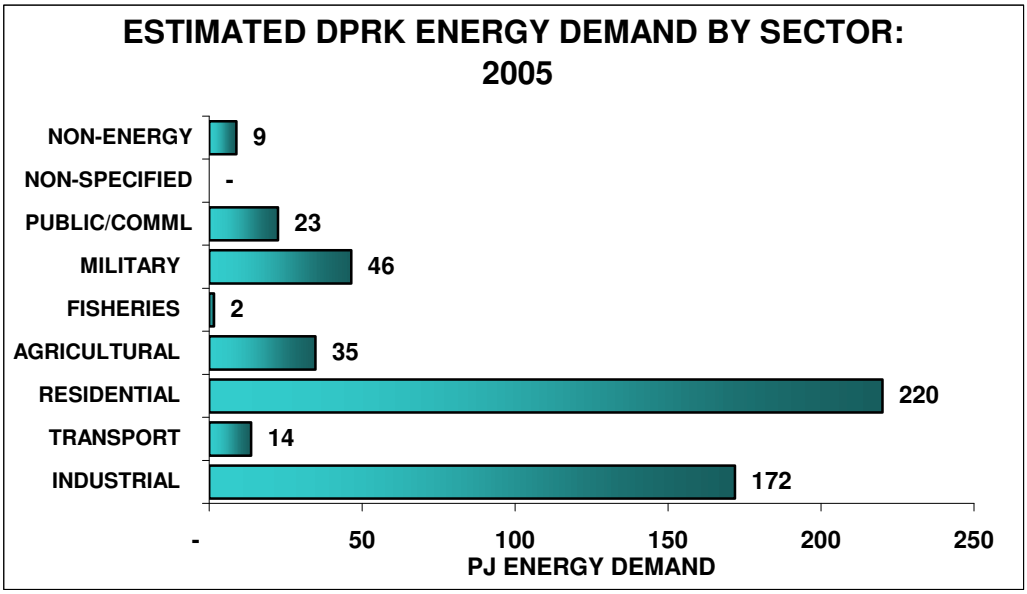
Prepared By David Von Hippel
Date Last Modified: 4/4/2007

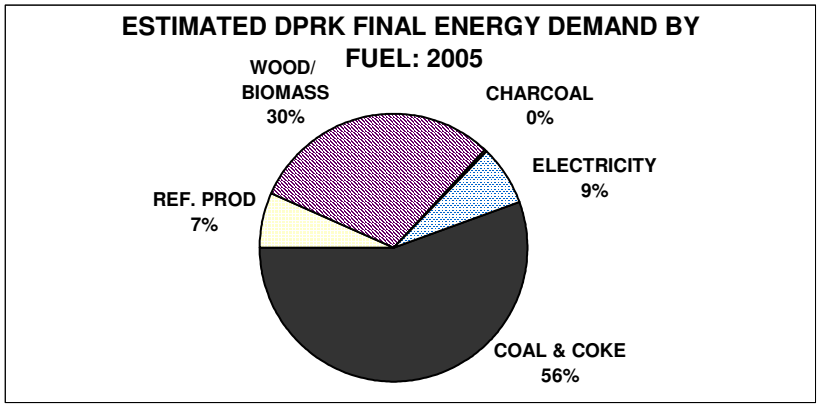
UNITS: PETAJOULES (PJ)	COAL & COKE	CRUDE OIL	REF. PROD	HYDRO/ NUCL.	WOOD/ BIOMASS	CHAR-COAL	ELEC.	**TOTAL**
ENERGY SUPPLY	405	24	17	33	162	-	(0)	642
Domestic Production	480	1	-	33	150	-	-	665
Imports	5	22	17	-	12	-	0	57
Exports	80	-	0	-	0	-	0	80
Stock Changes	-	-	-	-	-	-	-	-
ENERGY TRANSF.	(117)	(24)	17	(33)	(4)	1	37	(121)
Electricity Generation	(88)	-	(5)	(33)	-	-	60	(66)
Petroleum Refining	-	(24)	24	-	-	-	-	(0)
Coal Prod./Prep.	(23)	-	-	-	-	-	(3)	(26)
Charcoal Production	-	-	-	-	(4)	1	-	(3)
Own Use	-	-	(1)	-	-	-	(4)	(5)
Losses	(6)	-	-	-	-	-	(16)	(21)
FUELS FOR FINAL CONS.	289	-	35	0	158	1	37	520
ENERGY DEMAND	289	-	35	-	158	1	37	520
INDUSTRIAL	150	-	8	-	0	-	14	172
TRANSPORT	-	-	9	-	1	-	4	14
RESIDENTIAL	94	-	3	-	118	1	4	220
AGRICULTURAL	8	-	1	-	25	-	1	35
FISHERIES	0	-	1	-	-	-	0	2
MILITARY	22	-	12	-	4	-	9	46
PUBLIC/COMML	14	-	0	-	4	-	5	23
NON-SPECIFIED			-					-
NON-ENERGY	2		1		6			9
Elect. Gen. (Gr. TWhe)	5.23	-	0.17	11.15	-	-	-	16.55

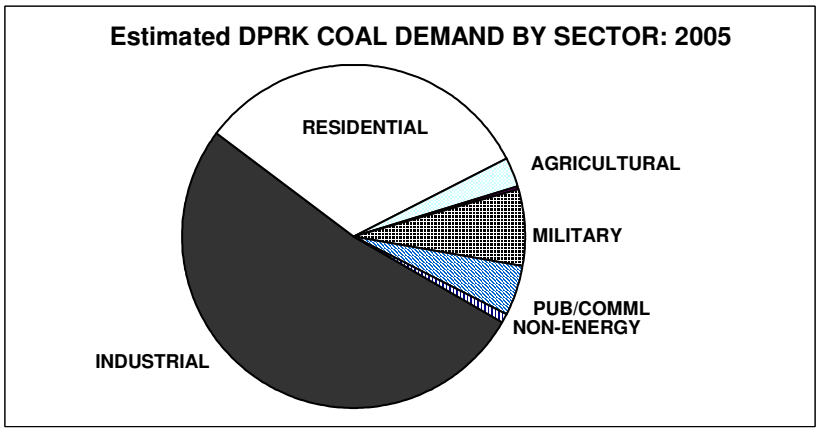
**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

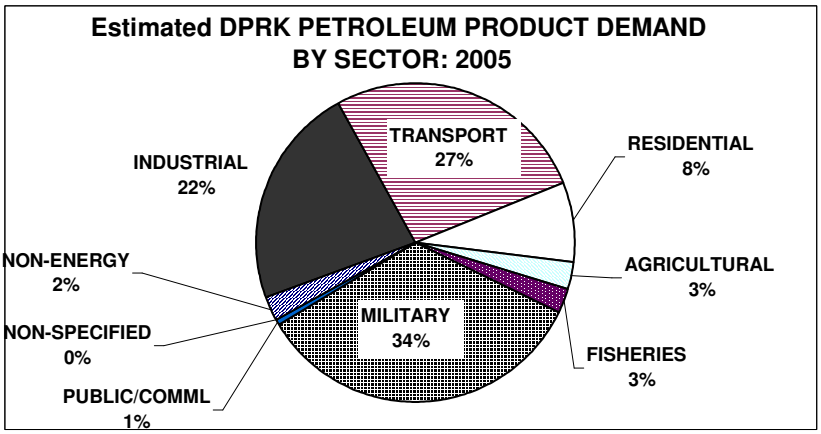

ESTIMATED DPRK ENERGY SUPPLY BY TYPE: 2005
WOOD/ BIOMASS 25%
HYDRO/NUCL. 5%
REF. PROD 3%
CRUDE OIL 4%
COAL & COKE 63%

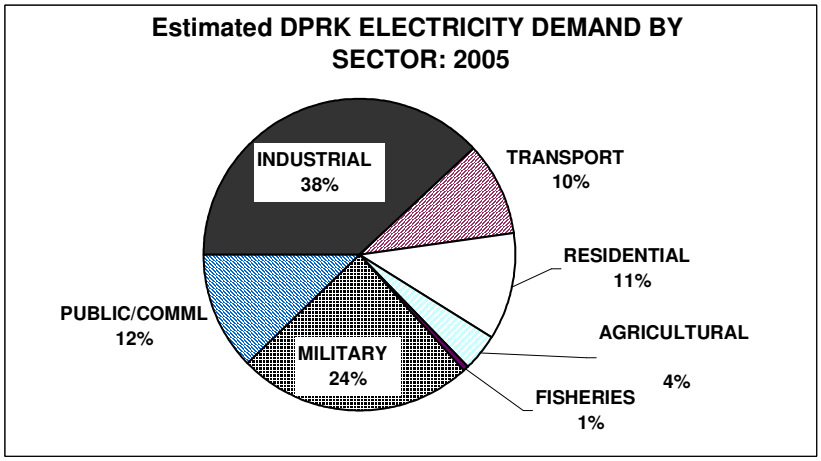

ESTIMATED DPRK ENERGY DEMAND BY SECTOR 2005
42%
7%
0%
9%
4%
0%
2%
33%
3%
INDUSTRIAL
TRANSPORT
RESIDENTIAL
AGRICULTURAL
FISHERIES
MILITARY
PUBLIC/COMML
NON-SPECIFIED
NON-ENERGY


ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 2005
NON-ENERGY 9
NON-SPECIFIED -
PUBLIC/COMML 23
MILITARY 46
FISHERIES 2
AGRICULTURAL 35
RESIDENTIAL 220
TRANSPORT 14
INDUSTRIAL 172
- 50 100 150 200 250
PJ ENERGY DEMAND


ESTIMATED DPRK FINAL ENERGY DEMAND BY FUEL: 2005
WOOD/ BIOMASS 30%
CHARCOAL 0%
ELECTRICITY 9%
REF. PROD 7%
COAL & COKE 56%


Estimated DPRK COAL DEMAND BY SECTOR: 2005
RESIDENTIAL
AGRICULTURAL
MILITARY
PUB/COMML
NON-ENERGY
INDUSTRIAL


Estimated DPRK PETROLEUM PRODUCT DEMAND BY SECTOR: 2005
TRANSPORT 27%
RESIDENTIAL 8%
INDUSTRIAL 22%
AGRICULTURAL 3%
NON-ENERGY 2%
MILITARY 34%
NON-SPECIFIED 0%
FISHERIES 3%
PUBLIC/COMML 1%


Estimated DPRK ELECTRICITY DEMAND BY SECTOR: 2005
INDUSTRIAL 38%
TRANSPORT 10%
RESIDENTIAL 11%
PUBLIC/COMML 12%
AGRICULTURAL 4%
MILITARY 24%
FISHERIES 1%

Workpapers—Energy Supply Sectors

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
COAL EXTRACTION AND PROCESSING, IMPORTS

Prepared By David Von Hippel
Date Last Modified: 3/12/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

					Source/Note:
Domestic Coal Production (official)					
Anthracite Coal	4.90E+07	te			*1, 21*
Brown Coal	2.10E+07	te			*1, 21*
Heat Content, Anthracite	6150	kcal/kg			*2*
Heat Content, Brown Coal	4250	kcal/kg			*2*
Weighted Ave Heat Content	5580	kcal/kg			
Official Ave. Heat Content	4500	kcal/kg			*10*
Conversion Factor	4.184	kJ/kcal			
Total Coal Production (official)	1317960000	GJ			
True-up factor to reduce coal supply to meet demand	98.0%				*Assumption*
Total Coal Production (revised)	1291600800	GJ			
Coal and Coke Imports					
Total Coal Imports	2.38E+06	te			*3*
Average Heat Content	26.2	GJ/te			*8*
Coal Imports	6.24E+07	GJ			
Coke Imports	2.09E+05	te			*3*
Average Heat Content	28.47	GJ/te			*4*
Coke Imports	5.95E+06	GJ, or	2.038E+05	Tce	
Total Coal and Coke Imports	6.84E+07	GJ			
Coal Exports					
Total Coal Exports (Anthracite)	1.17E+06	te			*5*
Heat Content, Anthracite	6200	kcal/kg			*8*
Conversion Factor	4.184	kJ/kcal			
	3.04E+07	GJ			
Coal Use in Coal Mining					
Per-unit coal use in mining	39.1	kg/te			*7*
Weighted Ave Heat Content	5580	kcal/kg			
Conversion Factor	4.184	kJ/kcal			
Coal Use in Mining Industry	6.26E+07	GJ			
Coal Transport Losses					
Coal Loss Rate	1%	of mined			*Guess*
Mass of Coal Lost	6.86E+05	te			
Energy content of Coal Lost	1.60E+07	GJ			
Electricity Use in Coal Mining					
Electricity intensity of mining	34.34	kWh/te			*6*
Conversion Factor	0.0036	GJ/kWh			
Electricity Used in Coal Mining	8.48E+06	GJ	6.43E-03		

COAL SUPPLY ESTIMATE

Coal Imports to the DPRK (China)	1.75E+06	te	(In 1993)	*11*
Coke Imports from FSU	2.09E+05	te	(In 1990)	*3*
Coal Exports to China	1.55E+05	te	(In 1993)	*11*

	1996	2000	2005	2	c.	
Coal Imports to the DPRK relative to 1993	18%	15%	8.4%		0%	*17*
Coke Imports to the DPRK relative to 1990	53%	28%	17%		7%	*12*
Total Estimated Coal+Coke Imports (GJ)	1.16E+07	8.40E+06	4.85E+06		+07	*Calculated*
Coal Exp. from DPRK rel. to 1993 Exp. to China	22%	232%	1989%		0%	*18, 19*
Total Estimated Coal Exports (GJ)	8.76E+05	9.32E+06	7.99E+07		+06	*Calculated*
Domestic Coal Production relative to 1990	49.82%	25.25%	37.18%		.8%	*13*
Total Estimated Domestic Coal Production (GJ)	6.43E+08	3.26E+08	4.80E+08		+08	*Calculated*
Estimated Coal Use in Coal Mining (GJ)	3.06E+07	1.55E+07	2.28E+07		+07	*Calculated*
Estimated Coal Losses (GJ)	7.82E+06	3.96E+06	5.84E+06		+06	*Calculated*
Estimated Electricity Use in Coal Mining (GJ)	4.14E+06	2.10E+06	3.09E+06		+06	*Calculated*

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Data on Coal Imports from and Exports to Other Countries, 2000

Data on Coal Exports from China to the DPRK and Imports to China from the DPRK ***(Source 15)***

			Export		Import	
Mer. ID	Name	Unit	Amount	US $	Amount	US $
27011100	Blend coal	kg	1,024,000	$ 40,960	8,142,700	$ 90,332
27011100	anthracite coal	kg	1,024,000	$ 40,960	8,142,700	$ 90,332
27011210	agglomerating(cindery) coal	kg	100,489,900	$ 3,616,390	-	-
27011290	other bituminous/soft coal	kg	17,406,100	$ 519,652	-	-
27011900	other coal	kg	53,646,410	$ 2,018,696	-	-
27040010	coking coal and semi-coking coal	kg	53,166,100	$ 3,001,260	-	-
27060000	coke tar; oil tar from distilling minerals	kg	154,500	$ 37,600	-	-
			225,887,010			

Data on Coal Exports to Japan from the DPRK ***(Source 16)***

Mer. ID	Name		
27011100	anthracite coal	351,069	tonnes

Data on Coal Imports from Australia to the DPRK

Total estimated coal imports from Australia ***(see Note 14)*** 31,127 tonnes

Data on Coal Imports from and Exports to Other Countries, 2005

Coal and coal products imports to the DPRK from China, as indicated in data collected as in ***Source 19***, (China Customs Statistics) are as follows for selected years: *Units: metric tonnes*

Year	Anthracite Coal	Bituminous Coal	Other Non-Agglomerated Coal	**Total Coals**	Coke; Retort Carbon	Pitch, Coke from Mineral Tars	Mineral Tars, Oils from Coal Tars
1996				**323,772**	100,053	6,152	5
1999	2,700	429,574	2,488	434,762	72,970	5,635	*185*
2000	1,024	117,956	53,646	172,627	53,166	4,243	155
2001	200	267,697	151,954	419,851	125,497	4,306	99
2002	969	234,810	26,684	262,463	155,914	4,959	380
2003	4,867	367,315	32,969	405,152	*87,141*	6,179	592
2004	19,011	241,040	4,271	264,322	22,213	4,488	125
2005	4,858	142,419	195	147,471	25,878	5,721	7

Coal and coal products exports from the DPRK to China, as indicated in data collected as in ***Source 19***, (China Customs Statistics) are as follows for selected years:

Year	Anthracite Coal	Bituminous Coal	Other Non-Agglomerated Coal	**Total Coals**	Coke; Retort Carbon	Pitch, Coke from Mineral Tars	Mineral Tars, Oils from Coal Tars
1996				33,777			50
1999				12,211			
2000				8,143			
2001				86,361			
2002				406,534			
2003				745,339			
2004				1,571,348			
2005				2,804,239			920

2005 "total coals" figure inclues 21 tonnes of lignite coal.

Coal and coal products exports from the DPRK to Japan as indicated in data collected as in ***Source 16***, (Japan Customs Statistics) are as follows for 2000 through 2005:

Mer. ID	Name
27011100	anthracite coal

Year	Tonnes	Average Cost, 1000 Yen/tonne
2000	351,069	3.61
2001	411,178	4.06
2002	354,491	4.15
2003	333,545	3.75
2004	255,945	4.47
2005	277,017	6.95

Notes:

1 1989 value from document in authors' files [HT1]. Other estimates are as high as 87 total Mte, and as low as 43 (both for 1990), and more recent outside ROK estimates are even lower (For example, the ROK's MOCIE and the Korean National Statistical Office estimate 1990 output of 33.15 million tonnes, declining to 21 million tonnes in 1996. Based on other information we have received, and on our analysis of DPRK energy demand in 1990 and 1996, these estimates appear too low.

2 Choi Su Young, Study of the Present State of Energy Supply in North Korea, RINU, 1993. P. 14.

3 Imports to NK. Choi Su Young, Study of the Present State of Energy Supply in North Korea, RINU, 1993. P. 23. Based on various statistics, including UN

4 J. Sinton, Editor, China Energy Databook, 1992 (Revised 1993). LBL. Page xii. Coal import figure assumes washed Chinese coal.

5 Exports to China. Choi Su Young, Study of the Present State of Energy Supply in North Korea, RINU, 1993. P. 25. Based on various statistics, including UN

6 Raw coal production electricity use, China, 1980, from "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL

7 Coal use in coal mining from [Chinese language spreadsheet dated 12-Feb-93 provided by J. Sinton],

8 Young Sik Jang, North Korean Energy Economics, Korea Development Institute, 1994 (p. 179). Value in this source for import coal to NK is within 1% of value for washed Chinese coal from reference 4.

10 Official 1989 value from document in authors' files [EE1].

11 J. Sinton, Editor, China Energy Databook (Revised 1996). Lawrence Berkeley National Laboratory (LBNL). Value is for the year 1993. Page VII-8.

12 Virtually all coke imported to the DPRK in 1996, 2000, and 2005 is assumed to come from China. Coke imports in these yeara are therefore assumed to be equal to imports from China as reflected in customs statistics, plus **10%** *to reflect additional imports from China not reported in customs statistics, plus small-volume imports from other countries, such as Russia.*

13 Set so as to balance demand+exports-imports. For 1996, value is consistent with the notes of some observers suggesting that coal output in that year was about half what it was in 1990, though estimates of of DPRK coal output over the years vary significantly. For 2005, the value shown is reasonably consistent with the "24.6 million tonnes of anthracite" figure provide in the State of the Environment DPR Korea 2003 report prepared with UNDP, and published by the United Nations Environment Programme. Of course, the value in the "SOE" report would have been a projection at the time that the report was written, but it is quite close to the value of 24 million tonnes cited by ROK sources (MOCIE, the National Statistical Service) for DPRK coal output in 2005. By comparison, the implied domestic coal output estimated here for 2000 is on the order of 25 to 30 percent lower than the 22.5 million tonnes that ROK sources (same as above) estimate for the DPRK.

14 "Democratic People's Republic of Korea Fact Sheet", from the Australian Department of Foreign Trade (www.dfat.gov.au/geo/dprk, visited 5/17/2002), lists Australian exports of coal to the DPRK during "2000-2001" with a value of ***1.70*** *million $AU. Data from http://www.australiancoal.com/exports.htm (visited 5/23/02) show that* 104.4 *million tonnes of "Metallurgical coal" and* 89 *million tonnes of "thermal" coal were exported overall by Australia in 2000-2001, with values, respectively, of* 6367.7 *and* 4194.9 *million $AU. This suggest that the average value per ton of coal shipped was* $ 54.62 *AU per tonne, so that if coal exports to the DPRK were of the same proportions of metallurgical and thermal coals as overall exports, a total of approximately* 31,127 *tonnes of coal would have been exported from Australia to the DPRK in 2000-2001.*

15 Data from China Customs Report 2000, pp. 1483-1495 (in Chinese).

16 From/derived from Japan customs statistics, http://www.customs.go.jp/toukei/info/index_e.htm, and http://www.customs.go.jp/toukei/download/index_d012_e.htm (the latter visited 2/2007).

17 Year 2000 value includes reported coal imports from China and Australia.

18 Year 2000 value includes reported coal exports to China and Japan.

19 China Customs Statistics reported coal exports from China to the DPRK of 147,471 *tonnes in 2005. As compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.*

20 Following data on coal products imports and exports from source as noted above.

Imports to the DPRK from China *Units: Metric Tonnes*

Commodity Code	Product/Product Group	2000	2001	2002	2003	2004	2005
2708	PITCH,COKE FM MN TARS	4,243.2	4,306.3	4,959.2	6,179.5	4,488.2	5,720.6
2701	SOLID FUELS FROM COAL	172,627	419,851	262,523	405,152	264,357	147,471
270111	ANTHRACIT COAL,N AG	1,024	200	969	4,867	19,011	4,858
270112	BITUMNOUS COAL,N AG	117,956	267,697	234,810	367,315	241,040	142,419
270119	OTHER COAL,NT AGGLM	53,646	151,954	26,684	32,969	4,271	195
270120	OTHER 2701	-	-	60	-	35	-

Exports from the DPRK to China *Units: Metric Tonnes*

Commodity Code	Product/Product Group	2000	2001	2002	2003	2004	2005
2701	SOLID FUELS FROM COAL	8,143	86,361	406,534	745,339	1,571,348	2,804,260
2706	MINERAL TARS						920
2702	LIGNITE,EXCLUDING JET						21

21 The report DPR KOREA : STATE OF THE ENVIRONMENT 2003, published by the United Nations Environment Programme, lists (tables 3.15 and 3.16) anthracite coal "primary consumption" of 45,409 *thousand tonnes, "bitumimous coal" primary consumption of* 11,934 *thousand tonnes, and total coal consumption of* 60,000 *thousand tonnes. Given that the DPRK is said to have very limited reserves of bituminous coal, and lignite coal is not listed in the tables referenced, we consider 21 million tonnes of lignite to be more believable. A set of figures in the authors' files [NKES-01], dated 2001 and citing a DPRK source, lists 1991 output figures that are similar to the above--45.4 million tonnes anthracite, 14.3 million tonnes of lignite, and 365,000 tonnes of "raphaelite". This appears roughly consistent with an estimate of 70 million tonnes for 1990, given that production declined after 1990. The same source provided the following coal production estimates for other years.*

Yearly coal production rates

Year	1991	1992	1993	1994	1995	1996	1997
Million* Tonnes	60	59	58	52.8	37.8	27.2	27
Year	1998	1999	2000				
Million* Tonnes	22	22.1	22.3				

** Stated by the source as "kilo-tonnes", which seems clearly to have been a units error.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

BACK-UP CALCULATIONS AND DATA: OIL IMPORTS, EXPORTS, AND REFINING

Prepared By David Von Hippel
Date Last Modified: 3/20/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

					Source/Note:
Domestic Crude Oil Production			0	te	
Crude Oil Imports, Total			2.60E+06	te	1
Conversion Factor			4.26E+01	GJ/te	
Crude Oil Imports, Total			1.11E+08	GJ	
Refined Products Imports					
FUEL	te	toe/te	Toe		
Gasoline	1.20E+05	1.05E+00	1.26E+05		3
Kerosene	5.00E+04	1.03E+00	5.16E+04		3
Diesel	3.00E+05	1.03E+00	3.10E+05		3
Heavy Oil	1.50E+05	9.91E-01	1.49E+05		3
TOTAL			6.36E+05	toe	
Conversion Factor			4.18E+01	GJ/toe	
Total Refined Products Imports			2.66E+07	GJ	
Total Oil Imports			1.37E+08	GJ	
Energy Use in Refining--West Coast Refinery			0.0578	toe/te of input	2
Energy Use in Refining-East Coast Refinery			0.0523	toe/te of input	17
Conversion Factor			4.18E+01	GJ/toe	
Total Refining Losses			6.29E+06	GJ	
Production of Refined Products, Total			1.04E+08	GJ	
LPG Consumption			2.55E+03	te	4
Conversion Factor			4.24E+01	GJ/te	
LPG Consumption, Total			1.08E+05	GJ	

ESTIMATE OF CURRENT AND FUTURE CRUDE OIL AND OIL PRODUCTS SUPPLY

Input Data for the Year 1996						
Crude Oil Imports from China, 1st through 3rd Quarters, 1996			7.48E+05	tonnes		5
Recorded Crude Oil Imports from China, all of 1996			936,170	tonnes		30
Estimate of other crude oil imports, 1996			0.00E+00	tonnes		13
Conversion Factor			4.26E+01	GJ/te		
Total Estimated Crude Oil Imports to DPRK, 1996			3.99E+07	GJ		
Official Refined Prod. Imports from China, 1st - 3rd Q., 1996			42,744	tonnes		5,6
Recorded Refined Products Imports from China, all of 1996			68,378	tonnes		30
Conversion Factor		1.050	toe/te			
HFO Supplied by KEDO, 1996 (11/1/95 to 10/31/96)			**500,000**	tonnes		7
Est. Conversion Factor, KEDO Oil		1.00	toe/te			
Other Imports of Refined Products, 1996	tonnes		toe/te	GJ		
Gasoline	1.26E+05		1.050	5.54E+06		14
Kerosene	1.20E+04		1.032	5.18E+05		14
Diesel	1.20E+05		1.032	5.18E+06		14
HFO	9.40E+04		0.991	3.90E+06		14
Total Estimated Refined Product Imports to DPRK, 1996			3.91E+07	GJ		
Estimated HFO placed in storage, 1996			160,653	tonnes		8
			6.66E+06	GJ		8

Input Data for the Year 2000					
DPRK Crude Oil Production			30,000	tonnes	*27*
Reported Crude Oil Imports from China, 2000			3.89E+05	tonnes	*18*
Other Imports of Crude Oil from China not Reported to Customs			0.00E+00	tonnes	
Total Estimated Crude Oil Imports from China, 2000			3.89E+05	tonnes	
Estimate of other crude oil imports, 2000 (unknown source)			0.00E+00	tonnes	*See below*
Conversion Factor			4.26E+01	GJ/te	
Total Estimated Crude Oil Imports to DPRK, 2000			1.66E+07	GJ	
Official Refined Prod. Imports from China, 2000			1.17E+05	tonnes	*18*
Extrapolated Official Refined Prod. Imports from China, 2000			1.17E+05	tonnes	
Conversion Factor	1.050	toe/te			
HFO Supplied by KEDO, 2000 (1/1/2000 to 12/31/2000)			**394,722**	tonnes	*19*
Est. Conversion Factor, KEDO Oil	1.00	toe/te			
Total Imports of Refined Products, 2000	tonnes	toe/te	GJ		
Gasoline	1.38E+05	1.050	6.08E+06	*Sum of*	
Kerosene	3.20E+04	1.032	1.38E+06	*Imports from*	
Diesel	2.05E+05	1.032	8.85E+06	*all nations*	
HFO	5.54E+05	0.991	2.30E+07	*(see below,*	
LPG/Refinery Gas/Non-Energy	6.43E+04	1.013	2.72E+06	*and note 15)*	
Total Estimated Refined Product Imports to DPRK, 2000			4.20E+07	GJ	
Estimated Refined Product Exports from DPRK, 2000 (to China)			tonnes	GJ	
HFO			68,135	2.83E+06	
LPG/Refinery Gas/Non-Energy			4,329	1.83E+05	
Total of above			72,464	3.01E+06	
Estimated Net HFO placed in storage, 2000			-	tonnes	*26*
			0.00E+00	GJ	*26*

Input Data for the Year 2005					
DPRK Crude Oil Production			30,000	tonnes	*27*
Reported Crude Oil Imports from China, 2005			522,844	tonnes	*30*
Other Imports of Crude Oil from China not Reported to Customs			-	tonnes	
Total Estimated Crude Oil Imports from China, 2005			522,844	tonnes	
Estimate of other crude oil imports, 2005 (unknown source)			-	tonnes	*See below*
Conversion Factor			42.59	GJ/te	
Total Estimated Crude Oil Imports to DPRK, 2005			2.23E+07	GJ	
Official Refined Prod. Imports from China, 2005			148,963	tonnes	*31*
Extrapolated Official Refined Prod. Imports from China, 2005			1.49E+05	tonnes	
Conversion Factor	1.050	toe/te			
HFO Supplied by KEDO, 2005			**0**	tonnes	*31*
Est. Conversion Factor, KEDO Oil	1.00	toe/te			
Total Imports of Refined Products, 2005	tonnes	toe/te	GJ		
Gasoline	8.39E+04	1.050	3.69E+06	*Sum of*	
Kerosene	5.30E+04	1.032	2.29E+06	*Imports from*	
Diesel	1.77E+05	1.032	7.62E+06	*all nations*	
HFO	6.04E+04	0.991	2.50E+06	*(see below,*	
LPG/Refinery Gas/Non-Energy	9.67E+03	1.013	4.10E+05	*and note 36)*	
Total Estimated Refined Product Imports to DPRK, 2005			1.65E+07	GJ	
Estimated Refined Product Exports from DPRK, 2005 (to China)			tonnes	GJ	
HFO			-	0.00E+00	
LPG/Refinery Gas/Non-Energy			4,393	1.86E+05	
Total of above			4,393	1.86E+05	
Estimated Net HFO placed in storage, 2005			-	tonnes	*26*
			0.00E+00	GJ	*26*

Implied total 2005 crude oil, oil products into the DPRK:	3.88E+07	GJ/yr, which implies annual use of			
(at a conversion rate of	7.33	bbl oil equivalent per tonne oil equivalent)	6.79E+06	bbl/yr or	
an average of	18,614	bbl per day, which consistent with totals estimated by source in *Note 37*.			

		2000	2005		
Crude Oil Imports from China relative to 1996 (rel to 2000 for 2005)		42%	134%	THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS	%
Other Crude Oil Imports (tonnes)		0.00E+00	0.00E+00		0
Domestic DPRK Crude Oil Production (tonnes)		30,000	30,000		
Official Refined Products Imports from China relative to 1996 (rel to 2000 for 2005)		172%	127%		%
HFO Supplied by KEDO (tonnes)		3.95E+05	0.00E+00		5
Total Imports of Refined Products (tonnes)	Gasoline	1.38E+05	8.39E+04		4
	Kerosene	3.20E+04	5.30E+04		4
	Diesel	2.05E+05	1.77E+05		5
	HFO	5.54E+05	6.04E+04		5
	LPG/Refinery Gas/Non-Energy	6.43E+04	9.67E+03		

Estimated Refinery Statistics--1990					
	West Coast	East Coast			
Capacity, barrels of crude/day	2.90E+04	4.20E+04			*12*
Capacity, tonnes of crude per year	1.446E+06	2.095E+06			
Output (Weight fraction of input)					
Heavy Fuel Oil	38%	34%			*11, 17*
Gasoline	22%	24%			*11, 17*
Diesel Oil	20%	15%			*11, 17*
Kerosene	4%	11%			*11, 17*
LPG/Refinery Gas/Non-Energy	12%	11%			*11, 17*
TOTAL	96%	95%			
Estimated Refinery Input, 1990 (tonnes)	1.16E+06	1.44E+06			
Estimated Refinery Output, 1990 (tonnes)			Toe/Te		
Heavy Fuel Oil	440,800	489,600	0.991		
Gasoline	255,200	345,600	1.050		
Diesel Oil	232,000	216,000	1.032		
Kerosene	46,400	158,400	1.032		
LPG/Refinery Gas/Non-energy (gross)	139,200	158,400	1.013		
Estimated Refinery Fuel Use (toe)	67,048	75,312			
Estimated Net Refinery Output, 1990 (GJ)			% of Net		
Heavy Fuel Oil	1.83E+07	2.03E+07	36.82%		
Gasoline	1.12E+07	1.52E+07	25.19%		
Diesel Oil	1.00E+07	9.33E+06	18.46%		
Kerosene	2.00E+06	6.84E+06	8.44%		
LPG/Refinery Gas/Non-Energy	5.09E+06	6.53E+06	11.10%		*10*
TOTAL	4.66E+07	5.82E+07	100.00%		
Estimated Net Refinery Output, 1990 (tonnes)	1,094,488	1,363,647	2,458,134		
Refinery use of electricity, kWh/tonne output	67.04				*28*
Estimated 1990 Refinery use of electricity	165	GWh or	5.93E+05	GJ	

Estimated Refinery Statistics--1996					
	West Coast	East Coast			
Capacity, barrels of crude/day	2.90E+04	4.20E+04			*12*
Capacity, tonnes of crude per year	1.446E+06	2.095E+06			
Output (Weight fraction of input)					
Heavy Fuel Oil	38%	34%			*11, 17*
Gasoline	22%	24%			*11, 17*
Diesel Oil	20%	15%			*11, 17*
Kerosene	4%	11%			*11, 17*
LPG/Refinery Gas/Non-Energy	12%	11%			*11, 17*
TOTAL	96%	95%			
Estimated Refinery Input, 1996 (tonnes)	9.36E+05	0			
Estimated Refinery Output, 1996 (tonnes)			Toe/Te		
Heavy Fuel Oil	355,745	-	0.991		
Gasoline	205,957	-	1.050		
Diesel Oil	187,234	-	1.032		
Kerosene	37,447	-	1.032		
LPG/Refinery Gas/Non-energy (gross)	112,340	-	1.013		
Estimated Refinery Fuel Use (toe)	54,111	-			
Estimated Net Refinery Output, 1996 (GJ)			% of Net		
Heavy Fuel Oil	1.48E+07	0.00E+00	39.22%		
Gasoline	9.05E+06	0.00E+00	24.06%		
Diesel Oil	8.08E+06	0.00E+00	21.50%		
Kerosene	1.62E+06	0.00E+00	4.30%		
LPG/Refinery Gas/Non-Energy	4.11E+06	0.00E+00	10.93%		*10*
TOTAL	3.76E+07	0.00E+00	100.00%		
Estimated Net Refinery Output, 1996 (tonnes)	883,299				
Refinery use of electricity, kWh/tonne output	67.04				*28*
Estimated 1996 Refinery use of electricity	59	GWh or	2.13E+05	GJ	

Estimated Refinery Statistics--2000					
(See below for smaller W. Coast Refinery)	West Coast	East Coast			
Capacity, barrels of crude/day	2.90E+04	4.20E+04			*12*
Capacity, tonnes of crude per year	1.45E+06	2.09E+06			
Output (Weight fraction of input)					
Heavy Fuel Oil	38%	34%			*11, 17*
Gasoline	22%	24%			*11, 17*
Diesel Oil	20%	15%			*11, 17*
Kerosene	4%	11%			*11, 17*
LPG/Refinery Gas/Non-Energy	12%	11%			*11, 17*
TOTAL	96%	95%			
Estimated Refinery Input, 2000 (tonnes)	3.95E+05	0.00E+00			
Estimated Refinery Output, 2000 (tonnes)			Toe/Te		
Heavy Fuel Oil	150,027	-	0.991		
Gasoline	86,858	-	1.050		
Diesel Oil	78,962	-	1.032		
Kerosene	15,792	-	1.032		
LPG/Refinery Gas/Non-energy (gross)	47,377	-	1.013		
Estimated Refinery Fuel Use (toe)	22,820	-			
Estimated Net Refinery Output, 2000 (GJ)			% of Net		
Heavy Fuel Oil	6.22E+06	0.00E+00	39.22%		
Gasoline	3.82E+06	0.00E+00	24.06%		
Diesel Oil	3.41E+06	0.00E+00	21.50%		
Kerosene	6.82E+05	0.00E+00	4.30%		
LPG/Refinery Gas/Non-Energy	1.73E+06	0.00E+00	10.93%		*10*
TOTAL	1.59E+07	0.00E+00	100.00%		
Estimated Net Refinery Output, 2000 (tonnes)	372,512				
Refinery use of electricity, kWh/tonne output	73.74	10% higher than in 1996			*28*
Estimated 2000 Refinery use of electricity	29.20	GWh or	1.05E+05	GJ	
(Includes small West Coast refinery)					

Estimated Refinery Statistics--2005				
(See below for smaller W. Coast Refinery)	West Coast	East Coast		
Capacity, barrels of crude/day	2.90E+04	4.20E+04		*12*
Capacity, tonnes of crude per year	1.45E+06	2.09E+06		
Output (Weight fraction of input)				
Heavy Fuel Oil	38%	34%		*11, 17*
Gasoline	22%	24%		*11, 17*
Diesel Oil	20%	15%		*11, 17*
Kerosene	4%	11%		*11, 17*
LPG/Refinery Gas/Non-Energy	12%	11%		*11, 17*
TOTAL	96%	95%		
Estimated Refinery Input, 2005 (tonnes)	5.28E+05	0.00E+00		
Estimated Refinery Output, 2005 (tonnes)			Toe/Te	
Heavy Fuel Oil	200,799	-	0.991	
Gasoline	116,252	-	1.050	
Diesel Oil	105,683	-	1.032	
Kerosene	21,137	-	1.032	
LPG/Refinery Gas/Non-energy (gross)	63,410	-	1.013	
Estimated Refinery Fuel Use (toe)	30,543	-		
Estimated Net Refinery Output, 2005 (GJ)			% of Net	
Heavy Fuel Oil	8.33E+06	0.00E+00	39.2%	
Gasoline	5.11E+06	0.00E+00	24.1%	
Diesel Oil	4.56E+06	0.00E+00	21.5%	
Kerosene	9.13E+05	0.00E+00	4.3%	
LPG/Refinery Gas/Non-Energy	2.32E+06	0.00E+00	10.9%	*10*
TOTAL	2.12E+07	0.00E+00	100.0%	
Input to/Output of Smaller Western Refinery relative to 2000 Estimate:			100%	*Assumption*

Crude Oil and Refined Products Imports from and Exports to China, 2000 ***(kilograms: See Note 18)***

Commodity	Imports	Exports
asphalt	4,203,170	
asphalt coke	40,000	
crude petroleum and crude oil from asphalt	389,236,142	
vehicle use gasoline and aviation gasoline	22,091,731	
rubber solvent oil, oil paint solvent	87,621	
Jet fuel	46,853,114	
light diesel oil	29,108,167	
other diesel oil and fuel oil	3,589,984	
lubricant grease	168,652	
lubricant oil	7,781,450	14,016
lubricant oil basic oil	1,789,195	
other heavy oil		19,920,914
liquefied butane for lighter, volume > 300 cuom	16,000	
other liquefied butane	30,400	
other unlisted liquefied petroleum gas and other aromatic gas		4,314,996
vaseline	75,735	
paraffin wax, content less than 0.75% in terms of weight	10,000	
microcystal wax	2,200	
unburnt petroleum coke	843,000	
petroleum asphalt	211,289	
other petroleum or residuals from asphalt smelting	563,217	
emulsified asphalt	10,450	
Total refined products (above less crude oil)	117,475,375	24,249,926

Summary of Above in Refined Products Balance Reporting Categories (tonnes)

Commodity	Imports	Exports
Heavy Fuel Oil	-	19,921
Gasoline/Aviation Gasoline	22,092	
Diesel Oil	32,698	
Kerosene/Jet Fuel	46,853	
LPG/Refinery Gas/Non-Energy	15,832	4,329
Total of Above	117,475	24,250

Crude Oil and Refined Products Imports from and Exports to China, 2005 ***(tonnes: See Note 30)***

Commodity	Imports	Exports
Light diesel oil	46,668	
Aviation kerosene	46,994	
Basic oils for lubricating oils	3,629	
Lubricating oils	2,320	
Fuel oils No. 5 ~ No. 7	3,573	
Other diesel oils and other fuel oils	1,187	
Lubricating grease	168	
Liquid paraffin and heavy liquid paraffin	0	
Other lubricating oils, greases and other heavy oil	4	
Motor gasoline, aviation gasoline	40,893	
Rubber solvent, paint solvent, extractive solvent	3.3	
Other light oils and preparations	51	
PETROLEUM,OTHER GASES	497	4,393
PETROLEUM JELLY;WAXES	109	
PETROLEUM COKE,RESIDUES	2,865	
BITMN,ASPHLT;TAR SAND	-	
BITUMEN,TAR RELATED	1.5	
Total refined products (above less crude oil)	148,963	4,393

Summary of Above in Refined Products Balance Reporting Categories (tonnes)

Commodity	Imports	Exports
Heavy Fuel Oil	3,573	-
Gasoline/Aviation Gasoline	40,893	
Diesel Oil	47,855	
Kerosene/Jet Fuel	46,994	
LPG/Refinery Gas/Non-Energy	9,646	4,393
Total of Above	148,963	4,393

Estimate of 2000 and 2005 Imports of Petroleum Products from Russia

Total Imports in 2000 estimated at: 1.5 kbbl/day *Source 20*

at an estimated 7.24 bbl/tonne (assumes average product density of .87 kg/l)

implies an annual level of imports of 7.56E+04 tonnes

Assume that 80% of these imports are diesel/gas oil, and

20% are heavy oil or the equivalent, then total

import from Russia were 6.05E+04 of diesel and

1.51E+04 of heavy oil.

Imports in 2005 are estimated at 1 kbbl/day on average. This is a rough estimate, but takes in to account higher (official) imports of crude oil and refined products from China to the DPRK in 2005, relative to 2000. Splits by product are assumed the same as in 2000.

Year 2000 Oil products imports from other countries

Oil products imports from Japan: 4.43E+04 tonnes *See Note 21*
- Fraction as heavy fuel oil: 99.51%
- Fraction as non-energy (solvents and lubricants): 0.49%
- Total imports of heavy fuel oil from Japan: 4.41E+04 *tonnes*
- Total imports of non-energy petrol. products from Japan: 2.15E+02 *tonnes*

Oil products from Singapore: Rough estimate of value: $14,000,000 *See Note 22*
Rough estimate of price: $ 0.70 per gallon *See Note 23*
Assume that imports are 90% gasoline and 10% diesel, and thus having
an average density of 0.74 kg/liter for gasoline and
and 0.87 kg/liter for diesel and
then at 3.78 liters per gallon,
implied oil imports are 20,000,000 gallons, or 5.03E+04 tonnes of gasoline and 6.58E+03 tonnes of diesel.

Oil Products from the ROK:
Rough estimate of maximum rate of imports from ROK: 10,000 Bbl/day for *See Note 24*
10% of the year, or an average of 1000 Bbl/day.
Assume that these oil products are (or can be used as) 70% diesel
and 30% heavy fuel oil at an assumed density of 0.95 kg/liter.
This implies imports from the ROK of 16,515 tonnes of heavy fuel oil and 35,290 of diesel.

Imports and Exports Associated with Asphalt Use for Road ***(see worksheet "Oil_Asphalt")***
Middle of estimated asphalt requirements for Nampo-Pyongyang Road built in 2000
48,214 tonnes
Assumed mass of heavy oil traded (probably to China) per tonne asphalt received:
1.00 , which implies heavy fuel oil exports of: 48,214 tonnes

Estimate of Output of Smaller West Coast Refinery *(see Note 25)*

We know little about the small refinery on the West Coast of the DPRK, except that it is thought to be dedicated all or in part to the military, and is a relatively crude fractionation or "topper"-type refinery. It is not know where the oil for this refinery comes from--it could be some of the Russian oil described above, or could be oil supplied in barter from China (and thus not part of trade statistics), or could be purchased on the spot market. It operates in a batch mode, and reportedly had an capacity factor of about 20% in 2000. We do not know the capacity of this refinery, but estimate it below based on what is known about the capacity of the oil-fired power plant that is near the refinery site, and on the following rough estimates of refinery outputs and related assumptions.

Fraction of heavy fuel oil produced by the refinery used in the nearby power plant: 95% *Assumption*
Gross efficiency of power plant (assumes relatively poor condition and operation in a cogeneration mode to provide steam for the refinery). 19%
Implied heavy oil input to power plant: 1,991,747 GJ, or 47,572 toe when the powerplant and refinery operate at **full capacity**. Assuming that the refinery and power plant operate at the capacity level indicated above, the output of the refinery is roughly:

Output (Energy fraction of input)	Assumptions	Implied Output toe	Implied Output GJ
Heavy Fuel Oil	41%	10,015	4.29E+05
Gasoline	24%	5,863	2.51E+05
Diesel Oil	21%	5,130	2.20E+05
Kerosene/Jet Fuel	5%	1,221	5.24E+04
LPG/Refinery Gas/Non-Energy	5%	1,221	5.24E+04
TOTAL	96%	23,450	1.01E+06

Implied required crude oil input to refinery: 24,427 toe or 1.02E+06 GJ
Consider 0% of these inputs to be crude oil imports not accounted for elsewhere. For 2000 and 2005 it is assumed that the DPRK has produced roughly 30,000 tonnes per year of crude oil from domestic sources (see Note 27). The reported site of the oil production is close enough to the reported site of the small West Coast refinery, and the estimated volume of crude oil required by that refinery is close enough to the assumed output, that we assume that either the 30,000 tonnes of domestic production goes to the small West Coast refinery, or, if there is in fact no significant domestic crude oil production in the DPRK, the crude oil used as feedstock from that refinery is imported from elsewhere (that is, is not captured in China Customs Statistics).

Input of refinery fuel to refinery (own use) at 0.0578 toe/te of input
is 1,412 toe or 5.91E+04 GJ

Year 2005 Oil products imports from other countries

Oil products imports from Japan			99.46	tonnes	*See Note 34*
Fraction as heavy fuel oil:				75.01%	
Fraction as non-energy (solvents and lubricants):				24.99%	
Total imports of heavy fuel oil from Japan			74.61	*tonnes*	
Total imports of non-energy petrol. products from Japan				24.86	*tonnes*
Oil products from Singapore:	Rough estimate of value:			$0	*See Note 35*
	Rough estimate of price:			$ 0.70	per gallon
Assume that imports are			90%	gasoline and	
			10%	diesel, and thus having	
an average density of		0.74	kg/liter for gasoline and		
and		0.87	kg/liter for diesel and		
then at	3.78	liters per gallon,			
implied oil imports are		-	gallons, or	0.00E+00	tonnes of gasoline and
				0.00E+00	tonnes of diesel.
Oil Products from the ROK:					
Rough estimate of rate of imports from ROK:				12,000	Bbl/day for *See Note 24*
	10%	of the year, or an average of		1200	Bbl/day.
Assume that these oil products are (or can be used as)					80% diesel
and	20%	heavy fuel oil at an assumed density of			0.95 kg/liter.
This implies imports from the ROK of			13,212	tonnes of heavy fuel oil and	
			48,398	of diesel.	

Sources/Notes:

1 Reference 3 reports 2.8 Mte. Note that the Korea Foreign Trade Association, in "Major Economic Indicators for North Korea", 1993. P. 33, lists a total of 2.43 million te oil, which includes imports from the former USSR, China, and Iran, but apparently does not include oil purchased On the spot market. 1990 figures. Other sources suggest that 2.8 Mte in 1990 is an over-estimate, thus we have assumed crude oil imports of 2.6 Mte in 1990.

2 Based on figures in: "Progress of Energy Saving in China's Petrochemical Industry", W.B. Shen, in Energy Markets and the Future of Energy Demand, LBL, 1988, p. 24-2.

3 Choi Su Young, Study of the Present State of Energy Supply in North Korea, RINU, 1993. P. 40

4 Young Sik Jang, North Korean Energy Economics, Korea Development Institute, 1994 (p. 62)

5 Exports to the DPRK from China. Source: China Customs Statistics.

6 Probably mostly gasoline (David Fridley, Lawrence Berkeley National Laboratory, Personal Communication).

7 Korean Peninsula Energy Development Organization (KEDO, 1996), Korean Peninsula Energy Development Organization, Annual Report, 1995. KEDO, Washington, D.C., July 31, 1996

8 Calculated estimate based on difference between estimated demand and estimated supply for heavy oil in 1996.

9 Note that 110% of estimated 1996 imports approximates the level of refined products imported from China (at least officially) as of 1993 (Sinton, J. (1996), China Energy Databook).

10 Net of refinery gas used in-plant, and calculated as LPG/Refinery gas-(input-other products output-refining loss)

11 Data for Western refinery estimates based on similar Chinese plants from David Fridley, Lawrence Berkeley National Laboratory (personal communication, 12/96). Data for Eastern (Russian-built) refinery from Source 17. Estimate from Fridley was modified by reducing heavy oil total by 7% to account for probable production of heavy non-energy products (bitumens/asphalts, petroleum coke, wax, lubricants), based very roughly on Chinese petroleum output statistics for 1990 (from Sinton, J. (China Energy Databook), p. II-55).

12 From International Petroleum Encyclopedia, 1996. Confirmed by other sources. East coast refinery has 7,300 barrels per day fluid cracking capacity.

13 Several sources have suggested that little, if any, crude oil beyond that imported from China has come into the DPRK in the two years prior to 1997--possibly one cargo at most (which would have been refined at Sonbong) --and almost certainly not in 1996.

14 Includes petroleum product imports reported to be "one-half of the output" of a 750,000 te (output) Chinese refinery located north of the Tumen River. This refinery is assumed to operate at a maximum of 80 percent of capacity (David Fridley, personal communication), yielding total output of 600,000 tonnes. Output shares of that refinery are assumed to be the same as in the West Coast DPRK refinery, but it is assumed that the products exported to the DPRK are weighted slightly toward diesel and gasoline and away from HFO, based on the higher need for motor fuels in the DPRK and the need for HFO to fuel power plants in adjacent areas of China. Our assumption is that 10,000 tonnes more of gasoline and of diesel are exported to the DPRK, and 20,000 tonnes less of HFO, relative to simply splitting the product slate of the refinery evenly between the two countries. For 1996, product imports also include 50,000 te each of gasoline and diesel reported to be provided by ship and rail from Russia. [Industry source--should be confirmed independently]

15 For 2000, includes quantities reported separately from the ROK, Russia, Singapore, and Japan, plus amounts of products similar to those received in 1996 from the Chinese refinery near the border (note 14).

16 Assumes that the capacity of the Sonbong refinery is increased to 2.5 times its original capacity, and that "cracking" capacity is added so that the relative fractions of refined products are as shown.

17 Personal communication [QR 9/97].

18 Exports to the DPRK from China from China Customs Report 2000 , pp. 1483-1495 (in Chinese).

19 From "Appendix 1: HFO Deliveries" of Korean Peninsula Energy Development Organization (KEDO) Annual Report 2001 , obtained from www.kedo.org, 5/31/2002. Note that this figure is for oil actually delivered during the calendar year 2000, as two of the shipments of the "HFO Year 2000" occurred in 2001.

20 Industry source reports probable barter imports of oil products ("gas oil and light crude") from Russia at "less than 1.5 kbbl/day". We have assumed an average of 1500 bbl/day.

21 From Japan customs statistics, http://www.customs.go.jp/toukei/info/index_e.htm. Composed of a combination of products, but 99 percent by mass are in the class designated "HS# 271000400". The designation of this code appears to be Heavy Fuel Oil of some kind, which is consistent with its specific gravity of near one.

22 Based on text in "Singapore" section of "Current Status and Features of North Korean Foreign Trade of the First Half of 2001", from www.kotra.or.kr/main/common_bbs which suggests that the maximum value of oil exports to the DPRK in the first half of 2000 would have been about $8.5 million (but could have been considerably less). The actual data on sales of oil products from Singapore to the DPRK are available, but could not be obtained by the time of this writing.

23 Data from the US DOE Energy Information Administration (table http://www.eia.doe.gov/pub/oil_gas/petroleum /data_publications/weekly_petroleum_status_report/current/txt/table13f.txt) suggests that spot prices for diesel fuel and gasoline in Singapore were in the range of $0.70 per gallon as of January, 2001. This figure is used to roughly calculate oil quantities purchased from Singapore.

24 An industry source suggests that the ROK sent to the DPRK in 2000 a maximum of "8 - 10 kbbl/day of off-spec HSFO for brief periods". "Off-spec" fuels do not meet ROK specifications for quality. We assume a rate of shipment of about 10 kbbl/day for about 10 percent of 2000. Lacking additional information, we assume the a slightly higher rate of exports from the ROK to the DPRK in 2005.

25 Information on this refinery from industry sources. Fuel output shares of refinery are very rough Nautilus estimates.

26 Assumes, based on industry sources, that very little KEDO HFO remained in storage at the end of 2000. The same assumption is made for 2005.

27 There have been reports that the DPRK "began to produce crude oil in a sea well off Sukchon County, South Pyongan Province" in 1998 (Lee Kyo Kwan, writing on www.chosun.com, "North Korea Exports Petroleum", probably sometime in 2001). This article suggests, without citing any figures that DPRK production was significant enough to allow the reduction of petroleum imports. Though our conversations with some experts in the industry have suggested that any production from DPRK wells was minimal, other sources in the literature suggest that DPRK oil production has indeed been enough to supply a significant fraction of DPRK needs. For example, Selig Harrison writes in Toward Oil and Gas Cooperation in Northeast Asia: New Opportunities for Reducing Dependence on the Middle East (published as Woodrow Wilson Center for International Scholars Asia Program Special Report No. 106, dated December 2002, and available as http://www.wilsoncenter.org/topics/pubs/asiarpt_106.pdf), that "an oil well [in Sukchon] began producing 2.2 million barrels annually in 1999". This is similar to a figure of 300,000 *tonnes crude oil per year quoted in several publications by Keun-Wook Paik, including Pipeline Gas Introduction to the Korean Peninsula, published by Chatham House, January 2005, and available as http://www.chathamhouse.org.uk/pdf/research/sdp/KPJan05.pdf.*
In the Chatham House report, Paik writes (p. 37) "Even though the scale of annual crude oil production from the Sook-Cheong County's Anju Basin is very small (0.3 mt/y), to the North Korean authorities it is a significant volume." In personal correspondence with Dr. Paik, he indicates that the information for this estimate came from an article in the ROK press in approximately 2001, and that while he has not seen the quantity of oil production confirmed, he he believes that some oil production is ongoing. Dr. Harrison indicates that his figure for DPRK oil production was likely taken from the work of Dr. Paik, or from the same original source. Other experts in the field consulted on this question have expressed skepticism that DPRK domestic oil production to date, if any, has been even close to as significant as the quantity reported.
Accordingly, we assume that a more reasonable figure for ongoing DPRK domestic oil production is 10% *of the reported value (which might also have been misreported due to an error in reporting units, as happens occasionally in the DPRK and elsewhere).*

28 Calculated based on 1990 data for China from J.E. Sinton, ed (1992). China Energy Databook. Lawrence Berkeley National Laboratory, Berkeley, CA, USA. (Revised 1996).

29 The website http://www.answers.com/topic/north-korea, visited 1/15/07, listed oil pipelines in the DPRK of total length 154 km as of 2004.

30 China Customs Statistics reported crude oil exports from China to the DPRK of 522,844.40 tonnes *in 2005. As compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.*
Crude oil and oil products imports to DPRK from China, as indicated by the same source, are as follows for other years:

Year	Crude Oil	Oil "(Not Crude)"	"PETROLEUM COKE,RESIDU"	"PETROLEUM OTHER GASES"
1996	936,170	66,533	1,845	-
1999	317,241	122,966.47	1,791.57	11.13
2000	389,236	111,501.04	1,617.51	46.40
2001	579,278	109,311.22	2,065.68	149.80
2002	472,167	82,471.55	6,547.86	215.85
2003	573,558	124,726.96	4,369.66	232.34
2004	531,785	127,968.58	5,283.75	354.37
2005	522,844	145,506.35	2,864.52	496.80

Units: metric tonnes

All crude oil shipped to the DPRK from China was recorded as coming from the Dalian district from 1999-2005.

Units: Kilograms

Commodity Code	Product/Product Group	2002	2003	2004	2005
2710	OIL (NOT CRUDE)	82,471,546	124,726,964	127,968,583	145,506,346
271019	OIL (NOT CRUDE) FROM PETROL	63,900,162	78,280,544	89,821,556	104,543,577
27101921	Light diesel oil	3,647,230	20,871,299	34,458,192	46,668,386
27101911	Aviation kerosene	46,649,237	46,307,578	46,572,203	46,994,450
27101993	Basic oils for lubricating oils	2,722,165	3,435,866	2,524,002	3,628,783
27101991	Lubricating oils	6,366,340	4,170,232	2,705,837	2,320,426
27101922	Fuel oils No. 5 ~ No. 7	-	2,569,560	2,600,000	3,573,156
27101929	Other diesel oils and other fuel oils	4,268,282	490,000	-	1,186,911
27101992	Lubricating grease	246,908	254,890	183,135	167,665
27101994	Liquid paraffin and heavy liquid paraffin	-	990	-	170
27101999	Other lubricating oils, greases and other heavy oil	-	180,129	778,187	3,630

Commodity Code	Product/Product Group	2002	2003	2004	2005
2710	OIL (NOT CRUDE)	82,471,546	124,726,964	127,968,583	145,506,346
271011	LIGHT OILS & PREP (NOT CRUDE)	18,571,384	46,446,418	38,147,027	40,947,469
27101110	Motor gasoline, aviation gasoline	18,328,384	46,199,539	38,144,787	40,893,374
27101130	Rubber solvent, paint solvent, extractive solvent	143,000	188,179	2,240	3,300
27101190	Other light oils and preparations	100,000	-	-	-
27101199	Other light oils and preparations	-	58,700	-	50,795

Units: Metric Tonnes

Commodity Code	Product/Product Group	2000	2001	2002	2003	2004	2005
2708	PITCH,COKE FM MN TARS	4,243.2	4,306.3	4,959.2	6,179.5	4,488.2	5,720.6
2711	PETROLEUM,OTHER GASES	46.4	149.8	215.9	232.3	354.4	496.8
2712	PETROLEUM JELLY;WAXES	87.9	59.0	187.0	157.8	149.0	108.9
2713	PETROLEUM COKE,RESIDUES	1,617.5	2,065.7	6,547.9	4,369.7	5,283.8	2,864.5
2714	BITMN,ASPHLT;TAR SAND	10.5	2.0	-	26.1	0.5	-
2715	BITUMEN,TAR RELATED	-	8.0	-	29.0	1.6	1.5

31 Assumes no KEDO oil remained in storage as of end-2005. KEDO suspended shipments of heavy oil to the DPRK as of December, 2002 (see, for example, http://www.kedo.org/).

32 Source cited in note 30 lists no imports of oil products from the DPRK into China in the categories below for the years 1995 to 2005 with the exception of 2002, as shown.

27101919	Other kerosene distillages	1,098	tonnes
27101999	Other lubricating oils, greases and other heavy oil	8,593	tonnes

and for the following years in a more aggregate categories "OIL (NOT CRUDE)" and "OIL (NOT CRUDE) FROM PETROL & BITUM MINERAL ETC" (used in 2002), as shown.

1997	1998	1999	2000	2002	
236,478	7,175	19,180	19,935	11,704	tonnes

Exports to China from the DPRK of gaseous petroleum products were recorded as:

Units: tonnes

Commodity Code	Product/Product Group	1995	1996	1997	1998	1999	2000
271119	OTHER,LIQUEFIED	11,703	10,450	5,874	4,100	4,534	4,315
2711	PETROLEUM,OTHER GASES	11,703	10,490	5,874	4,100	4,534	4,315

		2001	2002	2003	2004	2005
271119	OTHER,LIQUEFIED	8,747	8,558	4,679	6,598	3,844
271114	VARIOUS,LIQUEFIED	-	-	-	0	549
2711	PETROLEUM,OTHER GASES	8,747	8,558	4,679	6,598	4,393

33 Source cited in note 30 lists the following detail on imports of gaseous oil products into the DPRK from China in the categories below

Units: Kilograms

Commodity Code	Product/Product Group	1999	2000	2001	2002	2003	2004	2005
2711	PETROLEUM,OTHER GASES	11,130	46,400	149,800	215,850	232335	354365	496797
271119	OTHER,LIQUEFIED	-	-	17,400	13,850	21550	55707	125294
271113	BUTANES, LIQUEFIED	11,130	46,400	132,400	202,000	210755	298658	361826
271111	NATURAL,LIQUEFIED	-	-	-	-	0	0	9677
271112	PROPANE, LIQUEFIED	-	-	-	-	0	0	0
271129	OTHER GASES,GASEOUS	-	-	-	-	30	0	0

34 Data from files downloaded from http://www.customs.go.jp/toukei/download/index_d012_e.htm yields the following summary of oil products exports from Japan to the DPRK in 2005:

Commodity Code	Product/Product Group (Probable)	Quantity, kl	Quantity, kg	Value-Year (1000 Yen)	Implied value, 1000 yen/unit
'271019520'	"SOLID OR SEMI-SOLID LUBRICANT PREPN"	16	14397	4484	0.311
'271019590'	"Other Heavy Oils and Preparations"	78	74605	19174	0.257
'271019600'		0	1328	839	0.632
'271019900'	OTHER LUBRICATING OILS, OTH. HEAVY OILS	9	9131	1951	0.214
Sum of Petroleum Products Above			99,461		

Total petroleum products exports from Japan to the DPRK in 2005 were a tiny fraction of those in 2000.

35 Singapore oil trade statistics for 2005 had not yet been obtained as of the time of this writing. Calculatons shown have been retained in case needed at a later time. An industry source suggests that there may have been approximately 25,000 tonnes of petroleum products shipped periodically, perhaps every six weeks or so, from Singapore to the DPRK. The product shipped was reported to be likely "gas oil" for use in power generation, industry, and marine diesel engines. We have not included these potential imports, at least pending a review of Singapore export statistics, due to their uncertainty, and because including them would raise total oil supply to the DPRK above the total cited in note 37, below.

36 For 2005, includes quantities reported/estimated separately from China, the ROK, Russia, and Japan, plus amounts of products equal to half those estimated to have been received in 1996 from the Chinese refinery near the border (note 14).

37 A source familiar with the oil industry estimates that the DPRK in 2005 used "no more than 18 - 19 thousand barrels [of crude oil and oil products] per day" on average. Given the considerable uncertainties in some of the reported oil products imports to the DPRK (and a small portion of the DPRK's crude oil inputs), we have taken the middle of this range as a target total for the overall oil supply to the DPRK.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

ADDITIONAL BACK-UP CALCULATIONS AND DATA: OIL IMPORTS AND EXPORTS

ESTIMATE OF THE MATERIALS REQUIREMENT FOR SURFACING NEW SUPERHIGHWAY BETWEEN PYONGYANG AND NAMPO, DPRK

Prepared By David Von Hippel, 10/19/00, Modified 6/8/02: DRAFT

ASSUMPTIONS:

Asphalt paving is:	5%	to	8%	by weight Asphalt Cement *(see Note 1)*.
Paving on the Pyongyang--Nampo road will ultimately be:			15	cm thick *(see Note 2)*
Length of the Pyongyang--Nampo road recently constructed:			43	km *(Note 3)*
Pavement Width of the Pyongyang--Nampo road			50	meters (DVH on-site estimate)
Specific gravity of pavement mixture (asphalt cement plus aggregate):				2.3 *(Note 4)*

RESULTS:

Estimated volume of asphalt mixture used on road:			**322,500**	cubic meters, and
Estimated mass of asphalt mixture used on road:			**741,750**	tonnes
Estimated quantity of asphalt cement needed to make above quantity of asphalt mixture:				
37,088	to	**59,340**	tonnes, or, by comparison, about	**10%** to **16%**
of our estimate that 1996 DPRK refinery output of heavy oil was about:				379,000 tonnes.

NOTES AND SOURCES:

1 *The National Asphalt Pavement Association (NAPA), on its web site, defines Asphalt Cement (AC) as follows: "This is the black, sticky stuff produced by petroleum refineries. It is the "glue" that holds the pavement together. Generally, it makes up about less than 8%, by weight, of the total pavement mixture." Another asphalt-related site provided an estimate that AC was 5% of the weight of asphalt paving (a mixture of AC and aggregate). Information on the "FAQ" page of the Asphalt Institute WWW site (http://www.asphaltinstitute.org/faq/apcfaqs.htm#temp) suggests an intermediate concentration of 400 lbs of asphalt cement to 6000 lbs of asphalt paving (or about 6.7%).*

2 *Another asphalt www site visited suggested that 8 to 12 inches of asphalt paving (applied in at least two layers) was standard for roads used by heavy duty trucks. Where paving was observed being applied to the Pyongyang--Nampo road, the paving seemed to be thinner (perhaps 2-3 inches, or 5 to 7.5 cm), so it is assumed both A) that a second layer would be applied, and B) that the ultimate thickness will be somewhat less than would be recommended in the US for a highway of similar size.*

3 *In DPRK YOUTH BUILD PYONGYANG-NAMPO SUPERHIGHWAY by Jang Yong Chol, First Secretary, Pyongyang City Committee, Kim Il Sung Socialist Youth League, for the Korean Central News Agency, Pyongyang, 28 August, 2000, reference is made to the Pyongyang-Nampo having a "40-odd km-long roadbed, scores of metres wide.." 43 km is a guess, based on the assumption that longer than 45 km would likely be referred to as "nearly 50".*

4 *Density and specific gravity of asphalt will depend on the air void volume in the mix (typically 5 to 8 percent, as based on documents reviewed) and the density and shape of the aggregate used. An example given in a document on the Asphalt Institute's WWW site has a specific gravity of 2.363. http://www.infratech.com/technical_corner/tables_calculators/metric/density_asphalt_materials.htm provides a table entitled "DENSITY AND SPECIFIC GRAVITY FOR VARIOUS TYPES OF COMPACTED ASPHALT PAVEMENTS", which gives a specific gravity range of 2.1 to 2.5 for (combined) several types of asphalt pavements. The estimate of 2.3 for DPRK asphalt is a rough guess based on this range.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
BIOMASS AND WOOD PRODUCTION AND IMPORTS

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

					Sources/Notes:
Fuelwood Consumption (Residential and Industrial)					
Residential Fuelwood	6.00E+06	cu.m.			*1*
Industrial Fuelwood	1.50E+05	cu.m.			*1*
Conversion Factor	1.69	cu.m./te			*9*
Conversion Factor	16.00	GJ/te			*2*
Total Fuelwood Production	5.82E+07	GJ			
Charcoal Production					
Wood Input	6.50E+05	cu.m.			*1*
Conversion Factor	1.50	cu.m./te			*10*
Conversion Factor	16.00	GJ/te			*2*
Process Efficiency	30%				*Rough Estimate*
Total Wood used for Charcoal	6.93E+06	GJ			
Total Charcoal Production	2.08E+06	GJ			
Wood for Non-Energy Products					
Building Materials	1.00E+06	cu.m.			*13*
Pulp and Paper	5.00E+05	cu.m.			*1*
Conversion Factor	2.00	cu.m./te			*Assumed to be mostly softwood*
Conversion Factor	16.00	GJ/te			*2*
Total Wood, Non-Energy Products	1.20E+07	GJ			
Wood Imports					
Imports of wood from Russia	1.50E+06	cu.m.			*3*
Conversion Factor	2.00	cu.m./te			*Assumed to be mostly softwood*
Conversion Factor	16.00	GJ/te			
Wood Imports, Total	1.20E+07	GJ			
Total Domestic Wood Production	6.51E+07	GJ			
Other Biomass/Crop Wastes Production for Fuel					
Crop Wastes Used in Agriculture:	3.10E+06	te			*4*
Crop Wastes for Other Uses	2.57E+06	te			*Est. based on needs*
Conversion Factor	14.5	GJ/te			*2*
Total Biomass/Crop Wastes Production	8.22E+07	GJ, or	5.67E+06	tonnes	
TOTAL WOOD/BIOMASS PRODUCTION	1.47E+08	GJ			

ESTIMATE OF CURRENT AND FUTURE WOOD/BIOMASS SUPPLY

Category	1996	2000	2005	2	.	
Domestic wood production relative to 1990	110%	125.0%	138%		%	*6*
Domestic wood production (GJ)	7.16E+07	8.14E+07	8.98E+07		07	
Wood used to make charcoal relative to 1990	73.5%	59.0%	61.0%		%	*6*
Wood Used to make charcoal (GJ)	5.10E+06	4.09E+06	4.23E+06		06	
Charcoal production (GJ)	1.53E+06	1.23E+06	1.27E+06		06	
Wood imports relative to 1990	100%	100%	100%		%	*5*
Wood imports (GJ)	1.20E+07	1.20E+07	1.20E+07		07	
Biomass/crop wastes production relative to 1990	77.0%	66.6%	73.7%		%	*6*
Biomass/crop wastes production (GJ)	6.33E+07	5.48E+07	6.06E+07		07	
Pulp and Paper Imports from China (tonnes)	4.8	772.7	43.9			*7*
Pulp and Paper Imports from China (GJ)	7.68E+01	1.24E+04	7.02E+02			
Pulp and Paper Exports to China (tonnes)	225.2	49.2	1,211.6			*7*
Pulp and Paper Exports to China (GJ)	3.60E+03	7.87E+02	1.94E+04			

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

	1990	1996	2000	2005	
Total Implied Domestic Wood Harvest, tonnes	4.07E+06	4.48E+06	5.09E+06	5.61E+06	*Calculated from above*
Total Implied Domestic Wood Harvest, cu. meters	6.88E+06	7.57E+06	8.60E+06	9.49E+06	*Calculated from above*

Note: Totals above not adjusted for pulp and paper imports and exports (which are minor)

Summary of Information on Wood Stocks and Productivity in the DPRK

For 1996, Prof. Lee Seung-ho (see Note 8, below) estimates from remote sensing and other data that the growing stock of trees--including all above-ground biomass, was in the range of 251 to 293 million tonnes. The lower of these two estimates uses an average specific gravity for Korean hardwoods (0.65 versus 0.80) that appears to be more realistic for typical Korean hardwood species. This lower estimate implies average specific gravity of 1.37 cubic meters stem biomass per tonne above-ground biomass. Based on growth rates for forests in areas of the ROK that have forests similar to the types of forests found in the DPRK, and using data from three sources, Prof. Lee calculates a weighted-average annual growth rate of 3.06%, which implies an annual production from growing tree stocks in the DPRK of 7.68E+06 tonnes per year. Note that this figure includes all above-ground biomass, some of which (small twigs and leaves, for example) would likely not be used as fuel, and likely some of which would be lost during harvesting. Prof. Lee cites ratios of total above-ground biomass to tree stem volume ranging from 1.22 (for hardwoods) to 1.29 (for conifers). This implies that leaf and twig biomass might be on the order of 5 to 15 percent of total above-ground biomass. The table below, originally from the UNEP document cited in ***Note 11***, below, is included in Prof. Lee's presentation, and appears to paint a rosier picture of DPRK forest stocks (Table 3.1 from UNEP document--shaded row and column are values calculated from data in table), at least as of 1990.

Classification	Area (1000 hectares)	Biomass stock (ton/hectare)	Implied stock (million tonnes)
TOTAL Forested land	**8,201**	**62.3**	510.92
Forest of timber industry	5,440	74.55	405.55
Economic forest	1,436	48.3	69.36
Firewood forest	196	40.95	8.03
Protected forest	1,129	66.15	74.68
Non-timber forest land	436	3.15	1.37
Unforested area	383	-	-
Grass field	170	18	3.06
Total of Above	**9,190**	**61.16**	**562**

Professor Lee cites several different sources for surveys of the DPRK's forest area, as follows:

Estimate (Mha)	Date	Source
9.77	1970	DPRK
8.97	1987	FAO
8.45	1994	KFRI: Satellite Image Analysis
7.53	1997	DPRK: UNDP Round Table Meeting
7.53	1999	KFRI: Satellite Image Analysis

In addition, the UN FAO Global Forest Resource Assessment 2005 (see ***note 12***, below) offers the following estimated timeline of assessments of forest area

Estimate (Mha)	Date
8.20	1990
6.82	2000
6.19	2005

From the data above, the implied rates of change in forest lands in the DPRK were:

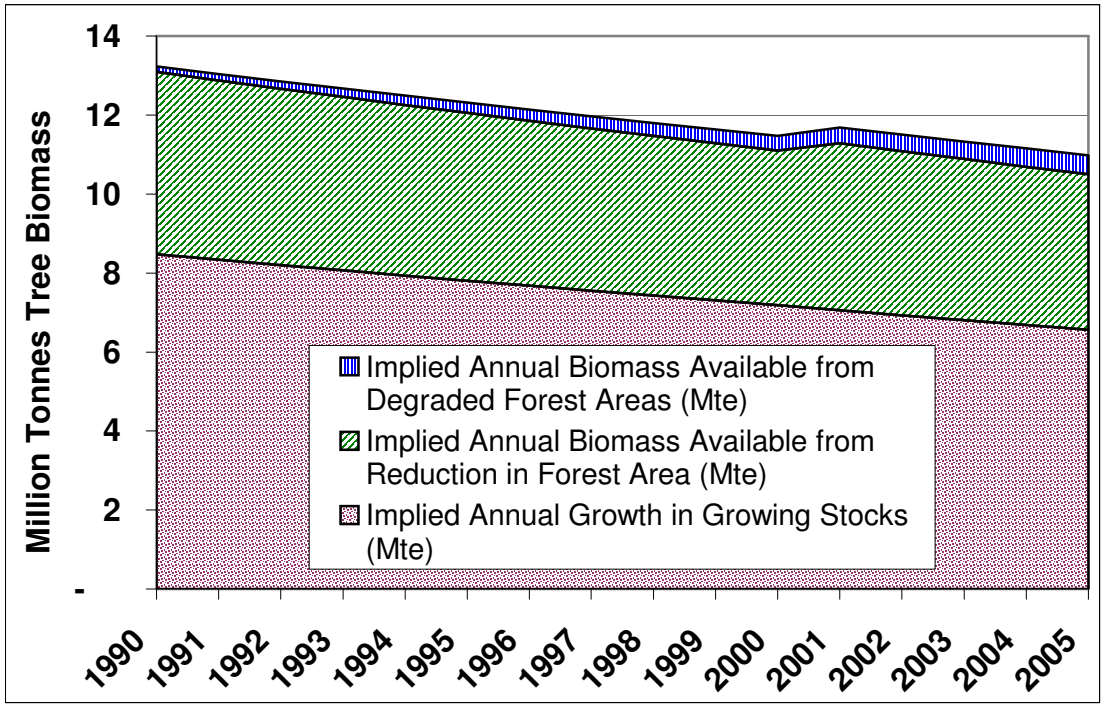
-1.45% per year, 1987 to 1999, using the multi-survey timeline cited by Prof. Lee, and
-1.83% per year, 1990 to 2000, and -1.93% per year, 2000 to 2005, using the FRA estimates.

Based roughly on the information above, we make the following estimate of forest area, wood stocks, and wood production over time.

Key Assumptions:

Estimate of forest area in 1990:	**8.20**	Million ha (DPRK State of Environment Report, 2003, and UN FAO FRA)
Change in extent of forest lands, 1990 to 2000:	**-1.64%**	per year (average of rates estimated above).
Change in extent of forest lands, 2000 to 2005:	**-1.80%**	per year (not quite as low as FRA estimate).
Growing wood stocks on forest lands, 1996:	**251**	million tonnes (estimate above by Prof. Lee)
Average annual growth on stocked forest lands:	**3.06%**	per year (estimate above by Prof. Lee)
Average growth per ha on forest lands	**0.94**	te/ha-yr, based on estimates above.
Total degraded forest lands as of about 1997:	**1.6317**	Million ha (from Prof. Lee presentation, slide 34; includes

"denuded forest", "unstocked forest", and "converted farmland", of which the latter is 59% of the total.
Average fraction of annual stocked-forest growth per hectare in degraded forests: 20% (placeholder estimate).


Million Tonnes Tree Biomass
14
12
10
8
6
4
2
-
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Implied Annual Biomass Available from Degraded Forest Areas (Mte)
Implied Annual Biomass Available from Reduction in Forest Area (Mte)
Implied Annual Growth in Growing Stocks (Mte)

Year	Mha Forest Lands	Growing Stocks (million te)	Implied Annual Growth in Growing Stocks (Mte)	Implied Annual Biomass Available from Reduction in Forest Area (Mte)	Implied Annual Woody Biomass Available from Forest Lands and Clearing (Mte)	Estimated Degraded Forest Lands (Mha)	Implied Annual Biomass Available from Degraded Forest Areas (Mte)	Implied Annual Woody Biomass Available from all Stocked and Degraded Forests (Mte)
1990	8.20	277	8.48	4.61	13.09	0.74	0.14	13.23
1991	8.07	273	8.34	4.54	12.88	0.87	0.16	13.04
1992	7.93	268	8.20	4.46	12.67	1.00	0.19	12.85
1993	7.80	264	8.07	4.39	12.46	1.13	0.21	12.67
1994	7.68	259	7.94	4.32	12.25	1.26	0.24	12.49
1995	7.55	255	7.81	4.25	12.05	1.39	0.26	12.31
1996	7.43	251	7.68	4.18	11.86	1.51	0.28	12.14
1997	7.31	247	7.55	4.11	11.66	1.6317	0.31	11.97
1998	7.19	243	7.43	4.04	11.47	1.75	0.33	11.80
1999	7.07	239	7.31	3.97	11.28	1.87	0.35	11.63
2000	6.95	235	7.19	3.91	11.10	1.98	0.37	11.47
2001	6.83	231	7.06	4.23	11.29	2.11	0.40	11.69
2002	6.71	227	6.93	4.15	11.09	2.23	0.42	11.50
2003	6.58	223	6.81	4.08	10.89	2.35	0.44	11.33
2004	6.47	219	6.69	4.01	10.69	2.47	0.46	11.15
2005	6.35	215	6.57	3.93	10.50	2.59	0.48	10.98

Notes:

1 Documents in authors' files provide estimates that cover a wide range. One source [FC1, p. 11] cites production of 8 - 10 million cubic meters of fuelwood, while other sources suggest total wood production of 4.7 to 7 million cubic meters. Professor Lee Seung-ho (see Note 8, below) provides an estimate of somewhat less than 4 million cubic meters of fuelwood in 1990, rising to 4 million by 1996, and increasing steeply to 5.5 million cubic meters by 1999. Lee cites UN FAO statistics as the source for these data. The UN FAO (2005, see Note 12, below) cites a fuelwood production figure of just over 5 million cubic meters. We use a figure roughly in the middle of this overall range for fuelwood. Other quantities linked to this note are from a the same document that provided the higher-range estimate for fuelwood use.

2 From document in authors' files [FC1, p. 7].

3 Annual imports from Russia. Document in authors' files lists imports of 2.5 million cubic meters [TP1, p. 4]. Note: other sources list these imports at 230 kcu.m./yr, and also list the number of DPRK workers sent to Russian forests at 16-20,000 annually. An abstract from a 1990s report on the Russian Far East forestry sector (C I N T R A F O R Working Paper Abstract, "The Forest Sector in the Russian Far East: Status and Near-Term Development", by Ekaterina Gataulina and Thomas R. Waggener, 1998, available as http://www.cintrafor.org/research_tab/links/WP/WP63.htm) suggests that the average productivity of Russian forest workers as of 1994 was "360 m^3 per worker (roundwood equivalent)", presumably per annum. This suggests, if the productivity of DPRK work crews were similar, that the DPRK crews might harvest up to about 7 million cubic meters per year, assuming the same rate of production (and the same access to harvesting equipment--which may well not be a given) as Russian crews. If, as has been reported, DPRK harvesting crews brought home approximately a quarter or a third of their harvest (the rest remaining in Russia), annual imports of wood back to the DPRK would be in the range from 1.4 to 2.4 million tonnes We assume that 1990 imports of wood to the DPRK from the RFE was at the lower end of this range.

4 Use of straw and bran in Agriculture from document in authors' files [HT1, p. 10].

5 Assumption

6 Adjusted to meet demand.

7 China Customs Statistics reported exports "woodpulp, etc" from the DPRK to China in 2005 of (HS #47) of 1,098 *tonnes. No shipments in this category were reported in 2000, and 1996 shipment were* 80 *tonnes.*
China also imported 726 and 145 tonnes of "paper and paperboard" (HS # 48) from the DPRK in 2003 and 2004 (no DPRK paper and paperboard exports to China were recorded in 2005). In 1996, exports from the DPRK were 145.35 *tonnes in this category, and exports in 2000 were* 49.215 *tonnes.*
An additional 114 *tonnes of paper and paperboard were recorded, however, as exported to Hong Kong from the DPRK in 2005, down from 566 tonnes in 2003 and 136 tonnes in 2004.*
China exported modest amounts of paper and paperboard to the DPRK: about 9.9, and 11.4 tonnes in 2003 and 2004, respectively, and 12.9 *tonnes in 2005,* 6.7 *tonnes in 2000, and* 4.8 *tonnes in 1996, along with a tonne or less of wood pulp in each of those years.*
Hong Kong also exported modest amounts of paper and paperboard to the DPRK: about 42, 38, and 31 *tonnes in 2003, 2004, and 2005, respectively, plus* 766 *tonnes of wood pulp (but no paper) in in 2000.*
Import/export data as compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.
United Nations Food and Agriculture Organization estimates for DPRK wood and wood products imports and exports are available from http://faostat.fao.org/site/381/DesktopDefault.aspx?PageID=381, and suggest imports and exports of wood and wood products from thousands to tens of thousands of cubic meters (or tonnes) per year over the period from 2000 to 2005. These data have not yet been directly used in the estimates prepared as above because A) in some cases, the use of a value for several consecutive years suggests primary data have not been used, and B) these quantitities have little effect on the overall wood supply/demand balance estimated above. A sample FAO data table (from the FAOSTAT site) is provided below (for "Korea, Dem People's Rep").

Item	Element	Unit	2000	2001	2002	2003	2004
Sawlogs+Veneer Logs (C)	Imports - Qty	Cum	0	0	0	0	0
Chips and Particles	Imports - Qty	Cum	950	0	0	0	0
Wood Residues	Imports - Qty	Cum	0	600	600	600	600
Wood Charcoal	Imports - Qty	Mt	0	700	700	700	700
Sawnwood (C)	Imports - Qty	Cum	1000	200	200	200	200
Sawnwood (NC)	Imports - Qty	Cum	200	300	300	300	300
Veneer Sheets	Imports - Qty	Cum	100	300	300	300	300
Plywood	Imports - Qty	Cum	1100	3000	3000	3000	3000
Particle Board	Imports - Qty	Cum	200	200	200	200	200
Hardboard	Imports - Qty	Cum	0	100	100	100	100
MDF	Imports - Qty	Cum	0	5500	5500	5500	5500
Fibreboard, Compressed	Imports - Qty	Cum	0	0	0	0	0
Insulating Board	Imports - Qty	Cum	0	0	0	0	0
Ind Rwd Wir (C)	Imports - Qty	Cum	10100	0	0	0	0
Mechanical Wood Pulp	Imports - Qty	Mt	0	100	100	100	100
Semi-Chemical Wood Pulp	Imports - Qty	Mt	0	0	0	0	0
Chemical Wood Pulp	Imports - Qty	Mt	11500	44700	44700	44700	44700
Ind Rwd Wir (NC) Tropica	Imports - Qty	Cum	0	0	0	0	0
Dissolving Wood Pulp	Imports - Qty	Mt	0	0	0	0	0
Other Fibre Pulp	Imports - Qty	Mt	0	200	200	200	200
Recovered Paper	Imports - Qty	Mt	800	2000	2000	2000	2000
Ind Rwd Wir (NC) Other	Imports - Qty	Cum	1100	0	0	0	0
Newsprint	Imports - Qty	Mt	400	5400	5400	5400	5400
Printing+Writing Paper	Imports - Qty	Mt	2900	16900	16900	16900	16900
Other Paper+Paperboard	Imports - Qty	Mt	1300	2200	2200	2200	2200

8 Data from presentation entitled "Forest and Other Biomass Production in the DPRK: Current Situation and Recent Trends as Indicated by Remote Sensing Data - Status of Forest Resources, Degradation & Biomass in North Korea using Remote Sensing Data" by Professor Lee Seung-ho of the Remote Sensing Laboratory, KOREA FOREST RESEARCH INSTITUTE.
as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Prof. Lee's paper is available as http://www.nautilus.org/DPRKEnergyMeeting/papers/Lee.ppt.

9 Calculated from data in Source 8 (slide 59) as weighted average: 1.69

10 Input to charcoal production assumed to be largely hardwood.

11 The report DPR KOREA : STATE OF THE ENVIRONMENT 2003, published by the United Nations Environment Programme, lists (table 3.2) oak as the dominant hardwood tree species in the DPRK (52.4 percent in deciduous forests).

12 The UN FAO Global Forest Resource Assessment 2005 (FRA) provides forest extent, forest stock, and other data over time for most nations, including the DPRK. DPRK data are available from www.fao.org/forestry/site/32086/en/prk. Key tables from this source are reproduced below.

Extent of forest and other wooded land	Area (1000 hectares)		
FRA 2005 categories	1990	2000	2005
Forest	8,201	6,821	6,187
Other wooded land	-	-	-
Forest and other wooded land	8,201	6,821	6,187
Other land	3,840	5,220	5,854
...of which with tree cover	-	-	-
Total land area	12,041	12,041	12,041
Inland water bodies	13	13	13
Total area of country	12,054	12,054	12,054

Data source: FAO, Global Forest Resources Assessment 2005.

Designated functions of forest and other wooded land

FRA 2005 categories/designated function	Area (1000 hectares)					
	Primary function			Total area with function		
	1990	2000	2005	1990	2000	2005
Forest						
Production	7,072	5,882	5,335	7,072	5,882	5,335
Protection of soil and water	-	-	-	8,201	6,821	6,187
Conservation of biodiversity	1,129	939	852	1,129	939	852
Social services	-	-	-	1,129	939	852
Multiple purpose	-	-	-	not appl.	not appl.	not appl.
No or unknown function	-	-	-	not appl.	not appl.	not appl.
Total forest	**8,201**	**6,821**	**6,187**	**not appl.**	**not appl.**	**not appl.**

Note--Table above only part of that provided in source, but the remainder of the table includes no data.

Growing stock in forest and other wooded land						
FRA 2005 categories	Volume (million cubic meters over bark)					
	Forest			Other wooded land		
	1990	2000	2005	1990	2000	2005
Growing stock in forest and other wooded land	504	429	395	-	-	-
Commercial growing stock	-	-	-	-	-	-

Data source: FAO, Global Forest Resources Assessment 2005.

Biomass stock in forest and other wooded land						
FRA 2005 categories	Biomass (million metric tonnes oven-dry weight)					
	Forest			Other wooded land		
	1990	2000	2005	1990	2000	2005
Above-ground biomass	434	369	340	-	-	-
Below-ground biomass	159	136	125	-	-	-
Total living biomass	593	505	464	-	-	-
Dead wood	87	74	68	-	-	-
Total	680	579	532	-	-	-

Data source: FAO, Global Forest Resources Assessment 2005.

Carbon stock in forest and other wooded land

FRA 2005 categories	Carbon (million metric tonnes)					
	Forest			Other wooded land		
	1990	2000	2005	1990	2000	2005
Carbon in above-ground biomass	217	185	170	-	-	-
Carbon in below-ground biomass	80	68	62	-	-	-
Carbon in living biomass	297	252	232	-	-	-
Carbon in dead wood	43	37	34	-	-	-
Carbon in litter	-	-	-	-	-	-
Carbon in dead wood and litter	43	37	34	-	-	-
Soil carbon	-	-	-	-	-	-
Total	340	289	266	-	-	-

Data source: FAO, Global Forest Resources Assessment 2005.

Removals of wood products						
FRA 2005 categories	Volume (1000 cubic meters over bark)					
	Forest			Other wooded land		
	1990	2000	2005	1990	2000	2005
Industrial roundwood	690	1,725	1,725	-	-	-
Woodfuel	5,055	6,318	6,967	-	-	-
Total	5,745	8,043	8,692	-	-	-

Data source: FAO, Global Forest Resources Assessment 2005.

This document also lists the area of forest lands affected by forest fires in the DPRK at 46 kha/yr.

13 A document in the authors' file lists "building materials" (assumed to be similar to "industrial roundwood", though the latter may also include wood for pulp) consumption at "3 to 5 million cubic meters/yr". By way of comparison, at this level, the DPRK would be using approximately twice as much roundwood per capita as China in 1990. We assume that the range above is an over-estimate, and that the UN FAO FRA value (see above) is more reasonable, though possibly still a bit of an under-estimate. We therefore use 1 million cubic meters for building materials as an estimate for 1990.

14 The following is a rough calculation of the annual availablity of livestock manures in 2005:

Animal Type	Number	kg VS/day	te VS/yr
Cattle	578000	2.2	464,134
Pigs	3200000	0.3	350,400
Chickens	21000000	0.01	76,650
Ducks	5500000	0.024	48,180
Goats	2750000		
Sheep	172000		
TOTAL			939,364

Note: VS = "volatile solids", essentially a measure of the amount of dry organic matter in the manure.
Animal numbers from UN Food and Agriculture Organization FAOSTAT, available as http://faostat.fao.org/site/568/default.aspx.
Estimates of manure production per animal are derived from data in Rural Energy Production: Biogas Plant, a Sustainable Source of Energy for Cooperative Farms, by Arthur Wellinger, dated December 12, 2003, and published by ADRA (Adventist Development and Relief Agency International) and Nova Energie. The Wellinger report provides case studies of the application of manure-fed biogas digesters in the DPRK.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
ELECTRICITY GENERATION IN 1990

Prepared By David Von Hippel
Date Last Modified: 3/1/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

				Sources/Notes:
Electricity Generation: Output by Fuel Type:				
	Total Gross Generation	4.80E+04	GWhe	*1*
	Fraction in Hydro Plants	46.3%		*2*
	Fraction in Thermal Plants	53.7%		*2*
	Generation in largest Oil-fired plant	1.28E+03	GWhe	*3*
	Fraction of Oil Generation in Largest Plant	100%		*4*
	Gross Generation, Hydro Plants	2.22E+04	GWhe	
	Gross Generation, Oil Plants	1.28E+03	GWhe	
	Gross Generation, Coal Plants	2.45E+04	GWhe	
	Conversion Factor	3.60E+03	GJ/GWhe	
	Gross Generation, Hydro Plants	8.00E+07	GJ	
	Gross Generation, Oil Plants	4.61E+06	GJ	
	Gross Generation, Coal Plants	8.82E+07	GJ	
	Own Use Rate, Hydro Plants	0.3%		*5*
	Own Use Rate, Oil Plants	8.00%		*5*
	Own Use Rate, Coal Plants	9.00%		*5*
	Own Use, Hydro Plants	6.66E+01	GWhe	
	Own Use, Oil Plants	1.02E+02	GWhe	
	Own Use, Coal Plants	2.21E+03	GWhe	
	Own Use, Hydro Plants	2.40E+05	GJ	
	Own Use, Oil Plants	3.69E+05	GJ	
	Own Use, Coal Plants	7.94E+06	GJ	
	Net Generation, Hydro Plants	2.215E+04	GWhe	
	Net Generation, Oil Plants	1.178E+03	GWhe	
	Net Generation, Coal Plants	2.230E+04	GWhe	
	Net Generation, Hydro Plants	7.97E+07	GJ	
	Net Generation, Oil Plants	4.24E+06	GJ	
	Net Generation, Coal Plants	8.03E+07	GJ	
	MW of hydro capacity used by China	700	MW	*11*
	Fraction of hydro generation exported in 1990	16%		*12*
	Exports of electricity to China	3.45E+03	GWhe	
	Exports of electricity to China	1.24E+07	GJ	
	"Emergency Losses" Rate, Coal Plants	5.0%		*6*
	"Emergency Losses", Coal Plants	1.23E+03	GWhe	
	"Emergency Losses", Coal Plants	4.41E+06	GJ	
	Total Net Generation, All Plants	4.44E+04	GWhe	
	Total Net Generation, All Plants	1.60E+08	GJ	
Transmission and Distribution Losses				
	Transmission Losses	10%		*7*
	Distribution Losses	6%		*7*
	Delivered Electricity	3.46E+04	GWhe	
	Delivered Electricity	1.25E+08	GJ	
Fuel Requirements for Electricity Generation				
	"Heat Rate" (Efficiency) Hydro Plants	100.00%		*8*
	Gross Generation Efficiency, Oil-Fired Plants	29.5%		*9*
	Gross Generation Efficiency, Coal-Fired Plants	28.0%		*10*
	Input Energy, Hydro Plants	8.00E+07	GJ	
	Input Energy, Oil Plants	1.56E+07	GJ	
	Input Energy, Coal Plants	3.15E+08	GJ	
	Fraction of energy input to Coal plants as residual oil	2.0%		*Assumption*
	Oil input to coal plants	6.30E+06	GJ	
	Total Input Energy, Electricity Generation	4.11E+08	GJ	

Sources/Notes:

1 Somewhat lower than value cited by Choi Su Young, Study of the Present State of Energy Supply in North Korea, P. 49 (55.5 TWh) as "Official NK Figures", compiled by RINU. Other estimates, published and otherwise place 1990 DPRK electricity output between about 28 TWh (RINU estimate) and 60 TWh.

2 Figures from document in authors' files [EE1, p. 15].

3 For Oung gi plant, one of (possibly) 2 grid-connected oil-fired plants. From document in authors' files [EE1, p. I-2].

4 The Oung gi plant is 200 MW. The second oil-fired plant listed by some sources must be quite small, if indeed it exists. Other sources claim that there is only one oil-fired plant in the DPRK, which we have assumed.

5 ROK rates in 1970. From p. 129,E-W.Kim et al, "The Electric Future of Korea" East-West Center, September, 1983. Own use rates for Chinese coal-fired plants are very slightly higher.

6 Rough estimate. A note in document in authors' files [EE1, p. 26] put the loss from "frequent emergencies" at Pyongyang power station at 7%. It is not clear whether this value is typical for the DPRK system as a whole.

7 Official Estimates. From document in authors' files [EP1, p. 3]. This source notes that these estimates may be optimistic.

8 As used in United Nations Energy Statistics Yearbook.

9 Author's estimate. Official rate of approximately 35% (as presented in UNDP (1994), Studies in Support of Tumen River Area Development Programme. Prepared by KIEP, Seoul, ROK for the UNDP, July, 1994) seems somewhat high given the reported condition of the power plant at Sonbong.

10 This rate is somewhat lower than that given for the Chongjin plant in source 9, and similar to the heat rates in Chinese coal plants in the late 1970's.

11 See "Energy Generation Facilities" sheet.

12 Assumes that exported electric energy is proportional to the fraction of capacity earmarked for Chinese use.

*13 The DPRK's Yongbyon nuclear plant, though frequently described as having a capacity of "5 MWe", 5 MW electrical output) is not configured to produce electricity (see, for example, North Korea's Nuclear Weapons Programme, by the International Institute for Strategic Studies, 2006, http://www.iiss.org/publications/strategic-*dossiers/north-korean-dossier/north-koreas-weapons-programmes-a-net-asses/north-koreas-nuclear-weapons-programme#weapons

The Yongbyon reactor does, however, provide some heat to buildings in the area. The reactor is said to have a rated output of about 25 MWth (a range of 20 - 30 MWth is often cited). Capacity factors of about *80 percent for this reactor have been cited, but other observers suggest that a capacity factor of* 60% *is "more realistic". For 1990, and pending the addition of "heat" as a separate balance category, we place the heat produced by the Yongbyon reactor, estimated at* 4.73E+05 GJ. In the "Hydro/Nuclear" *and the "non-specified" row of the energy balance, as well as in the "domestic production" row under supplies. See "Yongbyon 5-MW(e) Reactor" from http://www.globalsecurity.org/wmd/world/dprk/yongbyon-5.htm for estimates of Yongbyon capacity factor.*

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2006 UPDATE
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ELECTRICITY GENERATION FACILITIES

MAJOR THERMAL GENERATING FACILITIES

#	Name		Capacity (MW)	Fuel	Year Completed		***Sources/Notes:***
1	Pyongyang		500	Coal	1968		*1*
2	Bukchang		1600	Coal	1985		*1,2,7*
3	Chongjin		150	Coal	1984		*1,2*
4	Chonchonang		200	Coal	1979		*1,2*
5	Oungi		200	Oil	1973		*2*
6	Sunchon		200	Coal	1988		*1*
7	East Pyongyang		50	Coal	1992		*3*
TOTAL OF LISTED PLANTS			**2900**				

THERMAL GENERATING FACILITIES REPORTEDLY UNDER CONSTRUCTION OR RECENTLY COMPLETED AS OF 1996

#	Name	Capacity (MW)	Fuel	Year Started	Year Completed	***Sources/Notes:***
1	Pyunghung(?)	200	Coal			8
2	Suncheon(?)	200	Coal			8,12
3	Dongpyungyang	600	Coal		1993 - 1996	13
4	Kimchaek	150	Coal	1988		2
5	Hamhyng central	100	Coal	1994		2
6	12wol	150	Coal		1993	13
7	Haeju	Unknown	Coal	1990		13
8	Ahnju	1200	Coal	1989		13
9	Hamheung	150	Coal	1989		13, 14
TOTAL OF LISTED PLANTS		**2,750**				

MAJOR HYDRO GENERATING FACILITIES

#	Name	Capacity (MW)	Year Completed	Year Refurbished	***Sources/Notes:***
1	Supung	400			*1,2,4*
2	Kymgansang cascade	13.5	1930	1958	*2*
3	Puren cascade	28.5	1932		*2*
4	Puch'on-gang	260	1932	1956	*2,11*
5	Chanjin-gang	390	1936	1958	*2*
6	Hoch'on-gang	394	1942	1958	*2*
7	Tonno-gang	90	1959		*2*
8	Kangae	246	1965		*2*
9	Ounbong	200	1970		*2,5*
10	Sodusu-1	180	1974		*2,9*
11	Sodusu-2	230	1978		*2,9*
12	Sodusu-3	45	1982		*2,9*
13	Taedong-gang	200	1982		*2*
14	Mirim	32	1980		*2*
15	Ponhwa	32	1983		*2*
16	Hwan-gang	20	198?		*2*
17	Tonhwa	20	198?		*2*
18	T'aep'enmang	90	1989		*2,6*
19	Weewong	200	1989		*2,10*
20	Nam-gang	200	1994		*2*
21	Dokro river	36			*2,8*
TOTAL OF LISTED PLANTS		**3,307**			

HYDRO GENERATING FACILITIES REPORTEDLY UNDER CONSTRUCTION OR RECENTLY COMPLETED AS OF 1996

#	Name	Capacity (MW)	Year Started	Year Completed	***Sources/Notes:***
1	Taechun	750	1983		*2, 8, 15*
2	Kumgang Mountain	800	1985	1996 (1st Phase)	*2,8,13,16*
3	Sodusu-4	200	1990		*2*
4	Namkang	Unknown	1983		*13*
5	Youngwon	Unknown	1986		*13*
6	Ehrangcheon	Unknown	1986		*13*
7	Jabgjakang	240			*13*
8	P'och'on	820			*2*
9	Oranch'on	180			*2*
10	Heech'on	Unknown	1989		*2*
11	Kymyan-gang	Unknown			*2*
TOTAL OF LISTED PLANTS		**2,990**			

PARTIAL LISTING OF SUBSTATIONS IN THE DPRK

#	Name	Capacity MVA	Units	***Sources/Notes:***
1	Changjingang	48	1x28, 1x20	*1*
2	Chongjin	165	1x100, 1x5, 1x60	*1*
3	Pyongyang No. 2	100	2x50	*1*
4	Vynalon	200	2x50, 1x100	*1*
5	Pyongyang No. 1			*1*
6	Undok			*1*
7	Munsan			*1*
8	Kilju			*1*
9	Hamhung			*1*
10	Songchon			*1*
11	Sepo			*1*
12	Nampo			*1*
13	Kusong			*1*
14	Sinuiju			*1*
15	Pyongsong			*1*
16	Sin-Anju			*1*

LISTING OF PROVINCIAL CONTROL CENTERS FOR THE DPRK T&D GRID

Source 1

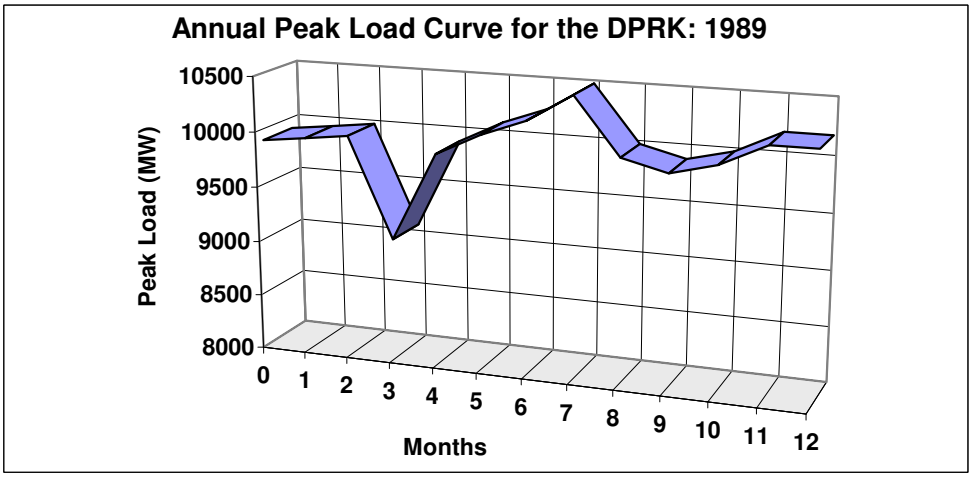
#	Name	Location (city)
1	North Kamgyong	Chongzin
2	Ryanggang	Hyesan
3	Chagang	Kanggye
4	South Hamgyong	Hamhung
5	South Pyongan	Pyongsong
6	Kangwon	Wonsan
7	North Hwanghae	Sariwon
8	Nampo	Nampo
9	South Hwanghae	Haeju
10	Kaesong	Kaesong
11	North Pyongan	Siniju

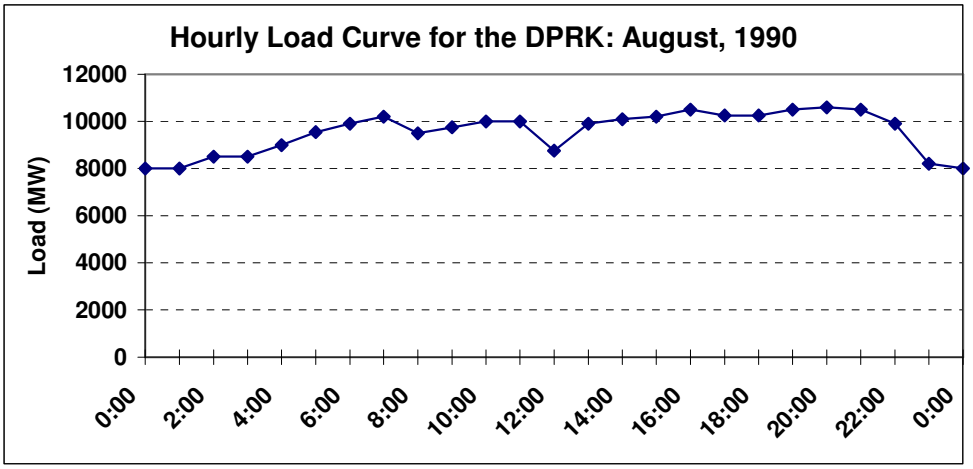
Annual Load Curve for 1989
(Source 1)

Month	Load (MW)
0	9900
1	9950
2	10000
3	9100
4	9900
5	10100
6	10250
7	10500
8	10000
9	9900
10	10000
11	10200
12	10200

Daily Load Curve for August, 1990
(Source 1)

Time	Load (MW)
0:00	8000
1:00	8000
2:00	8500
3:00	8500
4:00	9000
5:00	9550
6:00	9900
7:00	10200
8:00	9500
9:00	9750
10:00	10000
11:00	10000
12:00	8750
13:00	9900
14:00	10100
15:00	10200
16:00	10500
17:00	10250
18:00	10250
19:00	10500
20:00	10600
21:00	10500
22:00	9900
23:00	8200
0:00	8000





Sources/Notes:

1 *Documents in authors' files [EP1, EE1]*
2 *Moiseyev, V. (1996), The Electric Energy Sector of the DPRK. Paper presented at the workshop on "Security on the Korean Peninsula," November 21, 1996, Diplomatic Academy, Moscow, sponsored by the Center for Nonproliferation Studies at the Monterey Institute of International Studies (with funding from the Rockefeller Foundation).*
3 *Source 1 reports 50 MW of East Pyongyang plant completed in 1992. Source 2 suggests that the ultimate capacity of the plant will be (or was to have been) 400 MW*
4 *Source 2 lists the "Supun" plant as having a total capacity of 735 MW, with 210 MW of that capacity used to produce power for China.*
5 *Source 2 lists this plant as having a total capacity of 400 MW, with 200 MW going to China.*
6 *Source 2 lists this plant as having a total capacity of 190 MW, with 100 MW going to China.*
7 *Source 1 lists the in-service date of the Bukchang station as 1973. This may be the in-service date for the first of the units. (Plant name may also be translated as "Pukchang".)*
8 *Choi Su Young (1993), Study of the Present State of Energy Supply in North Korea, Research Institute for National Unification (RINU), Seoul, (ROK).*
9 *Source 8 lists the total capacity of the three phases of the Sodusu plant at 510 MW. Source 17 lists the plant capacity as 420 MW.*
10 *Source 2 lists this plant as having a total capacity of 390 MW, with 190 MW going to China.*
11 *Capacity listed by source 8 as 226 MW*
12 *Source 8 seems to indicate that this plant will be associated with an industrial facility making vinalon.*
13 *Dongseok Roh, Electricity Policy Division, Korea Energy Economics Institute (KEEI). Personal Communication, 1996.*
14 *This plant may well be the same as the project listed by source 2 as "Hamhyng central".*
15 *Source 8 lists the total capacity of this project at 800 MW. Source 13 describes the "first phase" as having a capacity of 660 MW.*
16 *Source 2 lists the capacity of this project at 810 MW. The first phase of the project, reportedly in the range of 100 to 200 MW, was reportedly brought on line in late 1996.*
17 *UNDP (1994), Studies in Support of Tumen River Area Development Programme. Prepared by KIEP, Seoul, ROK for the UNDP, July, 1994.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ASSUMPTIONS, BACK-UP CALCULATIONS AND DATA:
ELECTRICITY GENERATION AND FUEL REQUIREMENTS IN 1996 AND 2000

Prepared by David Von Hippel
Date Last Modified: 3/8/2007

ESTIMATE OF ELECTRICITY GENERATION IN 1996

	Hydro Plants	Coal Plants	HFO Plants	*Sources/Notes:*	
Electricity Generating Capacity as of 1990 (MW)	4,500	3,200	200		*4*
Estimated Gross Generation in 1990 (GWHe)	2.221E+04	2.45E+04	1.28E+03	*Based on 1990 est.*	
Implied Capacity Factor, 1990	56%	87.4%	73.1%		
Changes in Capacity, 1990 to 1996 (MW):	-3250	50	0		*5*
Average 1996 Capacity Factor Relative to 1990 Est.	90%	66.30%	71.2%		*3*
Estimated Gross Generation in 1996 (GWHe)	5.55E+03	1.65E+04	9.11E+02		
Estimated Power Exports to China, 1990 (GJ)	1.24E+07				
Fraction of 1990 Exports to China in 1996	28%				
Estimated Power Exports to China, 1996 (GJ)	3.47E+06				
Gross Generation Efficiency, 1996	100%	27.0%	28.00%		*2*
Fuel Input to generation, 1996 (GJ)	2.00E+07	2.20E+08	1.17E+07		
Fraction of fuel input as HFO	N/A	6.20%	100%		*1*
HFO Input to generation, 1996 (GJ)	N/A	1.36E+07	1.17E+07		
Own Use Fractions, 1996	0.30%	9.00%	8.00%	*Based on 1990 est.*	
Own Use of Electricity (GJ)	6.00E+04	5.35E+06	2.62E+05		
"Emergency Loss" Fractions, 1996	0%	7.5%	0%	*50% higher than 1990*	
Emergency Losses, 1996 (GJ)	0	4.46E+06	0		
Transmission and Distribution Loss rate (overall), 1996	23.10%			*50% higher than 1990*	
Transmission and Distribution Losses, 1996 (GJ)	1.60E+07				

ESTIMATE OF ELECTRICITY GENERATION IN 2000

	Hydro Plants	Coal Plants	HFO Plants	
Changes in Capacity, 1990 to 2000 (MW):	-1400	150	69.8	*Total capacity, not just operable*
Average 2000 Capacity Factor Relative to 1990 Est.	67%	10.3%	8.57%	*CF based on total capacity*
Estimated Gross Generation in 2000 (GWHe)	1.02E+04	2.64E+03	1.48E+02	
Gross Generation Efficiency, 2000	100%	21.0%	20.54%	
Fuel Input to generation, 2000 (GJ)	3.68E+07	4.53E+07	2.59E+06	
Fraction of fuel input as HFO	N/A	30.00%	100%	
HFO Input to generation, 2000 (GJ)	N/A	1.36E+07	2.59E+06	
Other Petrol Products (tires) input to gen., 2000 (GJ)	N/A	7.71E+05		
Estimated Power Exports to China, 1990 (GJ)	1.24E+07			
Fraction of 1990 Exports to China in 2000	0.7%			*Based on reported exports*
Estimated Power Exports to China, 2000 (GJ)	8.16E+04			
Imports of Electricity from China (GJ)	0.00E+00			
Own Use Fractions, 2000	0.30%	9.00%	8.00%	*Same as in 1990*
Own Use of Electricity (GJ)	1.10E+05	8.56E+05	4.26E+04	
"Emergency Loss" Fractions, 2000	0%	9.4%	0%	*30% higher than in 1996*
Emergency Losses, 2000 (GJ)	0	8.91E+05	0	
Transmission and Distribution Loss rate (overall), 2000	27.72%			*20% higher than 1996*
Transmission and Distribution Losses, 2000 (GJ)	1.25E+07			

ESTIMATE OF ELECTRICITY GENERATION IN 2005

	Hydro Plants	Coal Plants	HFO Plants	
Changes in Capacity, 1990 to 2005 (MW):	-383.6	150	69.8	
Average 2005 Capacity Factor Relative to 1990 Est.	55%	20.40%	10%	*See Note 12*
Estimated Gross Generation in 2005 (GWHe)	1.11E+04	5.23E+03	1.73E+02	
Gross Generation Efficiency, 2005	100%	21.0%	21.00%	
Fuel Input to generation, 2005 (GJ)	4.01E+07	8.97E+07	2.96E+06	
Fraction of fuel input as HFO	N/A	1.00%	100%	
HFO Input to generation, 2005 (GJ)	N/A	8.97E+05	2.96E+06	
Other Petrol Products (tires) input to gen., 2005 (GJ)	N/A	8.91E+05		
Estimated Power Exports to China, 1990 (GJ)	1.24E+07			
				Based on reported exports.
Fraction of 1990 Exports to China in 2005	2.6%			*See Note 11*
Estimated Power Exports to China, 2005 (GJ)	3.25E+05			
Own Use Fractions, 2005	0.30%	9.00%	8.00%	*Same as in 1990*
Own Use of Electricity (GJ)	1.20E+05	1.70E+06	4.97E+04	
Imports of Electricity from China (GJ)	2.37E+03			*See Note 10*
				Discussions, but no evidence
Imports of Electricity from Russia (GJ)	0.00E+00			*of transfers as yet*
Imports of Electricity from ROK (GJ)	2.62E+05			*For Kaesong; See Note 8*
Total Electricity Imports (GJ)	2.65E+05			
"Emergency Loss" Fractions, 2005	0%	9%	0%	*25% higher than in 1996*
Emergency Losses, 2005 (GJ)	0	1.70E+06	0	
				20% higher than in 1996; See
Transmission and Distribution Loss rate (overall), 2005	27.72%			*Note 9*
Transmission and Distribution Losses, 2005 (GJ)	1.55E+07			

Conversion Factor:	1.000	toe/te
Conversion Factor:	41.84	GJ/toe

Plant	Rating (MWe)	Assumed Gross Generation Eff.	Implied Max. fuel use (GJ/mo.)	Max. Listed HFO (te/mo.)	Max. Fract. HFO	***Sources/Notes:***
Pyongyang						
as start-up fuel	500	27.0%	4.87E+06	2,500	2.15%	*1*
as supplement	500	27.0%	4.87E+06	17,000	14.62%	*1*
Ch'ongjin	150	27.0%	1.46E+06	10,000	28.66%	*1*
Pukchang	1600	27.0%	1.56E+07	20,000	5.37%	*1*
Sunchon	200	27.0%	1.95E+06	2,000	4.30%	*1*
East-Pyongyang	150	30%	1.31E+06	3,000	9.55%	*1*
TOTAL	2600		2.52E+07	52,000	8.65%	*2*

Back-up Calculation: Actual KEDO Fuel Input to Power Facilities in 1996 (11/95 through 10/96)

Chongjin	3,755	te		*3*
Pyongyang	44,842	te		*3*
Pukchang	20,065	te		*3*
Estimated KEDO HFO used, nominally coal-fired plants:		68,662	te	
Estimated KEDO HFO used, nominally coal-fired plants:		2.87E+06	GJ	
Sonbong	279,891	te		*3*
Estimated KEDO HFO used, Sonbong oil-fired plant:		1.17E+07	GJ	
Implied average capacity factor at Sonbong plant, 1996:		52.0%		*4*

Sources/Notes:

1 Assumes start-up and fuel supplement use of HFO in coal plants at over 6 percent of total thermal input.

2 Hydro set at 100 percent for accounting purposes. Coal and oil as described in estimates made for 1990, except efficiency reduced to reflect deterioration of infrastructure.

3 Figures of 75 percent and 100 percent of 1990 capacity factors for oil-fired plants and hydroelectric plants are assumptions. Factor for coal-fired stations is used to balance demand with net generation.

4 Assumes UN estimate of 4500 MW hydro and 5000 MW thermal. For reference, the sum of the capacities of the seven largest thermal plants was reported to be 2900 MW. There is by at least one report one other oil-fired, grid-connected plant in addition to Sonbong, but other reports state that the plant at Sonbong is the only active oil-fired plant of any size in the DPRK--which has been our working assumption.

5 Information from one source is that "one or two" "small to medium" (less than 10 MW) hydro plants were damaged in the floods of 1995 and 1996. Another source states that there has without doubt been substantial flood damage, including reservoir siltation and other problems. We assume that the net impact of flood damage and opening of a new hydro facility at Kumgang Mountain has been the effective reduction in hydro capacity shown. For thermal facilities, we assume (and have been told) that the addition of one 50 MW unit of the 150 MW plant under construction at East Pyongyang is the only recent major change.

6 Assumes a slight improvement as a result, for example, of lessons learned in ongoing UNDP program.

7 Year 2000 losses assumed to be an additional 5 percent higher than in 1996, due to continuing deterioration of electricity transmission and distribution system. Year 2005 losses assumed to be about the same as in 2000, as improvement of grids in some areas with improving economies is balanced by continued deterioration in other areas.

8 Electricity exports from the ROK to the Kaesong (Gaesung) industrial region of the DPRK started from about mid-March, 2005, over a line with a capacity of 15 *MW. Assuming an average capacity factor of* 70% (rough estimate, based on consideration of baseload power needs of industry, and seconded by ROK *experts) for the supplies to this industrial area, and that supplies were available for 9 months of 2005, implied exports of power from the ROK to the DPRK during 2005 were about* 72.82 GWh.
Capacity of line from ROK from several sources, including KERI ("Analysis of Present Status and Future Supply /Demand Prospects for the DPRK Power System", by J.Y. Yoon, presented at the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Yoon's presentation is avaialble as http://www.nautilus.org/DPRKEnergyMeeting/Papers/Yoon.ppt.
A sample of the news reports on the initiation of power flows from the ROK to the DPRK is Agence France-Presse (AFP), dated: 16 Mar 2005, "South Korea supplies power to North for first time in five decades". Accessed at http://www.reliefweb.int/rw/RWB.NSF/db900SID/KHII-6AJ9J5?OpenDocument.

9 The presentation by Dr. Yoon referenced in Note 9, above, estimates DPRK transmission and distribution losses at "about 20%" and "above 20%". Other, anecdotal estimates of losses, particularly in areas away from large cities, suggest that losses could be considerably higher. The value used for this analysis for 2000 and 2005 is intended as a rough weighted average.

10 China Customs Statistics from World Trade Atlas lists 2005 exports of electricity from China to the DPRK as 657,068 *kWh. As compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf. Electricity exports from the DPRK to China, as indicated by the same source, are as follows for other years:*

Year	kWh
1999	115,200
2000	-
2001	63,250
2002	8,845,890
2003	11,107,121
2004	8,568,657

11 From China Customs Statistics; see "ELECTRICITY GENERATION IN 2005" Worksheet in this workbook, Note 2.

12 Output from hydroelectric plants based on data and assumptions presented in "ELECTRICITY GENERATION IN 2005" Worksheet. Output of oil-fired power plants assumes little change since 2000, and output of (mostly) coal-fired power plants is adjusted to reach total DPRK-wide output as reported in "ELECTRICITY GENERATION IN 2005" worksheet by adjusting capacity factor.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ASSUMPTIONS, BACK-UP CALCULATIONS AND DATA: ELECTRICITY GENERATION IN 2000

Prepared by David Von Hippel
Date Last Modified: 3/19/2007

Estimate of Status of Electricity Generating Plants as of 2000 *(see Note 1)*

Plant Name/Group	Design Fuel	Original Capacity (MW)	Operable Capacity as of 2000	Capacity Factor (fraction of operable capacity)	Estimated 2000 output (GWh)	Notes
Thermal Power Plants				***(Note 3)***		
Oungi (Sonbong refinery)	HFO	200	-	0%	-	Not in operation since 1999
(Plant associated with small W Coast Refinery)	HFO	60	*60*	*20%*	105	Operable capacity not from Source 1--estimate assuming full capacity available, but plant may have heat exchanger problems. Much of output may be dedicated to nearby refinery.
Pukchang	Coal	1,600	180	*45%*	710	3x100 MW units in operation, further 40% reduction in capacity due to heat exchanger problems.
Pyongyang	Coal	500	190	*45%*	749	*See also Note 16*
East Pyongyang	Coal	100	40	*45%*	158	*See also Note 16*
Taechon	Coal	200	50	*45%*	197	
Songlim (internal combustion)	HFO/diesel	9.8	9.8	*50%*	43	Capacity factor rough estimate
Songlim	Coal	100	-	0%	-	Plant reportedly not operating
Sariwon	Coal	100	-	0%	-	Plant reportedly not operating
Sunchon	Coal	100	-	0%	-	Plant reportedly not operating
Total of Above		2,970	530		1,961	
Thermal Capacity included in 1996 estimate but not in the above:	Coal	350	*210*	*45%*	828	Operable capacity not from Source 1--estimate assuming full capacity available, but down-rated by 40% because plants likely have heat exchanger problems.
Total of Large Thermal		3,320	740	43%	2,789	

Plant Location/Category	Design Fuel	Original Capacity (MW)	Operable Capacity as of 2000	Estimated Capacity Factor (fraction of operable capacity)	Estimated 2000 output (GWh)	Notes
Hydro Power Plants						
Plants on Chinese Border	Hydro	700	700	*17.5%*	1,073	*See Note 2*
Other Hydro Plants as of 1996	Hydro	3,925	2,944	36%	9,155	Assumes about 75% of non-border-region capacity is operable (or that the average available capacity is 75% of nameplate), and capacity factor is 70% of 1996 estimate.
Total Estimated Operable Hydro Capacity		4,625	3,644	32%	10,228	Excludes portion of capacity at Chinese border used exclusively by China.
TOTAL IMPLIED DPRK ELECTRICITY OUTPUT, 2000					**13,018**	GWH ***(see Note 4)***

Recorded Electricity Exports to China 22.66 GWh ***(see Note 5)***
Recorded Electricity Imports from China 0.00 GWh ***(see Note 5)***

Input of used tires as fuel for electricity generation 7.71E+05 GJ ***(See Notes 6 and 7)***

Sources/Notes:

1 Information on status of electricity generating facilities from an industry source, except as noted below.

2 An industry source with knowledge of operating procedures for the hydroelectric power plants along the China/DPRK border estimates that there are approximately 700 MW of capacity providing power to the DPRK from the 4 hydroelectric cascades on the rivers that form the border between the DPRK and China. Further, this capacity, if it was damaged in the floods of the mid-1990s, is now operational. Standard procedures for operating the shared hydro capacity on the DPRK/China border is to run the plants on a peaking basis (low capacity factor) except for August, when rivers are full and the plants are run at full capacity. Availability of water thus limits output. As 2000 was reportedly a relatively low water year (perhaps 70% of normal), we assume that the average capacity factor for these plants was 10% *for all months except August, and thus the overall annual average capacity factor was approximately* 17.5% *.*

3 An estimated 50% capacity factor for the operable thermal units is roughly consistent with the level of output we assumed for 1996, with some reduction to account for difficulties in obtaining coal supplies. Still, 50 percent may be a generous estimate. By way of comparison, the KEEI data set provided to Nautilus (workbook titled "DPRK Energy Data", based on information from the ROK National Statistics Office) suggests total (probably not all operable) thermal capacity of 2960 MW, and output of 9200 GWh, for an average capacity factor of 35 percent. The average hydroelectric capacity factor from the same source for 2000 is 25%.

4 This total is lower than the 19.3 TWh quoted by The Wall Street Journal (Jay Solomon, "EUROPE ENGINEERS WAIT FOR U.S. MOVE TO OFFER ENERGY HELP TO NORTH KOREA," Seoul, 03/21/01) as having been estimated by Siemens AG, and is also lower than the 19.4 TWh estimated production in 2000 as provided in the KEEI data set described in Note 3. The total, however, does not seem unreasonable given the difficult status of the power generation and fuel supply infrastructure in the DPRK described by recent visitors. The total calculated also is similar to the value (apparently) attributed to "ROK Officials" by the Associated Press in a 1998 article focusing on potential South-North Power Transfers ("KOREA ELECTRIC POWER CHIEF OFFERS SURPLUS POWER TO N. KOREA," Seoul, 06/08/98) as "most of the DPRK's power plants are fossil-fired and only produce about 1.5 million kilowatts daily, about one- fifth of their total capacity, because of fuel shortages". If the reference here, which is not entirely clear, is interpreted to mean that the average output of DPRK electricity plants was 1500 MW as of mid-1998, the implied total annual generation would be about 13 TWh.

5 Exports from the DPRK to China from China Customs Report 2000 , pp. 1483-1495 (in Chinese).

6 Source from the industry reports that the DPRK likely received a total of 25,000 tonnes of used auto tires from Japan and Taiwan in 2000 for use as a supplemental boiler fuel. The DPRK has reportedly been requesting similar cargoes from Europe. This estimate corresponds well with data from Japan Customs Statistics (data from files downloaded from http://www.customs.go.jp/toukei/download/index_d012_e.htm) that lists year 2000 exports from Japan to the DPRK in a category (HS # 400400000) that is defined as "Waste, parings and scrap of rubber (other than hard rubber) and powders and granules obtained therefrom" at a total level of 22,156 *tonnes. We use this value as the estimated input of waste tires to electricity generation in the DPRK in 2000. For 2005, exports from Japan to the DPRK in the same category were recorded as* 25,599 *tonnes. The reported value of cargoes of this product averaged about 3600 Yen/tonne in 2000, and was about 3000 Yen per tonne from 2003 through 2005. By way of comparison these per-tonne value were less, sometimes significantly less, than the amount paid by Japan for coal exported from the DPRK to Japan in those years. Exports of this waste-rubber product were higher in all of the other years between 2000 and 2005, peaking at over 110,000 tonnes in 2003.*

7 Oxford Recycling Inc. (http://www.oxfordrecycling.com/product.html#5, visited 6/8/02) lists a fuel energy content of 15,000 *Btu/lb, or* 34.82 *GJ/tonne, for fuel from shredded tires. the same source lists a sulfur content of* 1.30% *for the same fuel.*

8 An article entitled "Defector from Pyonyang: 'Thirty thousand constructing soldires were died (sic) in Guemgangsan Plant'", by Han Yo'ng-chin, published 14 Feb, 2006, in The Daily NK WWW (Seoul), includes a reference to the Anbyun Youth Power Plant, near Mount Guemgang (Kumgang) as having a second step of construction completed in 2000, with final construction completed in 2003, and having a capacity of 200 MW.

9 An article in KCNA in English (Pyongyang), dated 14 December, 2004, and entitled "Leader Gives Field Guidance to Construction of Power Station", refers to the under-construction Orangch'on (hydro) Power Plant in North Hamgyong Province. The generating room of "Power Station No. 1" is described as "entering the construction stage".

10 An article in KCNA in English (Pyongyang), dated 26 May, 2005, and entitled "Kim Jong Il Visits Wo'nsan Power Station", refers to the under-construction Wo'nsan Youth Power Station (hydro) in Kangwo'n Province. This plant seems to be in the construction phase, with the dam at least partially completed. No figures on capacity are given.

11 An article in KCNA in Korean (Pyongyang), dated 19 September, 2005, and entitled "DPRK Leader Visits Moranbong Theater Under Reconstruction", includes a reference to the construction of a series of "10 small- and medium-sized power plants in tiers along [the] To'kchi River", with the implication that construction of the dam and related elements are complete or nearly so. The article also references the completion and starting of the To'kchinggang No.9 power plant, and refers to an under-construction No. 4 power plant. No information on plant capacity is provided.

12 An broadcast by KCNA in Korean (Pyongyang), dated 20 December, 2005, and on the subject "DPRK TV on Leader's Inspiring People to Build New Power Plants on 'Large Scale'", includes reference to the Naep'yo'ng No. 2 Kunmin Power Plant and the Wo'nsan Youth Power Plant, and notes that "Kim Jong Il visited all the power plant construction sites in the country for the last 10 years." The transcript of the broadcast also refers to the volume of the dam at the Wo'nsan Youth Power Plant as 1.7 million cubic meters, with 16 km of aqueducts, and refers to assembly of generators No. 2 through 5. There is also a reference to the Ku'mjingang Hu'ngbong Youth Power Plant in South Kamgyo'ng Province on the Ku'mjin River, to "large scale hydraulic power plants" such as the Orangch'o'n Power Plant and the Paektusan So'ngun Youth Power Plant, plus "scores of" small and medium-scale power plants including the "(Word Indistinct) No. 2 Railway Youth Power Plants, the Naso'n Youth Power Plant, the Singye Kunmin power plant, the (Word Indistinct) Mine No. 2 Power plant, [and the] (? Taegak) Youth Power Plant." There is a reference to a photo of "one or a power plant of the Susongch'o'n Second-stage Five Powr Plants".

13 An article in Korea Today (Pyongyang, via Naenara Internet, in English), dated 12 January, 2006, includes an interview with Kim Su Nam, "Bureau Director of the Ministry of Electric and Coal Industries". In the interview, Kim states, in part, "A large number of hydroelectric power stations have been built, including the Taedonggang, Namgang, Anbynon Youth, Thaechon, and Kanggye Youth Power Stations. Hydroelectric generating capacity has steadily grown with the builiding of many minor hydropower stations on the principle of combining large, medium, and small power plants. Along with this, thermal power plants have been erected in Pyongyang, Pukchang, Sunchon, and other parts of the country to meet the growing demand for electricity." The interview also refers to the completed construction of a dam of the Nyongwon Power Station, and to medium and (smaller) power stations in Jagang, South Haymgyyong, Ryanggang, and other provinces. Kim also refers to efforts to increase capacity at existing hydro and thermal power stations.

14 The article in Nodong Sinmun (Pyongyang, in Korean), dated 29 December, 2002, page 1, by Chong Yong-ch'ol, "At North Hwanghae Province: Power Plants Wherever the Water Flows", refers to power plants including the Yosonggang Power Plant in North Hwanghae Province, power plants in Yont'an and Unp'a County, a power plant in P'yongsan County, a power plant in Koksan County (on the stream of the same name), a plant at Taech'on-ri in Insan County, plants under construction in Singye and Yonsan Counties (Singye Power Plant No. 1, and Hwangdaech'on Power Plant, respectively, with the latter apparently in early construction phases, and the former more advanced). There is a reference to "power plant constructed at Holdong Mine".

15 From China Customs Statistics. See Note 10 in "Electric--96-on" Worksheet in this workbook.

16 A set of figures from a 2001 document in the authors' files [NKES-01], citing a DPRK source, provided the following information about the Pyongyang Thermal Power plant. The coal consumption figure shown corresponds to a relatively high efficiency if it is interpreted as referring to average heat-content coal, and an efficiency of about 26% *of it refers to grams of coal equivalent. The same source also includes the following information: "The Pyongyang area has 600MW of thermal power plants (Pyongyang Thermal Plant 500MW, East Pyongyang Thermal Plant 100 MW), which receive coal supplies from the Chikdong Mine and the Chonsong Mine. Electric power production these days is only 1,700,000 MWh (Pyongyang Thermal Plant 1,225,000 MWh, East Pyongyang Thermal Plant 475,000 MWh)." The latter figures, if true, suggest that year 2000 electricity output was somewhat higher than estimated above, at least for these plants. It should be noted that the Pyongyang and in particular, East Pyongyang plants are among the most recent additions to the DPRK fleet of thermal power plants.*

Pyongyang Thermal Power Facilities*

Thermal Condensing Turbine	50 MW x 7 (USSR)
Extraction Steam Condensing Turbine	50 MW x 1 (German)
Steam Condensing Turbine	100 MW x 1 (German)
Steam Boiler	12 Unit
Heating Boiler (210t) 100Gcal/h	2 Unit
Total Operating Hours	300,000
Consumption of Anthracite	470g/kwh (approximately)

Based on a very rough calculation, 2 boilers of this size could supply space heat and hot water for tens of thousands of households (perhaps 25,000 to 100,000)

** This table has been edited slightly for clarity.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ASSUMPTIONS, BACK-UP CALCULATIONS AND DATA: ELECTRICITY GENERATION IN 2005

Prepared by David Von Hippel
Date Last Modified: 4/11/2007

Estimate of Status of Electricity Generating Plants as of 2005 *(see Note 1)*

Plant Name/Group	Design Fuel	Original Capacity (MW)	Operable Capacity as of 2005	Capacity Factor (fraction of operable capacity)	Estimated 2005 output (GWh)	Notes
Thermal Power Plants				***(Note 3)***		
Oungi (Sonbong refinery)	HFO	200	-	0%	-	Reportedly not in operation since 1999 as of 2000. Assumed not to have operated since 2000, as associated refinery remains inactive.
(Plant associated with small W Coast Refinery)	HFO	60	*60*	*20%*	105	Assumed same as 2000
Pukchang	Coal	1,600	*??*	*??*		Recent news articles suggest that this plant is a mainstay of the current DPRK electricity system, and has been upgraded recently, but an estimate of currently operable capacity is not available. See also *Note 13*.
Pyongyang	Coal	500	*??*	*??*		
East Pyongyang	Coal	100	*??*	*??*		
Taechon	Coal	200	*??*	*??*		
Songlim (internal combustion)	HFO/diesel	9.8	9.8	*50%*	43	Assumed same as 2000
Songlim	Coal	100	*??*	*??*		Plant reportedly not operating
Sariwon	Coal	100	*??*	*??*		Plant reportedly not operating
Sunchon	Coal	100	*??*	*??*		Plant reportedly not operating
Total of Above		2,970	70		148	
Thermal Capacity included in 1996 estimate but not in the above:	Coal	350	*??*	*??*		
Total of Large Thermal		3,320	2,040	30%	5,400	Operable capacity and output from data reported by KERI (for 2004)--see source in *Note 1*. Total capacity roughly consistent with data in *Note 12.*

Plant Location/Category	Design Fuel	Original Capacity (MW)	Operable Capacity as of 2005	Estimated Capacity Factor (fraction of operable capacity)	Estimated 2005 output (GWh)	Notes
Hydro Power Plants						
Plants on Chinese Border	Hydro	700	864	37%	2,800	Estimated based on 2004 figures for plants shared with China as provided in source listed in *Note 1*.
Other Hydro Plants as of 1996	Hydro	3,925	3,066	30%	8,100	Estimated based on 2004 figures for plants other than those shared with China as provided in source listed in *Note 1*.
Total Estimated Operable Hydro Capacity as of end-2004	Hydro	4,625	3,930	32%	10,900	Excludes portion of capacity at Chinese border used exclusively by China. Total capacity roughly consistent with data in *Notes 12, 16*.
New large hydro capacity added in 2005			100	15%	132	Rough estimate. New reports in the last few years such as those described in *Notes 6 - 11* list several new large hydro facilities in different stages of construction, but few quantitative details are available.
New medium hydro capacity added in 2005	Hydro		86.4	15%	114	See *Note 14*. Capacity factor for medium and large hydro plants added in 2005 assumed half of average for existing plants not shared with China (to roughly account for operation starting at different times of the year).
TOTAL IMPLIED DPRK ELECTRICITY OUTPUT, 2005					**16,546**	GWh (See ***Note 15***)

Recorded Electricity Exports to China 90.15 GWh ***(see Note 2)***

Input of used tires as fuel for electricity generation 8.91E+05 GJ ***(See Notes 3 and 4)***

Sources/Notes:

1 For 2005, we do not yet have the same estimates of plant-by-plant operational status that we had in 2000. We therefore use overall estimates of capacity and capacity factor for thermal and hydroelectric power plants as reportedly provided by DPRK engineers to KERI (Korea Electrotechnical Research Institute) staff (and as cited in "Analysis of Present Status and Future Supply /Demand Prospects for the DPRK Power System", by J.Y. Yoon, presented at the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Yoon's presentation is available as http://www.nautilus.org/DPRKEnergyMeeting/Papers/Yoon.ppt.

2 Exports from the DPRK to China from China Customs World Trade Atlas As compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf. Electricity imports to China from the DPRK, as indicated by the same source, are as follows for other years:

Year	MWh
2000	22,665
2001	36,289
2002	9,979
2003	31,838
2004	83,350
2005	90,146

3 Source from the industry reports that the DPRK likely received a total of 25,000 tonnes of used auto tires from Japan and Taiwan in 2000 for use as a supplemental boiler fuel. The DPRK has reportedly been requesting similar cargoes from Europe. This estimate corresponds well with data from Japan Customs Statistics (data from files downloaded from http://www.customs.go.jp/toukei/download/index_d012_e.htm) that lists year 2000 exports from Japan to the DPRK in a category (HS # 400400000) that is defined as "Waste, parings and scrap of rubber (other than hard rubber) and powders and granules obtained therefrom" at a total level of 22,156 tonnes. We use this value as the estimated input of waste tires to electricity generation in the DPRK in 2000. For 2005, exports from Japan to the DPRK in the same category were recorded as 25,599 tonnes. The reported value of cargoes of this product averaged about 3600 Yen/tonne in 2000, and was about 3000 Yen per tonne from 2003 through 2005. By way of comparison these per-tonne value were less, sometimes significantly less, than the amount paid by Japan for coal

4 Oxford Recycling Inc. (http://www.oxfordrecycling.com/product.html#5, visited 6/8/02) lists a fuel energy content of 15,000 *Btu/lb, or* 34.82 *GJ/tonne, for fuel from shredded tires. the same source lists a sulfur content of* 1.30% *for the same fuel.*

5 An article entitled "Defector from Pyonyang: 'Thirty thousand constructing soldires were died (sic) in Guemgangsan Plant'", by Han Yo'ng-chin, published 14 Feb, 2006, in The Daily NK WWW (Seoul), includes a reference to the Anbyun Youth Power Plant, near Mount Guemgang (Kumgang) as having a second step of construction completed in 2000, with final construction completed in 2003, and having a capacity of 200 MW.

6 An article in KCNA in English (Pyongyang), dated 14 December, 2004, and entitled "Leader Gives Field Guidance to Construction of Power Station", refers to the under-construction Orangch'on (hydro) Power Plant in North Hamgyong Province. The generating room of "Power Station No. 1" is described as "entering the construction stage".

7 An article in KCNA in English (Pyongyang), dated 26 May, 2005, and entitled "Kim Jong Il Visits Wo'nsan Power Station", refers to the under-construction Wo'nsan Youth Power Station (hydro) in Kangwo'n Province. This plant seems to be in the construction phase, with the dam at least partially completed. No figures on capacity are given.

8 An article in KCNA in Korean (Pyongyang), dated 19 September, 2005, and entitled "DPRK Leader Visits Moranbong Theater Under Reconstruction", includes a reference to the construction of a series of "10 small- and medium-sized power plants in tiers along [the] To'kchi River", with the implication that construction of the dam and related elements are complete or nearly so. The article also references the completion and starting of the To'kchinggang No.9 power plant, and refers to an under-construction No. 4 power plant. No information on plant capacity is provided.

9 An broadcast by KCNA in Korean (Pyongyang), dated 20 December, 2005, and on the subject "DPRK TV on Leader's Inspiring People to Build New Power Plants on 'Large Scale'", includes reference to the Naep'yo'ng No. 2 Kunmin Power Plant and the Wo'nsan Youth Power Plant, and notes that "Kim Jong Il visited all the power plant construction sites in the country for the last 10 years." The transcript of the broadcast also refers to the volume of the dam at the Wo'nsan Youth Power Plant as 1.7 million cubic meters, with 16 km of aqueducts, and refers to assembly of generators No. 2 through 5. There is also a reference to the Ku'mjingang Hu'ngbong Youth Power Plant in South Kamgyo'ng Province on the Ku'mjin River, to "large scale hydraulic power plants" such as the Orangch'o'n Power Plant and the Paektusan So'ngun Youth Power Plant, plus "scores of" small and medium-scale power plants including the "(Word Indistinct) No. 2 Railway Youth Power Plants, the Naso'n Youth Power Plant, the Singye Kunmin power plant, the (Word Indistinct) Mine No. 2 Power plant, [and the] (? Taegak) Youth Power Plant." There is a reference to a photo of "one or a power plant of the Susongch'o'n Second-stage Five Powr Plants".

10 An article in Korea Today (Pyongyang, via Naenara Internet, in English), dated 12 January, 2006, includes an interview with Kim Su Nam, "Bureau Director of the Ministry of Electric and Coal Industries". In the interview, Kim states, in part, "A large number of hydroelectric power stations have been built, including the Taedonggang, Namgang, Anbynon Youth, Thaechon, and Kanggye Youth Power Stations. Hydroelectric generating capacity has steadily grown with the buiilding of many minor hydropower stations on the principle of combining large, medium, and small power plants. Along with this, thermal power plants have been erected in Pyongyang, Pukchang, Sunchon, and other parts of the country to meet the growing demand for electricity." The interview also refers to the completed construction of a dam of the Nyongwon Power Station, and to medium and (smaller) power stations in Jagang, South Haymgyyong, Ryanggang, and other provinces. Kim also refers to efforts to increase capacity at existing hydro and thermal power stations.

11 The article in Nodong Sinmun (Pyongyang, in Korean), dated 29 December, 2002, page 1, by Chong Yong-ch'ol, "At North Hwanghae Province: Power Plants Wherever the Water Flows", refers to power plants including the Yosonggang Power Plant in North Hwanghae Province, power plants in Yont'an and Unp'a County, a power plant in P'yongsan County, a power plant in Koksan County (on the stream of the same name), a plant at Taech'on-ri in Insan County, plants under construction in Singye and Yonsan Counties (Singye Power Plant No. 1, and Hwangdaech'on Power Plant, respectively, with the latter apparently in early construction phases, and the former more advanced). There is a reference to "power plant constructed at Holdong Mine".

12 The table below is from http://www.asiatradehub.com/n.korea/power.asp., "Asia Trade Hub: North Korea, Energy (Power)" The year to which these data apply was not recorded, but seems likely to be 2000 or shortly thereafter. The ultimate source of these data is unknown.

Hydraulic Power Plants

	Name	Location	Capacity (Unit: 10,000 kw)	Remarks
Eastern Region	Soedusoo	North Hamkyung	51	A valley-remodeling type
	The Huhchon River	South Hamkyung	39.4	"
	The Changjin River	"	38.1	"
	The Pujon River	"	26.2	"
	Anbyon Youth	Kangwon	10	A dam-type
	Soopung	North Pyongan	70	"
	Taechon	"	40	A valley-remodeling type and a dam type
Western Region	Woonbong	Jagang	40	A dam-type
	Wiwon	"	39	"
	Kanggye Youth	"	24.6	A valley-remodeling type
	The Daedong River	South Pyongan	20	A dam type
	Taepyongman	North Pyongan	19	"
	The Jangja River	Jagang	9	"
TOTAL of Above			426.3	

Thermal Power Plants

	December	Location	Capacity (Unit: 10,000 kw)	Remarks
Eastern Region	Seonbong	North Hamkyung	20	
	Chongjin	Chongjin	15	
Western Region	Bukchang	South Pyongan	169	A condensed water type
	Pyongyang	Pyongyang	50	A combined heat type
	The Chongchon River	South Pyongan	20	"
	Soonchon	South Pyongan	20	"
	East Pyongyang	Pyongyang	5	"
	December	Nampo	5	"
TOTAL of Above			304	

13 Note from presentation by DPRK Delegation, "THE PROSPECT OF ELECTRICAL ENERGY DEVELOPMENT IN DPRK AND REGIONAL CO OPERATION IN NORTH EAST ASIA," September 31, 2003. From Nautilus Institute 3rd Workshop on Grid Interconnection in Vladivostok, Russia, September 31, 2003. "Puk Chang thermal power plant at center of electrical system of DPRK has capacity of 1,600,000 kW. All hydro plants connected to Puk Chang through 220kW network."

14 The table below (which has been edited slightly for clarity) was provided in the KERI presentation referenced in Note 1. It lists capacity in small and medium power plants, but notes that "effect of small power plant was not high". A trend toward construction of larger-capacity "medium" hydro plants is noted.

Units: kW

Category	As of 2000	2001	2002	2003	2004	2005	Total
Planned (number)	6,840	370	250	?	100	43	
Number Constructed (under construction)	6,615	98	40	30	10	48(18)	6,841(18)
Capacity (kW)	292,000	24,500	30,000	30,000	20,000	86,400	470,900
kW/unit	31	250	750	1,000	800	1,800	

15 Source in Note 1 cites estimates of total DPRK generation in 2004 ranging from 16.3 TWh (KERI estimate, based on data provided by DPRK) to 20.4 (ROK government estimate). We feel that the former is likely closer to actual DPRK generation.

16 A source familiar with the DPRK energy sector suggests that about 3.9 GW of hydroelectric capacity was operable as of 2004, which is consistent with the estimate provided here.

17 Table below is from Some Thoughts on DPRK's Natural Geological Conditions and Their Evaluation - On the Distribution and Development of Hydropower Resources and the Electric Industry , by Professor Sagong Jun, Korea University in Japan, Available as http://www1.korea-np.co.jp/pk/112th_issue/99091601.htm

Hydraulic Resources in DPRK (II)

Name	GWh	(%)
Amrok River	39,635.00	47.9
Tumen River	8,134.61	9.5
Taedon River	7,508.17	9.1
Chongchon River	4,407.00	5.3
Rimjin River (north)	2,806.10	3.4
Pukhang River (north)	3,422.10	4.1
Resong River	701.34	0.8
Songchon River	1,675.00	2.0
Kumya River	1,617.17	2.0
Tanchonnam River	1,692.40	2.0
Orangchon River	1,451.80	1.8
Kiljunam River	7,670.80	0.9
TOTAL OF ABOVE	80,721.49	88.8

Units in original source given as "1,000,000 kw/h", but apparently GWh is the intended unit.
Above corresponds to 9.21 *average GW of power.*

18 Li Dunqiu, in his presentation "DRPK's Reform & Sino-DPRK Economic Cooperation", as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA, and available as http://www.nautilus.org/DPRKEnergyMeeting/Papers/Li.ppt, notes the following power exchange project between China and the DPRK, presumably starting in 2005 or 2006:
"Jilin Province has reached "barter" agreement with DPRK, transmitting electricity to DPRK in exchange of exploitation rights of its Youth Copper Mine. The project has a total investment of 0.22 billion RMB and represents DPRK's typical experiment in exchanging electricity with mineral [resources]."

Workpapers—Energy Demand Sectors

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCE
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
INDUSTRIAL SECTOR ENERGY DEMAND

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

GENERAL ASSUMPTION:

DPRK Industrial processes assumed to be **10%** more energy intensive than in China when Chinese intensities are used, and **15%** more energy intensive than in Russia when Russian intensities are used

				Notes/Sources:
Coal Consumption, All Industries	4.74E+08			
All Coal Consumption: Iron and Steel				
Annual Steel Production:	6.00E+06	Te		*4, 49*
Coal Use intensity:	1.64	tce/Te Steel		*6*
Total Coal Use:	3.25E+08	GJ coal		
Coking Coal Consumption: Iron and Steel				
Coking Coal Use intensity:	0.79	tce/Te Steel		*5*
Conversion Factor:	29.3	GJ/tce		
Total Coking Coal Use:	1.53E+08	GJ coal		
Other Coal Consumption: Iron and Steel				
Coal Use intensity:	0.85	tce/Te Steel		*45*
Conversion Factor:	29.3	GJ/tce		
Total Other Coal Use:	1.72E+08	GJ coal		
Coal Consumption: Cement				
Annual Cement Production:	1.10E+07	Te		*1, 48*
Coal/Oil Use intensity:	6.9	GJ/te clinker		*2*
Fraction of fuel needs by coal	90%			*46*
Total Coal Use:	6.81E+07	GJ/yr		
Coal Consumption: Fertilizers				
Annual Fertilizer Consumption:	6.00E+05	Te Nitrogen		*12*
Annual Fertilizer Imports	1.00E+05	Te Nitrogen		*43*
Annual Ammonia prod capacity	5.80E+05	te/yr		*30*
Annual Urea Production capacity	1.35E+06	te/yr		*30*
Ratio of Ammonia Mass to N	1.214			
Ratio of Urea Mass to N	2.50			
Capacity Utilization Factor	49%			
Estimated Ammonia Production	2.85E+05	te/yr		
Estimated Urea Production	6.63E+05	te/yr		
Total coal use/te NH_3	2	te/te		*29*
Fraction coal used as feedstock:	50%			
Conversion factor:	25.1	GJ/te		*29*
Coal Use, Ammonia Production	1.83E+07	GJ/yr for energy		*29*
Coal Use, Ammonia Production	1.83E+07	GJ/yr as feedstock		
Annual Superphosphate product.	2.47E+05	te		*35*
Fract. Phosphorus in Superphos.	44%			
Energy int., phosphorous prodn.	8.83	tce/te		*36*
Conversion Factor:	29.3	GJ/tce		
Total Coal Use, Superphos prodn.	5.70E+06	GJ/yr (net of elect. use)		*36*
Total Coal Use, fertilizer prodn.	1.83E+07	GJ/yr--non-energy feedstock		
Total Coal Use, Fertilizer Prod.	2.40E+07	GJ/yr--as fuel		

Coal Consumption: Other Chemicals			
Annual Carbide production:	3.50E+05	te (from coal, Hamhung)	*31*
Coal Use, carbide production:	0.96	te/te Ca Carbide	
Conversion factor:	25.1	GJ/te coal	*29*
Total Coal Use, Carbide Prod:	8.43E+06	GJ/yr	
Caustic Soda Production:	9.86E+04		*33*
Therm. En. Int., caustic soda prod.:	14.64	th GJ/te caustic soda	*44*
Boiler efficiency	60%	thermal GJ/tce	*Assumption*
Total Coal Use, caustic soda prod.:	2.77E+06	GJ/yr	
Total Coal Use, Unspec. Chem:			
Total Coal Use, Other Chem.:	1.12E+07	GJ/yr	
Coal Consumption: Pulp and Paper			
Paper production:	1.82E+05	Te	*7*
Wood Pulp/Unit Paper	0.85	Te/Te	*8*
Fraction of fuel needs by coal	50%		*10*
Ratio of fuel use to electr. use:	0.001061	tce/kWh	*11*
Conversion factor:	29.3	GJ/tce	
Total Coal Use:	4.03E+06	GJ/yr	
Coal Consumption: Other Metals			
Zinc Production	1.70E+05	Te	*15*
Copper Production	2.90E+04	Te	*15*
Aluminum Production	2.10E+04	Te	*15*
Lead Production	8.40E+04	Te	*15*
Zinc Coal Use intensity:	2.47	tce/te	*27*
Copper Coal Use intensity:	1.705	tce/te	*17*
Aluminum Coal Use intensity:	1.916	tce/te	*16*
Lead Coal Use intensity:	2.693	tce/te	*20*
Coal Use, Zinc Production	4.20E+05	tce	
Coal Use, Copper Production	4.94E+04	tce	
Coal Use, Aluminum Production	4.02E+04	tce	
Coal Use, Lead Production	2.26E+05	tce	
Conversion factor:	29.3	GJ/tce	
Total Coal Use: Other Metals	2.37E+07	GJ	
Coal Consumption: Other Minerals			
Magnesia Production	1.00E+06	Te	*40*
Magnesia Production assumed Oil-based in 1990			
Coal Use, Other Minerals	0.00E+00		
Coal Consumption: Textiles			
Textile Production	5.20E+08	running meters	7
Average textile weight	2.47E-04	te/running meter	*21*
Coal use, printing and dyeing	4.39E-04	tce/running meter	*22*
Coal Use per unit "vinalon" fiber	7.04	te coal/te	*31*
Conversion factor:	25.104	GJ/te coal	29
Conversion factor:	29.3	GJ/tce	
Total Coal Use: Textiles	2.94E+07	GJ	
Coal Consumption: Building Materials			
Glass production in China, 1990	8.07E+07	Cases	*37*
Population of China, 1990	1.14E+09	People	*37*
Per Capita Glass prod., China	7.06E-02	Cases/Person	
DPRK Population, 1990	2.20E+07	People	*38*
Est. Glass production, DPRK	1.55E+06	Cases	
Coal Consumption Intensity/Case	30.85	kgce/case	*20*
Conversion factor:	29.3	GJ/tce	
Total Coal Use: Glass Production	1.40E+06	GJ/yr	
Brick Production in China, 1990	4.49E+11	Pieces	*37*
Per Capita Brick product., China	392	Pieces/Person	
Est. Brick production, DPRK	8.63E+09	Pieces	
Coal Consumption Intensity	2390	kgce/10,000 pieces	*39*
Total Coal Use:Brick Production	6.04E+07	GJ/yr	
Total Coal Cons., Bldg Materials.	6.20E+07	GJ/yr	
Coal Consumption: Non-specified Industry	9.60E+07	GJ/yr	*26*
Oil Consumption, Cement:			
Fraction of heat input provided by oil	10%		*46*
Heavy Fuel oil use, cement product.	7.57E+06	GJ/yr	

Oil Consumption, Other Minerals:				
Magnesia Production	1.00E+06	Te		*40*
Magnesia Fuel Use intensity:	12.6	GJ/te		*41*
Hvy Fuel Oil Use, Magnesia Prod.	1.26E+07	GJ		
Oil Consumption: Non-specified Ind. (Diesel):	3.00E+06	GJ	*Placeholder value*	
Oil Consumption: Non-specified Ind. (Hvy Oil):	7.50E+05	GJ	*Placeholder value*	
Oil Consumption, All Industries	2.39E+07	GJ		
Wood/Biomass Consumption: Pulp and Paper	4.03E+06	GJ	*Complements coal consumption noted above*	
Wood Consumption: Non-specified Industry				
Fuelwood consumption	1.50E+05	cu.m.		*23*
Conversion Factor	1.50E+00	cu.m./te		*24*
Conversion Factor	1.60E+01	GJ/te		*24*
Total Fuelwood Consumption	1.60E+06	GJ		
Electricity Consumption, All Industries	6.54E+07			
Electricity Consumption: Iron and Steel				
Electricity Use intensity:	700.0	kWh/te crude steel		*47, 5*
Conversion Factor	3.60E-03	GJ/kWh		
Total Electricity Use:	1.74E+07	GJ/yr		
Electricity Consumption: Cement				
Electricity Use intensity:	100.0	kWh/te cement		*3*
Conversion Factor	3.60E-03	GJ/kWh		
Total Electricity Use:	4.36E+06	GJ/yr		
Electricity Consumption: Fertilizers				
Electricity Use intensity:	5.76	MWh/te Ammonium		*29*
Conversion Factor	3.60E+00	GJ/MWh		
Electricity Use, Ammonium Prod.	1.26E+07	GJ/yr		
Electricity Use intensity:	16.258	MWh/te phosphorous		*36*
Electricity Use, Superphos. Prod.	6.30E+06	GJ/yr		
Total Electricity Use:	1.89E+07	GJ/yr		
Electricity Consumption: Other Chemicals				
Elect. Use, Carbide production:	4571	kWh/te Ca Carbide		*31*
Conversion factor:	3.60E-03	GJ/kWh		
Total Elect. Use, Carbide Prod:	5.76E+06			
Elect. Use, Caustic Soda prod.:	2413	kWh/te		*32*
Total Elect., Caustic Soda Prod:	8.57E+05			
Total Elect. Use, Unspec. Chem:				
Total Elect. Use, Other Chem.:	6.62E+06			
Electricity Consumption: Pulp and Paper				
Electricity Use intensity:	1522	kWh/te pulp		*9*
Conversion Factor	3.60E-03	GJ/kWh		
Total Electricity Use:	9.32E+05	GJ/yr		
Electricity Consumption: Other Metals				
Zinc Elect. Use intensity:	3844	kWh/te		*28*
Copper Elect. Use intensity:	1240	kWh/te		*17*
Aluminum Elect. Use intensity:	16050	kWh/te		*18*
Lead Elect. Use intensity:	184.92	kWh/te		*28*
Elect. Use, Zinc Production	6.53E+08	kWh		
Elect. Use, Copper Production	3.60E+07	kWh		
Elect. Use, Aluminum Production	3.37E+08	kWh		
Elect. Use, Lead Production	1.55E+07	kWh		
Conversion factor:	3.60E-03	GJ/kWh		
Total Elect. Use: Other Metals	4.13E+06	GJ/yr		
Electricity Consumption: Other Minerals				
Magnesia Elect. Use intensity:	100.0	kWh/te Magnesia		*42*
Conversion Factor	3.60E-03	GJ/kWh		
Elect. Use, Magnesia Production	3.96E+05	GJ/yr		
Electricity Consumption: Textiles				
Elect. Use, Vinalon production	5400	kWh/te		*31*
Conversion factor:	3.60E-03	GJ/kWh		
Total Electricity Use: Textiles	2.50E+06	GJ/yr		

Electricity Consumption: Building Materials				
Electricity Int., Glass Production	30.81	kWh/case		*20*
Conversion factor:	3.60E-03	GJ/kWh		
Electricity Use: Glassmaking	1.72E+05	GJ/yr		
Total Elect. Use: Bldg. Materials	1.89E+05	GJ/yr		
Electricity Consumption: Non-specified Industry		1.00E+07	GJ	*25*

Notes/Sources:

1 The National Report of DPRK to UNCED, 1992, lists 13.9 million tonnes cement output for 1990. See also note 48.

2 Based on document in authors' files [CE1]. which cites 1645 kcal/kg "clinker". This is somewhat higher than a figure given for the Chinese cement industry, but only about 5% higher than the 1980 average for Russian cement plants.

3 Approx 1981 fig., China "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL

4 Document in authors' files [IF1] lists a figure of 7 million tonne figure (as of 1989) for crude steel output.

5 1987 fig. for "Key, Medium, and Small" plants in China is 890 kWhe/te. Source: "The Energy Efficiency of the Steel Industry in China", M. Ross and L. Feng, Energy, 1991. Also see note 6.

6 Note that this figure is about 30% higher than 1987 Average Chinese energy intensities.

7 Economist Intelligence Unit, "China, North Korea Country Profile 1992-93", p.72 (Original Source, "Industry of the DPRK" by M. Trigubenko).

8 Approximation based on author's experience. Remainder of paper weight is chemicals and binders, such as clay.

9 Chinese 1985 value: "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL V. Kalashnikov (personal communication, 9/97) suggests that the Russian historical average for electricity use in papermaking is somewhat lower--671 kWh/te paper (not pulp) as of 1965. We use the Chinese value here.

10 Working assumption, no data. Rest of fuel would probably be wood-derived.

11 For Chinese plants, 1980. Sum of non-electric fuel use (mostly coal) per kWh electricity used. Source: China Energy Databook, 1992 Edition, page IV-30

12 Based on document in authors' files [HA1]. Figure is probably from 1989 or 1990, and is generally consistent with other estimates and official figures for fertilizer production and consumption.

13 Ammonia, med. plants, tot. energy use; and elect. gen. eff. From "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL. Figures are for 1981 Chinese plants.

14 Assumes all non-electric energy use is coal. Subtracts coal input to electric power plants from total energy use.

15 Economist Intelligence Unit, "China, North Korea Country Profile 1992-93", p.72 (Original Source, "Industry of the DPRK" by M. Trigubenko). Data for 1990.

16 For aluminum oxide production (not clear if per te AlOx or Al), China, 1990. [Chinese data compendium provided by J. Sinton], p. 2.

17 Coal use in copper refining, China, 1990, from [Chinese data compendium provided by J. Sinton], p. 2. 1980 Russian figure for electric intensity of copper production (V. Kalashnikov, personal communication, 9/97). Value is substantially higher (3-fold) than estimates for electricity use in copper production in China.

18 1980 Russian figure for electric intensity of aluminum production (V. Kalashnikov, personal communication, 9/97). 1981 China figure for electrolytic aluminum, DC use, (from "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL) is very similar.

19 Document in authors' files [HT1, p. 10]. Reference to oil use is assumed to be all use of refined products in nation.

20 Chinese language spreadsheet of energy intensities obtained from J.Sinton, dated Feb 12, 1993. 1980 data

21 Ratio of textile length to weight as implied by figures in Korea Foreign Trade Association, "Major Economic Indicators for North Korea, 1993". (Page 9).

22 1990 (?) figures for China. P. 23: Energy of China, 1993 (Chinese-lang. compendium provided by J. Sinton, LBL)

23 Industrial Fuelwood, from document in authors' files [TO1, p. 22]. Upper end of range (100 - 150 kte/yr).

24 From document in authors' files [FC1, p. 7]

25 Placeholder value to bring total industrial demand up to 60% of total electricity consumption as estimated in: document in authors' files [EP1].

26 Placeholder estimate to bring total industrial/electric generation coal consumption up to (approximately) 75% of coal available, as estimated in document in authors' files [EE1]

27 1980 figures for China, section 8-37 of Chinese language document (1991) provided by J. Sinton, LBL.

28 For zinc, uses Russian electric intensity value from 1980 (V. Kalashnikov, personal communication, 9/97). Zinc figure is about 30% higher than 1990's figures for China, page 369 of Chinese language document ("China Energy ____") (1994) provided by J. Sinton, LBL. Lead intensity figure is from the latter document. Includes electricity used in ore milling (c. 1/3 of total for lead).

29 Based on flow diagram for Hamhung Fertilizer Complex as presented in document in authors' files [HT1, Annex 8]. Assumes that all nitrogen fertilizer starts with ammonia production. Coal is assumed to have a calorific value of 6000 kcal/kg (as specified for Anthracite in Annex 7 of the same document). Electricity consumption is also based on the flow diagram, which shows a total of 200 MW of power input to the process that produces 250 kte/yr ammonia. 7200 operating hours per year assumed, as stated in Annex 7 for the vinalon plant in the same complex. Electricity use is assumed (based on the flow diagram) to also account for conversion of ammonia into other fertilizer products, such as urea.

30 Based on values in Annex 7 of document described in 29. Note that these production capacities are the sum of data provided for specific large complexes in DPRK, and thus probably represent most, but not all, of the productive capacity in the country.

31 Based on values for carbide and vinalon production from flow diagrams presented in Annex 7 of the document described in 29.

32 Chinese 1980 value: "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL

33 from document in authors' files [TX1: Annexure 1].

34 Electricity use in caustic soda (sodium hydroxide) production refining, China, 1990, from [Chinese data compendium provided by J. Sinton].

35 Based on values for superphosphate production from flow diagrams presented in Annex 7 of the document described in 29. Assumes productive capacity of 400 kte/yr at full capacity and actual operation 7200 hours/yr.

36 Assumes that superphosphate is produced from phosphorous, and that the energy/electricity intensities of phosphorous production is as noted in "Chinese Energy Conservation" (1993), a Chinese-language compendium provided by J. Sinton of LBL. This assumption probably overstates the energy use in manufacturing superphosphate.

37 Data on production of glass and bricks in China contained in spreadsheet provided by J.Sinton of LBL.

38 As in "Residential" spreadsheet in this Workbook.

39 Russian value for bricks for 1965 obtained from V. Kalashnikov (personal communication, 9/97). Used without inflator. 1980 value from China (Chinese language spreadsheet of energy intensities obtained from J.Sinton, dated Feb 12, 1993) gives an energy intensity slightly more than half of the 1965 Russian value. We do not know whether the Russian and Chinese bricks are the same size, but assume that DPRK bricks will more closely resemble Russian models.

40 Economist Intelligence Unit, "China, North Korea Country Profile 1992-93", p.72 (Original Source, Industry of the DPRK by M. Trigubenko). Magnesia is MgO, or magnesium oxide.

41 Rough of intensity from US Bureau of Mines publication as relayed by Ms. Deborah A. Kramer of the U.S. Geological Survey is 10 MMBtu/short ton. This estimate is on the same order of magnitude as the energy required to produce chemically similar calcium oxide from calcium carbonate. A separate estimate of DPRK magnesite fuel use intensity (personal communication [QR 9/97]) was slightly higher: 300 kg fuel oil/te. The latter figure was used.

42 Estimated to be similar to electricity requirements for production of cement "clinker" from limestone.

43 Estimated imports of nitrogen fertilizer in 1990. Assumed mostly from the (former) Soviet Union.

44 1980 Russian figure for thermal energy use (assumed to be as heat) in caustic soda production (V. Kalashnikov, personal communication, 9/97).

45 Rough estimate based on 1965 and 1980 Russian figures for coal use in iron making plus steelmaking. (V. Kalashnikov, personal communication, 9/97).

46 It has been reported that some fuel oil is used in cement production. The figure shown here is a guess on our part.

47 Based on 1965 and 1980 Russian figures for electric energy use in steelmaking (V. Kalashnikov, personal communication, 9/97).

48 Data from the Korean National Statistical Office and the Korea Cement Industrial Association suggest a considerably lower figure for DPRK cement output in 1990--6.13 million tonnes. Other sources place DPRK cement production at 10.1 million tonnes in 1986, 10 million tonnes in 1988 (the latter from the Economist Intelligence Unit, "China, North Korea Country Profile, 1992-93", p.79, Original Source, Mining Journal, Mining Annual Review, 1991), 4.75 million tonnes in 1992, 7.5 million tonnes in 1993, and 12 million tonnes in 1993. Of these, our subjective judgement is that the 7.5 million tonnes in 1993 figure may well be the best-informed of the group, and given the substantial decline in all industrial output in the DPRK between 1990 and 1993, we believe that a 1990 figure of about 11 million tonnes is a reasonable estimate.

49 Data from the Korea Iron & Steel Association suggests a considerably lower figure for DPRK steel output in 1990--3.36 million tonnes. Other sources place DPRK steel production at 5.8 million tonnes in 1993, 4.2 million tonnes in 1990, 5.1 million tonnes in 1990 (the latter from the Economist Intelligence Unit, "China, North Korea Country Profile, 1992-93", p.79, Original Source, Mining Journal, Mining Annual Review, 1991), 1.79 million tonnes in 1992, and 5.98 million tonnes in 1993. Of these, our subjective judgement is that a 1990 figure below the 7 million tonne figure cited in Note 4 (for 1989) is likely for 1990 (most observers suggest that 1989 was a peak year for industrial output in many subsectors), but that the Korea Iron and Steel Association figure is probably too low (or represents an incomplete count of output). We therefore adopt an estimate of 6.0 million tonnes of steel output in 1990 for the DPRK.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ASSUMPTIONS, BACK-UP CALCULATIONS AND DATA:
INDUSTRIAL SECTOR ENERGY DEMAND IN 1996, 2000, AND 2005

Prepared By David Von Hippel
Date Last Modified: 3/12/2007

ASSUMPTIONS FOR CHANGES IN INDUSTRIAL ENERGY USE, 1996, 2000, and 2005

	Production Relative to 1990				Energy Intensity Relative to 1990			
Subsector	1996	2000	2005	20[illegible]	1996	2000	2005	20[illegible]
Iron and Steel ***(See Notes 1, 17)***	35%	18.1%	15%		110%	115%	112%	%
Cement ***(See Note 2)***	40%	30%	32%		110%	115%	112%	%
---- fraction of heat from heavy oil	10%	24.5%	12.0%					
Fertilizers ***(See Note 3)***	25%	8%	11%		110%	115%	112%	%
Other Chemicals	30%	18%	18%		110%	115%	112%	%
Pulp and Paper	30%	18%	18%		110%	115%	112%	%
Other Metals ***(See Note 19)***	30%	18%	60%		110%	115%	112%	%
Other Minerals ***(See Note 18)***	30%	30%	50%		110%	115%	112%	%
---- fraction of heat from heavy oil	80%	80%	50%					
Textiles	30%	18%	20%		110%	115%	112%	%
Building Materials	30%	30%	30%		110%	115%	112%	%
Non-Specified Industry--non-oil fuels	30%	18%	20.6%		110%	115%	112%	%
Non-Specified Industry--diesel oil	20%	18.1%	10%		110%	115%	112%	%
Non-Specified Industry--heavy oil	30%	36%	15%		110%	115%	112%	%

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THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

(See Note 4)

Subsector	1996 Production Relative to 1990	2000 Production Relative to 1990	2005 Production Relative to 1990
Iron and Steel	35%	18%	15%
Cement	40%	30%	32%
---- fraction of heat from heavy oil	10%	25%	12%
Fertilizers	25%	8%	11%
Other Chemicals	30%	18%	18%
Pulp and Paper	30%	18%	18%
Other Metals	30%	18%	60%
Other Minerals	30%	30%	50%
Textiles	30%	18%	20%
Building Materials	30%	30%	30%
Non-Specified Industry--non-oil fuels	30%	18%	21%
Non-Specified Industry--diesel oil	20%	18%	10%
Non-Specified Industry--heavy oil	30%	36%	15%

Notes/Sources:

1 www.koreascope.com, in "Production of Major Industrial Items and World Ranking" (visited 6/3/02), lists the ROK production of steel in 1999 as 41 million tonnes. In "Economic and Social Comparison between the Two Koreas", on the same WWW site, the ROK's steel production is listed as being 33 times that of the DPRK, implying an annual production of about 1.24 million tonnes. This figure, about 18 percent of 1990 production levels, seems plausible (though possibly high). A figure that is probably from the same ultimate source, the Korea Iron & Steel Association, suggests a value of 1.086 million tonnes in 2000, along with 1.208 million tonnes in 1996, and 1.168 million tonnes in 2005. It is unclear how these figures were derived. Based on consideration of existing estimates, observations of the overall DPRK economy, and trends in iron and steel products trade with China (see notes 13 through 17, below), we adopt iron and steel production estimates of 2.1 million tonnes in 1996, 1.08 million tonnes in 2000, and 0.87 million tonnes in 2005, describing a slow decline, in more recent years, in primary iron and steel production in the DPRK.

2 *The source noted above, in the "Economic and Social…" page, lists a DPRK cement production of 4.1 million tonnes, or about 41 percent of year 1990 production, in 1999, which seems plausible. Data that are probably from the same ultimate source, the Korean National Statistical Office and the Korea Cement Industrial Association, suggest that year 2000 cement output was 4.6 million tonnes, output in 1996 was 3.79 million tonnes, and output in 2005 was 5.93 million tonnes. It is unclear how these numbers were derived, and though one would expect the cement industry to decline somewhat less than other industries, as it is/was not largely an export industry, the observed lack of recent construction activity in the DPRK would suggest that the level of 1996 to 2005 increase that the latter source shows is not what one would expect. We assume cement output of 4.4 million tonnes in 1996, 3.3 million tonnes in 2000, and 3.52 million tonnes in 2005, showing a trend of slightly increased construction-sector demand for cement (for example, for hydroelectric dams) in recent years in the DPRK.*

3 *www.nis.go.kr/english/democratic/industry07.html, dated 2001, by the ROK National Intelligence Service, suggests that current supplies of fertilizer cover only 40 percent of fertilizer needs in the DPRK. Causes and Lessons of the "North Korean Food Crisis", by Tony Boys of Ibaraki Christian University Junior College (2000), lists total fertilizer supply in the DPRK in 1999 of 200 ktonnes of "NPK", of which 32% was produced domestically, 10% imported, and the remainder provided in aid. This would imply that about* 11% *of 1990 levels of fertilizer production were achieved in 1999. This document is available as "dprke.pdf" on the WWW. The same document shows total fertilizer availability of about* 170 *ktonnes in 1996. Assuming fertilizer aid at that time was minimal, and assuming fertilizer imports were approximately as in 1999, domestic fertilizer production in 1996 can be estimated at* 25% *of 1990 levels.*

As an alternative source, the presentation "Agriculture and Fertilizer Situation in DPR Korea", by R.V. Misra, available as http://www.fertilizer.org/ifa/publicat/PDF/2006_crossroads_misra_slides.pdf (from the International Fertilizer Industry Association), presented as part of the "IFA Crossroads ASIA-PACIFIC 2006 Conference 'Growing markets, nurturing success'", Chiangmai, Thailand, 13-16 November 2006, includes the graph at right. This suggests that 1999 production of fertilizer in the DPRK was 63 *thousand tonnes of nitrogen, which is roughly consistent with the level suggested in the article by Tony Boys that is quoted above. Assuming this figure is correct, we adopt Misra's 2000 fertilizer production figure of* 37.5 *thousand tonnes or nitrogen, or* 7.5% *of 1990 production levels. The analogous figure for 2005 is* 56 *thousand tonnes or nitrogen, or* 11.2% *of 1990 production levels. A companion paper by Misra available from the same source notes that of the* 362.8 *thousand tonnes of annual nitrogen fertilizer production capacity listed (see reproduction of Table 5 from that paper, below),* 27 *kte of capacity use a fuel-oil based fertilizer process, electrolysis is the basis for* 61 *kte of capacity and* 239 *kte of N fertilzer capacity use "coal and naptha" as feedstocks. No information is provided on the relative proportions of these inputs, or on the relative capacity factors typical for the different production complexes. The same paper quotes an estimated energy intensity of fertilzer output of* 50 *GJ/te N to produce ammonia, and an additional* 25 *GJ/te N to produce urea. Which fuels these estimates include are not specified, but these estimates seem reasonably consistent with the estimates we have used for 1990 energy consumption in the fertilizer subsector.*

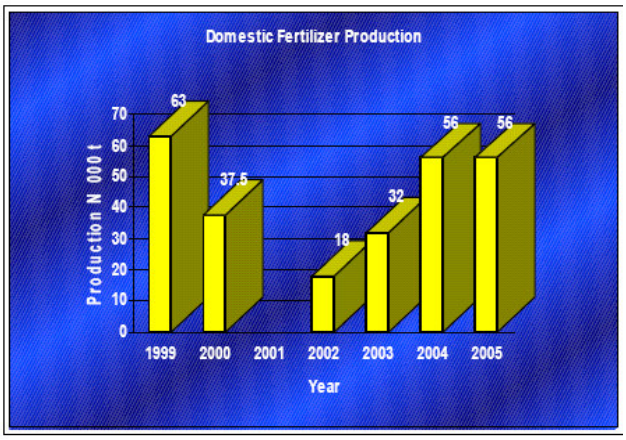


Table 5. Nitrogen Fertilizer Production Units and their Capacity

Production Unit	Product	Capacity ('000 t)	
		Product	Nutrient (N)
Hungnam	Urea	170	78
	Ammonium Nitrate	180	61
	Ammonium Sulphate	170	35
Namhueng	Urea	360	161
	Ammonium Sulphate	4	0.8
July 7 Chemical Complex, Undok	Ammonium Nitrate	80	27

On the basis of these data, and largely as placeholder values, we assume that 5% *of (non-energy) fertilizer feedstocks are heavy oil (in 1990 and beyond), and* 20% *are naptha, relative to the reported coal used as feedstock (at 1 te per tonne ammonia produced). Consumption of these feedstocks is reported in the "non-energy" sheet in this workbook. At this level, the naptha use in the fertilizer sector is still less than half of the 220,000 tonnes of naptha reportedly used in the industrial sector as a whole in 1990 in the report State of the Environment DPR Korea 2003 (Table 3.14) prepared by the DPRK with UNDP, and published by the United Nations Environment Programme. Other figures in the same table, however, appear somewhat overstated relative, at least, to our estimates for 1990.*

4 With the exception of "Other Minerals" and "Building Materials", we assume that the level of activity in other industries relative to 1990 in the year 2000 is approximately the same as in the iron and steel sector. The building materials and other minerals subsectors are assumed to have activities relative to 1990 similar to the cement industry. The other minerals subsector includes magnesite (or, when processed like lime for cement, magnesia), which is a valuable export product. An industry source indicates that an 8000 tonne shipment of magnesia (although it may have been magnesite) arrived in Europe in early 2001. Japan imported $3.5 million worth of magnesia in the first half of 2000 (Korea Trade-Investment Promotion Agency data from http://www.kotra.or.kr/main/common_bbs, visited 6/3/02, "Trade Tendencies of the Major Countries"), which, if annualized and assuming a sales price of $US 100 to $200 per tonne (within the range suggested in Queensland Department of Minerals and Energy Mineral Information Leaflet No 5: MAGNESITE, dated January 1998, suggests exports of 35 to 70 thousand tonnes to Japan alone, which in turn suggests relatively active production of the mineral. On our trip to the DPRK in October of 2000 we saw working brick or tile production facilities, some of the very few active industrial facilities we saw during our time in the DPRK. For 2005, with the exception of the subsectors treated explicitly in other notes, we assume that the generally-percieved modest upturn in the DPRK economy has translated in into a small increase, relative to 2000, in activity and energy use in industry, for example, in the cement, building materials, and textiles subsectors, though the upturn in the latter may be mostly due to garment assembly on commission, rather than the much more energy-intensive manufacturing of cloth. We increase non-oil fuels in "unspecified industry" more than other categories to reflect the probable increase in demand for electricity, and also some coal, from development of export-oriented light industry. A Bank of Korea estimate placed the production of cement in the DPRK at 5.6 million tonnes in 2004, which is considerably higher than the 4.1 million tonnes we use for 2000. We assume, in part reflecting information in Note 5, below, that the Bank of Korea figure is probably an over-estimate for 2005.

5 The document Seoul T'ongil Kyongje, dated August 2000, pages 39-48, article by Hong Sun-chik entitled "North Korean Industry (Part II): Cement Industry", suggests that cement output in 1998 was 3.15 million tonnes, but grew substantially in 1999. The capacity factor of DPRK factories was 26.2 percent in 1998, compared with 51 percent in 1990. The article lists a year-2000 capacity of 12.01 *million tonnes, of which 96.3 percent was in the 10 largest factories. The DPRK had 49 kilns, and the average capacity of 0.25 million tonnes each was less than one quarter the average capacity of kilns in the ROK. The article cite DPRK limestone reserves of about 100 billion tonnes. The article references a year-2000 source listing the Ch'onnae-ri Cement plant with "Annual production of 1.1 Million tonnes, the largest on the East Coast". In a discussion of cement quality, the article says that cement made in the DPRK is lower in quality (due to poorer quality control, kiln breakdown due to oil shortages, and lack of input supplies) than ROK cement, but that DPRK cement is similar in quality and price to Chinese cement. Problems in the Cement industry listed in the article include outdated production facilities, with automated facilities in use for only about one sixth of kilns, poor cement quality (due in part to lack of fuels, which prevent kilns from being operated normally), lack of paper for packaging of cement products (leading to difficulties in exporting cement), the presence of wastes in the cement, and "an inefficient use that causes environmental pollution".*

6 The document Seoul T'ongil Kyongje, dated December 2000, pages 36-44, is an article by Hong Sun-chik entitled "North Korean Industries (Part V): Automobile Industry". This article notes a new plant in Nampo, opening 9/2000, to "modif[y] imported secondhand automobiles", with a planned second phase to assemble Fiats. In the 1970s, the DPRK developed production lines for 2.5-, 10-, and 25-tonne trucks. The article states that "most of the key parts that require elector-circuit systems and precision processing such as cylinder heads and starter motors are imported" due to problems with the quality of domestically-produced parts. Although a 90 percent "self-sufficieny rate" is claimed by the DPRK, the author estimates a rate under 60% is more likely. 1999 auto production capacity in the DPRK was estimated at 33,000 units, with production of 7,300 that year. The Sungni Motor General Plant accounts for 80 percent of the DPRK's output of cars and trucks. Starting in 1995, this factory began producing a diesel-fueled passenger car to try and shift transport fuel consumption to lower-cost diesel oil (and away from gasoline). This transition is also (as of 2000) being undertaken for new 2.5-tonne trucks (gasoline-to-diesel). The article contains an estimate that 70 to 90 percent of cars being used in Pyongyang are imported. The article estimates that the DPRK's domestic automobile demand is 20,000 to 30,000 units per year, of which passenger cars account for 30-40 percent. Engines have been imported from Japan, the Czech Republic, and other countries since 1988.

7 China Customs Statistics reported imports of television sets to the DPRK from China increased approximately five-fold, on average, between 1998-2000 and 2003-2005. Televisions (HS #8528) were the number one import in the "electrical equipment" category for the DPRK during the latter years, at an average of about 400,000 sets per year. At the same time, imports to the DPRK from China of the rare earth metal Yttrium (HS # 2846) , which is used in making phosphors for televisions, declined from about 55 tonnes in the mid-1990s to zero by 2000 and 2005. China was (as of the mid-1990s) by far the world leader in production of Yttrium (see http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/741397.pdf). The increase in television imports from China, and the decrease in Yttrium imports, is circumstantial evidence of (though, admittedly, hardly proof of) a decline in the DPRK appliance sector since the mid-1990s. Import data as compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.

8 Many of the top imports to the DPRK from China, by value, in 2005 in the Machinery (HS # 84) category appear to be tools related to mines, mining, or the mineral industry. These include minerals sorting devices, compressors and pumps (air and liquid), bulldozers and related self-propelled equipment, furnaces, derricks, and cranes. These purchases would appear to point to an upturn in the DPRK metals and minerals subsector (or perhaps an upturn to come in the next few years). In most of these categories, purchases increased significantly in recent years. In the "machinery" category overall, the DPRK's imports from China nearly doubled (in reported value) between 2004 and 2005. Source same as cited in note 7, above.

9 Imports of plastics and plastic goods to the DPRK from China, by weight, in 2005 in the Plastics (HS # 39) category were over 45,000 tonnes, which was an increase of more than 50 percent over year 2004 imports, and about four-fold higher than plastics imports in the mid-1990s. This may indicate a combination of a decline in the DPRK's capacity to produce plastics domestically, plus an increase in the demand for plastic goods, particularly as the non-state economy began to develop. Source same as cited in note 7, above.

10 Imports of iron and steel products (for example, rolled steel and steel bar, not finished goods--"Iron and Steel", HS # 72 category) to the DPRK from China, by weight, averaged about 57,000 tonnes per year from 2003 through 2005. This was an increase of more than 4-fold over 1995-1997 imports, and may indicate a combination of a decline in the DPRK's capacity to produce such products domestically. Source same as cited in note 7, above A similar pattern exists for finished iron and steel goods ("Iron and Steel Products", HS #73), where year 2005 imports from China (at about 25,000 tonnes) were significantly higher than in previous years, and about five-fold higher than the approximately 4000 - 6000 tonnes level of imports of these goods that prevailed from 1995 through 1999. Among these products, the DPRK imported over 24,000 tonnes of railway track (HS# 7302) in both 2001 and 2005, far more than imports in other years. Likewise, imports of inorganic chemicals (HS # 28), at about 50,000 tonnes in 2005, were over 50% higher than in 2003 and 2004, and about 3 times imports in the mid-1990s. Aluminum oxides and carbonates (HS# 2818 and 2836, respectively) made up almost 40,000 of the total imports by the DPRK from China in this category in 2005.

11 Similar to the pattern noted in 10, above, Imports of aluminum and aluminum products (HS # 76 category) to the DPRK from China, by weight, averaged about 57,000 tonnes per year from 2003 through 2005 (see data below). This was an increase of about 5-fold over 1995-1997 imports, and, similar to the iron and steel sector, may indicate a combination of a decline in the DPRK's capacity to produce such products domestically. The most commonly imported products in this category, by weight, were "bar, rod, profiles", "other structures", "plate, sheet, strip > 0.2 mm thick", "household articles", and "foil =< 0.22 mm thick (except backing)" (?). Imports of aluminum "tubes and pipes" (HS # 7608) were just under 19 tonnes in 2005. Source same as cited in note 7, above.

	2003	2004	2005	
76 ALUMINUM	1,655	2,286	4,285	*Quantity: tonnes*

12 In 2005, the DPRK exported to China somewhat under 4700 tonnes of lead (HS # 78) and over 9300 tonnes of Zinc and zinc products (HS # 79). Lead exports from the DPRK to China were recorded as zero in 2003 and 2004 (or, possibly, not recorded), but varied from about 1200 to 4200 tonnes per year from 1995 through 2002. Zinc/zinc products exports were much higher in 2004--about 35,000 tonnes, and also higher--about 15,500 tonnes--in 2003. Source same as cited in note 7, above.

13 In 2003 - 2005, the DPRK exported to China the quantities of ores (HS # 26) noted below. Only selected ore exports are shown (largely, top exports by volume). Many ore exports to China showed large increases in 2005, and also between the late 1990s and 2005. Exports from the DPRK to China of 90.54 tonnes of "Uranium, Thorium Ore and Concentrate" was listed for the year 2004, but Uranium exports from the DPRK to China are not listed for other years between 1995 and 2005. Source same as cited in note 7, above.

Description	HS #	2003	2004	2005	
IRON ORES+CONCENTRATE	2601	270,854	937,159	1,320,458	*Units: Tonnes*
ZINC ORES+CONCENTRATE	2608	5,242	16,109	30,389	
PRECIOUS METAL ORES+C	2616	55,788	60,007	-	
MOLYBDENUM ORE+CONCEN	2613	230	384	619	
LEAD ORES+CONCENTRATE	2607	20,608	14,301	14,090	
COPPER ORES+CONCENTRA	2603	7,298	6,987	7,856	
TUNGSTEN ORE+CONCEN	2611	398	542	1,252	
OT WASTE MANU IRN/STL	2619	-	568	7,169	
OTHER ORES AND CONCENTRATES	2617	-	2	2,962	

14 In 2003 - 2005, the DPRK exported to China the quantities of iron and steel products (HS # 72) noted below. Only selected exports are shown (largely, top exports by volume). Exports to China in this category also, overall, showed large increases between the late 1990s and 2005, particularly in scap exports. In addition to the quantities noted above, smaller amounts of iron and steel products (about 1100 tonnes in 2003, but only 82 and 87 tonnes in 2004 and 2005, respectively) were imported to Hong Kong from the DPRK. Source same as cited in note 7, above.

Description	HS #	2003	2004	2005	
FERROUS WASTE,SCRAP;O	7204	221,719	275,687	358,293	*Units: Tonnes*
PIG IRON,SPIEGELEISEN	7201	118,874	155,377	98,060	
SEMIFINSH IRON,NONAST	7207	69,183	47,767	47,538	
FERROALLOYS	7202	3,318	6,139	9,843	
PRIMARY FORMS,NT 7203	7206	8,084	4,677	2,042	
BAR,ROD,H ROLLD,I/NAS	7214	738	2,485	798	

15 From 1995 - 2005, the DPRK exported to China small quantities of finished iron and steel products (HS # 73) in quantities ranging, by year, from near zero to about 800 tonnes. The largest single year's export of a single product was 707 tonnes of railway track in 2004. Source same as cited in note 7, above.

16 Since 1998, the DPRK has exported to China less than a million USD per year of goods in "machinery" category (HS # 84.) Exports for 1998 and for several other years in the late 1990s were higher, by value. Source same as cited in note 7, above.

17 The data on trade in iron ore and iron and steel goods between China and the DPRK, as described in notes 10, 13, and 14 above, suggest a pattern whereby the DPRK (and/or Chinese businesses operating in the DPRK) are focusing on exporting increasing amounts of raw materials (ore, scrap) from the DPRK to China, and increasing imports of finished and semi-finished iron and steel products into the DPRK from China. Based on this pattern and on reports (and our own observations) of the continued decline of DPRK heavy industry, we assume a continued reduction in output of iron and steel and iron and steel products in the DPRK between 2000 and 2005.

18 Dr. Chung Woo-jin, in his presentation entitled "Mineral Resources in DPRK", as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA), and available as http://www.nautilus.org/DPRKEnergyMeeting/Papers/Chung.ppt. lists 2004 DPRK output of Magnesite of 1 million tonnes, the same as in 1990. What is not known is what fraction of that output might have been simply exported as a raw ore (and thus not processed to Magnesia), and what fraction might of ore processing was fueled with heavy oil versus coal. We make the assumption, for the year 2005, that about 50% *of magnesite was processed to Magnesia, and about* 50% *of the fuel input for that processing was provided by heavy fuel oil (the rest being provided by coal).*

19 *In the presentation referenced above, Dr. Chung provides estimates of the production of lead and zinc metal (ingots) in 2004 in the DPRK at levels of* 60 *and* 100 *kte, respectively, or about* 71% and 59% *of 1990 output. Copper ingot production was estimated by Dr. Chung at* 13 kte, or 45% of 1990 output as *estimated. The heavy imports of aluminum products (at levels well beyond even the reported output of aluminum in 1990) from China into the DPRK, as reported in Note 11, above, suggest that domestic DPRK production of aluminum in 2005 could have been low (which would also be consistent with electricity shortage, as aluminum manufacture is quite electricity-intensive). Based on these data, we estimate a rough average activity for the overall "other metals" subsector for 2005 at* 60% of 1990 levels.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

BACK-UP CALCULATIONS AND DATA: TRANSPORTATION SECTOR ENERGY DEMAND

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

GENERAL ASSUMPTION:

DPRK transport assumed to be **20%** more energy intensive than in China or Russia

				Notes/Sources:
Oil Use: Road Vehicles				
Freight Transported:	4.20E+07	te		1
Average Distance of transport	75	km	Guess	
Energy Intensity, Diesel Trucks	3.08	MJ/te-km		19
Fract Freight on Diesel Trucks	23.8%		Guess	
Diesel Use, Road Freight	2.30E+06	GJ		
Energy Intensity, Gasoline Trucks	5.77	MJ/te-km		19
Fract Freight on Gasoline Trucks	71.3%		Guess	
Gasoline Use, Road Freight	1.30E+07	GJ		
Total Road Freight Oil Use	1.83E+07	GJ		
Number of Civilian Autos in Use	15,500			11
Average km traveled/yr	8,500		Guess	
Efficiency, Civilian Autos	1.10E+01	km/liter gasoline		11
Conversion factor	0.0325	GJ/liter		
Gasoline Use, Civilian Autos	3.90E+05	GJ		
Economically Active Population	1.38E+07			3
Per capita Trips/yr	300		Guess	
Average Trip Distance	16	km	Guess	
Fract. Trips by Motor Transport	25%		Guess	
Fraction of Trips by Road	30%			10
Fraction of km in Diesel Veh.	50%		Guess	
Energy Intensity, Diesel Oil Transport	75	kgce/kpass-km		4
Conversion Factor	0.0293	GJ/kgce		
Total Passenger Road Diesel Use	5.47E+06	GJ		
Fraction of km in Gasoline Veh.	50%		Guess	
Energy Intensity, Gasoline Transport	98.2	kgce/kpass-km		4
Total Passenger Road Gas Use	7.16E+06	GJ		
Total Oil Use, Pass Vehicles	1.42E+07	GJ		
Total Oil Use, Road Vehicles	3.25E+07	GJ		
Biomass Use, Road Vehicles				
Fract Freight on Biomass-fueled Trucks	5%			14
Efficiency of biomass trucks relative to gasoline		50%		13
Biomass use, road freight	1.82E+06	GJ		
Oil Use: Rail Transport				
Freight Transported:	1.69E+08	te		1
Fraction of Freight on Diesel Rail	12.5%			10
Average Distance of transport	250	km	Guess	
Energy Intensity, Diesel Rail	10.5	kgce/kte-km		18
Conversion Factor	0.0293	GJ/kgce		
Total Rail Freight Oil Use	1.95E+06	GJ		
Oil Use: Water Transport				
Freight Transported:	1.80E+07	te		1
Average Distance of transport	200	km	Guess	
Energy Intensity, Diesel/Heavy Fuel Oil Ships	9.9	kgce/kte-km		5
Conversion Factor	0.0293	GJ/kgce		
Total Ship Oil Use	1.25E+06	GJ		
Fraction of Ship Oil Use as Heavy Fuel Oil	50%		Guess	
Total Diesel Oil Use in Ships	6.27E+05			
Total Heavy Oil Use in Ships	6.27E+05			

Oil Use: Air Transport				
Number of Planes (Total)	24			*8*
Number of Planes that are Tu-154 jets	3			*16*
Average Number of Seats/Plane (non-jets)	50			*15, 16*
Average Airspeed During Operation (non-jets)	500	km/hr		*15*
Average Number of Seats/Plane (jets)	166			*15*
Average Airspeed During Operation (jets)	900	km/hr		*15*
Annual Operating Hrs/plane-yr--non-jets	300		*Guess*	
Annual Operating Hrs/plane-yr--jets	750		*Guess*	
Implied total seat-km per year	4.94E+08			
Average Fraction of Seats Occupied	75%		*Guess*	
Implied Air Passenger-km	3.70E+08			
Fuel use per hour (An-24s)	3582	liters/hr		*12*
Fuel use per hour (Tu-154s)	5073	liters/hr		*17*
Conversion factor	0.0321	GJ/liter gasoline		
Conversion factor	0.0350	GJ/liter jet fuel		
Total Domestic Air Aviation Gasoline Use	7.24E+05	GJ		
Total Domestic Air Jet Fuel Use	3.99E+05	GJ		
Total Domestic Oil Products Use	1.12E+06	GJ		
Implied Intensity, all planes	3.03E-03	GJ/passenger-km		
International Aviat. Fuel Supplied by DPRK		0 GJ	*Guess*	
Total Air Transport Oil Use	1.12E+06	GJ		
Oil Use: Non-Specified Transport	1.00E+06	GJ	*Placeholder value*	
Electricity Use: Rail Transport				
Fraction of Freight on Electr. Rail	87.5%			
Average Distance of transport	300	km	*Guess*	
Energy Intensity, Electric Rail	28.6	kWh/kte-km		*18*
Conversion Factor	0.0036	GJ/kWh		
Total Rail Freight Elect Use	5.48E+06	GJ		
Fract. pass. Transp on Elect Rail	70%			
Energy Intensity, Electric Rail	13.2	kgce/kpass-km		*7*
Conversion Factor	0.0293	GJ/kgce		
Total Pass. Rail Elect Use	5.39E+06	GJ		
Total Electricity Use, Rail Transp.	1.09E+07	GJ		
Coal Use: Rail Transport	0	GJ		
Coal Use: Water Transport	0	GJ		
Electricity Use, Non-specified Transport	6.00E+05	GJ	*Placeholder value*	

Notes:

1 Estimated Freight transported. Korea Foreign Trade Association, "Major Economic Indicators for North Korea, 1993". Page 34.

2 Chinese 4-ton truck, "CA-10B", c. 1985, from [Chinese data compendium provided by J. Sinton], p.2.

3 Korea Foreign Trade Association, "Major Economic Indicators for North Korea", page 9.

4 For Pass. Vehicles. From: "Energy and Transport in China" in "Energy Markets and the Future of Energy Demand", LBL, 1988. Chinese data for 1985. Probably high for DPRK.

5 Per 1000 net te-km. From: "Energy and Transport in China" in "Energy Markets and the Future of Energy Demand", LBL, 1988. Chinese data for 1985. Probably a bit low for DPRK.
Russian (1970s) energy intensities for ships fueled with heavy oil are very similar to the Chinese value used. Russian intensities for marine diesel-fueled ships are lower (about 7 kgce/kte) than the value used, but Russian intensities for inland waterways shipping are higher, about 13 kgce/kte. Russian intensities from V. Kalashnikov (personal communication, 9/97).

6 Electric generation efficiency, China, 1981. From "Physical Intensity of Selected Industrial Products" Spreadsheet printout from J. Sinton, LBL.

7 Very rough estimate based on US value for 1989 for commuter rail. From D. Gordon, Steering a New Course: Transportation, Energy, and the Environment, 1991, p.33. NK fuel efficiency is probably lower than US but passenger-km per seat is probably much higher.

8 Korea Foreign Trade Association, "Major Economic Indicators for North Korea", page 37.
9 Rough estimate: DPRK planes assumed to be twice as energy intensive per seat mile as US commercial commuter airlines in 1989 (US data from reference 7).
10 Economist Intelligence Unit, "China, North Korea Country Profile 1992-93"
11 Estimate by recent visitors of cars in Pyongyang, including 4000 Volvo sedans (of which 3000 are operable), and assuming five years worth of imports of approximately 2500 vehicles per year (used, from Japan, also from former East Bloc). Fuel economy assumed to average 25 miles/gallon. Other observers estimate less than 10,000 autos total as of approximately 1990.
12 Fuel use and airspeed is as estimated cor An-24 in Aircraft spreadsheet of Military Energy Use workbook.
13 Assumes that efficiency of gasification of biomass for use as motor fuel is about 50 percent.
14 One observer reports that "most trucks outside Pyongyang are fueled with biomass". Other observers, on the other hand, report few or no biomass trucks in use. We assume 5 percent for 1990.
15 Assumes (based on source 16) that planes that are not jets are An-24s. These are reported to carry 48 to 52 passengers (World-wide Web site "Turkish World Russian Aircraft", http://www.rz.uni.franfurt.de/~puersuen/tac.htm).
16 Federal Research Division, US Library of Congress (1993), North Korea, A Country Study, edited by Andrea M. Savada.
17 Assumes Tu-154s, with a range of 5500 km (source 15) have a fuel capacity similar to that of the Boeing 727 (31,000 liters--data from World-wide Web site http://boeing.com/bck_html/Boe727.html), an aircraft similar in size (the 727 is a few percent lighter) and configuration to the Tu-154.
18 Based on energy intensity of Russian rail freight in the 1970s (V. Kalashnikov, personal communication, 9/97).
19 Based on energy intensity of Russian road freight in the 1970s (V. Kalashnikov, personal communication, 9/97). Note that these values are substantially higher (in the case of gasoline trucks, by a factor of 2) than published Chinese values (for example, see note 2).

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ASSUMPTIONS, BACK-UP CALCULATIONS AND DATA:
TRANSPORT SECTOR ENERGY DEMAND IN 1996, 2000, AND 2005

Prepared By David Von Hippel
Date Last Modified: 3/20/2007

ASSUMPTIONS FOR CHANGES IN TRANSPORT ENERGY USE, 1996, 2000, AND 2005

Sources/Notes:

(See Note 5 for Assumptions for 2000)

Population Growth Rate through 2000:	**-0.14%**	/yr	***(See Note 20 in "Residential" worksheet)***				
Econ. Active. Population Growth Rate 2000-on:	**0.60%**	/yr					*(See Note 22 in "Residential" worksheet)*
			1996	2000	2005	2010	
Economically Active population relative to 1990:			99%	99%	102%	105%	*Calculated*

	1996	2000	2005	2				
Total Road Freight rel. to 1990	30%	15%	20%				%	
Fraction Road Freight, biomass truck	8%	10.0%	10%				%	*8*
Fraction Road Freight, diesel truck	20.0%	36.0%	50.0%				%	*9*
Fraction Road Freight, gasoline truck	72%	54.0%	40%				%	*Calculated*

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

	Activity Relative to 1990					Energy Intensity Relative to 1990				
Subsector--End Use	**1996**	**2000**	**2005**	**2**	**Dec.**	**1996**	**2000**	**2005**	**2 Dec.**	
Road--Freight--Gasoline	30%	11%	11%		%	110%	110.0%	105.0%	%	*2*
Road--Freight--Diesel	25%	23%	42%		%	110%	100.0%	100.0%	%	*2*
Road--Freight--Biomass	48%	30%	40%		%	100%	100%	100%	%	
Road--Civilian Auto Pass-km	100%	90%	115%		%	105%	103.0%	95.0%	%	*10*
Road--Passenger Bus, Diesel	45%	41.0%	41%		%	110%	106.0%	105.0%	%	*3*
Road--Passenger Bus, Gasoline	58%	19%	14%		%	110%	100.0%	100.0%	%	*3*
Rail--Freight, Diesel	40%	30%	31%		%	100%	100%	100%	%	*2*
Rail--Freight, Electric	40%	30%	33%		%	105%	100%	100%	%	*2*
Rail--Passenger, Electric	45%	28%	33%		%	105%	100%	100%	%	*3*
Water--Freight, Diesel and HFO	40%	37%	39%		%	100%	100%	100%	%	*2*
Air--Passenger: Activity levels	80%	75%	100%		%	100%	100%	100%	%	*Assumption*
Air--Passenger: Fraction as Jet Fuel	36%	45%	55%		%					*4*
Non-Specified Transport (Oil/Elect.)	0%	0%	0%		%	100%	100%	100%	%	

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Sources/Notes:

1 US Central Intelligence Agency, "Korea, North". CIA Factbook, 1995 (World Wide Web Version). USCIA, Washington, D.C., USA. 1996.

2 Consistent with general decrease in industrial production

3 Assumes that per-capita passenger transport use decreased to 45 to 60 percent of 1990 due to austerity measures, with the decrease continuing through 2000 before increasing slightly in 2005 (based on the anecdotal observations of visitors to the DPRK).

4 Based on general observations of a decline in air travel through 2000, increasing somewhat in 2001 and 2002, as more international visitors came to Pyongyang in those years, but declining somewhat thereafter to a current level that is similar to that in 1990. It is assumed that a larger fraction of travelers are carried on jet aircraft as opposed to the older propellor-driven DPRK planes.

5 No specific data were available for the transport sector for 2000, so estimates of the parameters in these tables are rough figures based on the experiences of Nautilus staff and others in the DPRK. It is assumed that the use of producer-gas-fueled trucks would increase somewhat as a fraction of overall freight transport, but that the increase would be modest. Visitors to the DPRK have generally noted a modest increase in the use of small "private" cars and mini-vans in the last several years. The use of other vehicles, however, seems to have stayed the same or decreased slightly, thus the slight decrease in vehicle use between 1996 and 2000 relative to 1990. No change in the efficiency of vehicles was assumed between 1996 and 2000, as any efficiency gains through the introduction of a few new vehicles seems likely to be counterbalanced by continuing problems with the availability of spare parts. We saw many disabled trucks along the road in areas not far from Pyongyang.

6 The website http://www.answers.com/topic/north-korea, visited 1/15/07, listed the following as the ships in the DPRK merchant marine as of 2005: "total: 238 ships (1,000 GRT or over) 985,108 GRT/1,389,389 DWT by type: bulk carrier 13, cargo 191, container 2, livestock carrier 4, passenger/cargo 5, petroleum tanker 13, refrigerated cargo 5, roll on/roll off 5 foreign-owned: 52 (China 1, Denmark 2, France 1, Greece 4, Italy 1, Lebanon 4, Lithuania 1, Netherlands 1, Pakistan 2, Romania 10, Russia 2, Singapore 2, South Korea 2, Syria 9, Turkey 6, Ukraine 1, UAE 3).

7 China Customs Statistics reported transport vehicles exports from China to the DPRK as follows for 2000 through 2005. As compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.

ROAD VEHICLES IMPORTS TO DPRK FROM CHINA

Units: Number of Vehicles

Description	HS (code)	2000	2001	2002	2003	2004	2005
MOTOR TRUCKS	8704	770	677	955	1409	2108	2444
PASSENGER MOTOR	8703	1529	629	0	65	145	244
OT SPEC PURPOSE M VEH	8705	75	40	9	10	26	29
MOTORCYCLES	8711	1354	62	30	1	701	3433
TRACTORS,NOT IN 8709	8701	28	47	86	65	234	401
PUB TRANS MV>10PERS	8702	337	233	14	38	82	89
PART/ACCESS 8701-8705	8708	0	0	0	0	0	0
PART,ACCESS 8711-8713	8714	0	0	0	0	0	0
BICYCLES+OTHER CYCLES	8712	12400	4066	53601	1020	7745	12,958
TRAIL,ET,NT MEC PROPL	8716	0	0	0	0	0	0
M VHCL CHASSIS W/ENGN	8706	10	4	16	2	2	24
MOTOR VEHICL BODIES	8707	3	2	6	7	15	38
CARRIAGES FOR DISABLED PERSONS,MOTORIZED OR NOT	8713	200	0	387	132	548	552

RAIL EQUIPMENT IMPORTS TO DPRK FROM CHINA

Units: Number of Vehicles except as noted

Description	HS (code)	2000	2001	2002	2003	2004	2005	
N-S-P RLWAY FRGHT CAR	8606	0	0	53	36	12	176	
LOCOMOTV/R STOCK PRTS	8607	0	0	0	0	0	0	
OT N-EL LCMTV;TENDERS	8602	5	5	13	8	6	7	
RAIL LOCOMOTIVE,ELECT	8601	0	0	3	1	3	12	
RLWAY FXTUR; MECH EQP	8608	83000	83000	83400	61300	80000	57472	*Units: KG*
OT S-PRPL RLWAY COACH	8603	0	0	35	5	47	20	
CONTNR (1+TRANS MODE)	8609	1	1	14	21	4	1	
RLWAY MAINT/SERV VHCL	8604	0	0	0	2	0	2	
N-S-P RWAY PASS COACH	8605	0	0	1	5	0	0	

SHIPS AND BOATS AND RELATED EQUIPMENT IMPORTS TO DPRK FROM CHINA

Units: Number of Vessels except as noted

Description	HS (code)	2000	2001	2002	2003	2004	2005
SHIPS AND BOATS	89	23	0	18	183	1295	59
FISH VESSEL;OTH SHIPS	8902	0	0	1	0	5	11
YCHT & OT PLEAS VESSL	8903	20	38	0	19	51	30
TRANSPORT PERSON/GOOD	8901	1	0	4	0	0	4
TUGS AND PUSHER CRAFT	8904	1	0	0	0	0	0
LGT-VESS,FL DOCKS ETC	8905	0	0	0	0	0	0
OT VESSEL,N ROW BOATS	8906	1	0	13	4	9	7
OT FLT STRUCT,RFT,ETC	8907	0	0	0	160	1230	7

Note: Based on their reported value of $1.45 million US, the four "transport person/goods" vessels imported by the DPRK in 2005 seem likely to be fairly large vessels.

8 Anecdotal reports indicate that the use of biomass-fueled (gasifier-using) trucks remain very common in some areas of the DPRK, even in the years 2000 - 2005.

9 Visitors to the DPRK, including the authors, have noted an increase in the number of imported, mostly diesel, trucks in use in the DPRK. Increasing imports of trucks from China from 2001 through 2005 reinforce these observations.

10 Visitors to the DPRK, including the authors, have noted an increase in the number of imported automobiles in recent years. This observation is reinforced by the import statistics above. We assume that these vehicles are more efficient, on average, than the older vehicles (a declining percentage of them DPRK-made) in the DPRK automobile fleet, thus the improvement in energy intensity that is assumed over time. The increase in the number of imports of motorcycles noted above also supports this trend in efficiency improvement (gasoline use by private motorcycles is reported in the same row as gasoline use in private autos).

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
RESIDENTIAL SECTOR ENERGY DEMAND

Prepared By David Von Hippel
Date Last Modified: 3/20/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

					Sources/Notes:
Estimate of Rural and Urban Households					
Total DPRK Population	2.20E+07				*1*
Military Personnel	1.20E+06				
Population in Households	2.08E+07				
Urban HH pop. fract	60%				*1*
Rural HH pop. fract	40%				*1*
Persons/HH, Urban	4.65				*4*
Persons/HH, Rural	4.65				*3*
Number of Urban HH	2,683,871				
Number of Rural HH	1,789,247				
Coal Use: Urban Households					
Fraction Using Coal:	100%				*5*
Average HH Dwelling Size	50	sq. meters			*19*
Te coal per HH/yr	2.20				*19*
GJ/Te Coal	24				
GJ Coal Use/HH	52.74				
Total Coal Use, Urban HH		1.42E+08	GJ/yr		
Coal Use: Rural Households					
Fraction Using Coal:	50%				*6*
Te coal per HH/yr	2.8				*2, 26*
GJ/Te Coal	24				*7*
GJ Coal Use/HH	67.2				
Total Coal Use, Rural HH		6.01E+07	GJ/yr		
Electricity Use: Urban Households					
Fraction Electrified HH:	100%				*8*
MWh per HH/yr	0.768				*9*
GJ/MWh	3.6				*10*
GJ Electricity Use/HH	2.7648				
Total Electricity Use, Urban HH		7.42E+06	GJ/yr		
Electricity Use: Rural Households					
Fraction Electrified HH:	100%				*8*
MWh per HH/yr	0.512				*9, 24*
GJ/MWh	3.6				*10*
GJ Electricity Use/HH	1.8432				
Total Electricity Use, Rural HH		3.30E+06	GJ/yr		
Oil Use: Urban Households					
Fraction using LPG/Kero:	25%	(for Cooking)			*11*
te per HH/yr	0.21				*12*
GJ/te	44.4				*13*
GJ LPG/Kero Use/HH	9.324				
Total LPG/Kero Use, Urban HH		6.26E+06	GJ/yr		
Oil Use: Rural Households					
Fraction using LPG:	2%	(for Cooking)			*30*
te per HH/yr	0.22				
GJ/te	44.4				
GJ LPG Use/HH	9.6				
Total LPG Use, Rural HH		3.44E+05	GJ/yr		

Charcoal Use: Urban Households				
Fraction Using Charcoal:	10%	(for Cooking--specialty foods)		*16*
Te Charcoal per HH/yr	0.15			*17, 27*
GJ/Te Charcoal	28.8			*18*
GJ Charcoal Use/HH	4.224			
Total Charcoal Use, Urban HH		1.13E+06	GJ/yr	
Charcoal Use: Rural Households				
Fraction Using Charcoal:	12%	(for Cooking--specialty foods)		
Te Charcoal per HH/yr	0.15			*29*
GJ/Te Charcoal	28.8			*18*
GJ Charcoal Use/HH	4.32			
Total Charcoal Use, Rural HH		9.28E+05	GJ/yr	
Wood/Biomass Use: Rural Households				
Fraction Using Wood/Biomass:	48%	(all End Uses)		*6*
Te Wood/Biomass per HH/yr	6.6	(Dry basis)		*14, 28*
GJ/Te Wood/Biomass	15.25			*15*
GJ Wood/Biomass Use/HH	100.3			
Total Wood/Biomass Use, Rural HH		8.61E+07	GJ/yr	

1996, 2000, AND 2005 ENERGY USE IN RESIDENTIAL SECTOR

Growth in total number of households	-0.14%	/yr (1990 to 2000 Estimate)			*20*
	0.60%	/yr 2000-on			*22*
Fraction of Households as:	**1996**	**2000**	**2005**	**2**	.
Urban	60%	57%	55%		% *21*
Rural	40%	43%	45%		% *21*
Number of Households					
Urban	2,660,581	2,512,903	2,502,661		
Rural	1,773,721	1,895,699	2,047,632		

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Coal Use per Household relative to 1990:	**1996**	**2000**	**2005**	**2**	.
Urban	55%	45%	50%		%
Rural	50%	40%	40%		%
Electricity Use per Household relative to 1990:	**1996**	**2000**	**2005**	**2**	.
Urban ***(See Notes 23, 31)***	65%	32%	53%		%
Rural ***(See Notes 24, 31)***	50%	10%	15%		%
Wood/Biomass Use per Household rel. to 1990:	**1996**	**2000**	**2005**	**2**	.
Rural	120%	120%	120%		%
Charcoal Use per Household rel. to 1990:	**1996**	**2000**	**2005**	**2**	.
Urban	75%	60%	60%		%
Rural	75%	60%	60%		%
Kero/LPG Use per Household rel. to 1990:	**1996**	**2000**	**2005**	**2**	.
Urban	30.0%	44%	43.0%		%
Rural ***(See Note 25)***	25.0%	80%	75.0%		%

Sources/Notes:

1 from document in authors' files [HT1].

2 From document in authors' files [FC1]. Average figure based on figure for use in a central area of DPRK.

3 Value for Ongjin area (southern DPRK) from document in authors' files [FC1]. Value is similar to estimates given for rural areas in the central and northern regions of DPRK.

4 Assumed same as rural value.

5 Assumes all urban households, most in multi-unit concrete buildings, use coal for space heating. Urban households also, except in Pyongyang, use coal for cooking. From document in authors' files [R1].

6 Fractions cited for three different areas of DPRK, from document in authors' files, vary from 8 to 50% coal use. Other observers of the DPRK situation suggest that the fraction of coal use in rural households as of 1990 or so was higher, perhaps 60%. We use an estimate of 50% as an estimated national average.

7 From document in authors' files [FC1]. This value may be somewhat high.

8 Document in authors' files [HT1, p. 14], says "government reports that 100 percent of homes and industry are electrified".

9 Estimated based on 1.6X (rural) and 2.4X (urban) 1975 value for per household consumption of electricity in the Republic of Korea, as derived from pp. 121, 90, and 102 of "The Electric Future of Korea" East-West Center, September, 1983. At these levels, total sectoral energy use is approximately 10% of total national electricity consumption, as suggested in UNDP "Project of the Government of DPRK: Electric Power Management System".

10 Unit conversion (3600 kJ/kWh), no generation losses included.

11 From document in authors' files [FA1]. This source notes that cooking in (apparently Pyongyang) is by LPG or Kerosene stoves. Figure shown assumes that that petroleum-based fuels are rarely used outside Pyongyang, and that the 1990 population of Pyongyang is approximately 3.2 million (Microsoft Encarta lists a 1984 estimate of 2.64 million, Korea Foreign Trade Association lists 3.288 million for 1990)).

12 Estimated assuming petroleum product stoves have on average 50 percent of the energy intensity of wood stoves, and that wood use for cooking is approximately 19.2 GJ/HH-yr (estimate from Kumgang area, as given in from document in authors' files [FC1].

13 Rough ave. assuming fuel is 50% LPG (at approx. 45.5 GJ/te) and 50% Kerosene (at approx. 43.3 GJ/te)

14 Original value (earlier versions of analysis) based on est. (13.7 te/HH-yr) from Kumgang area, as given in document in authors' files [FC1].

15 Based on average of values for wood (16 MJ/dry kg) and crop residues (14.5 MJ/kg), source as in 14)

16 Placeholder estimate.

17 Originally assumed heat energy requirements as for wood-fired rural cooking, but assumed fuel input per unit heat supplied to the cooking vessel was two-thirds that for wood stoves (original value 0.44 tonnes/HH-yr). Assumption has changed based on input from observers--see note 27.

18 Based on value used in LEAP (SEI-B) default data set (which is based on international sources)

19 Based on Chinese figure of 30 kgce/sq.m.-yr for centrally-heated residential buildings, and a rough average dwelling size of 50 sq. meters (from in-country observations by visitors to DPRK). An alternative "typical" dwelling size estimate of 120 sq. meters (from document in authors' files [FA1]. would seem to be large based on Chinese figures, which show less than 10 square meters/person ("Energy Use and Conservation in China's Residential and Commercial Sectors: Patterns, Problems, and Prospects", by Feng Liu, LBL, March, 1993.). Per-unit floor area figure from China increased by 20 percent to account for more severe weather, on average, in DPRK.

20 US Central Intelligence Agency, "Korea, North". CIA Factbook, 2001 (World Wide Web Version). USCIA, Washington, D.C., USA. 2001, http://www.odci.gov/cia/publications/factbook/geos/kn.html lists a 2001 estimated growth rate of 1.22 %/yr and a total population of just under 22 million. The USDOE Energy Information Administration lists a year 2000 population of 21.7 million in its North Korea Country Analysis Brief (www.eia.doe.gov/emeu/cabs/nkorea.html, visited 5/2002). A file of "DPRK Energy Data" provided to Nautilus by the Korea Energy Economics Institute (KEEI, 2002) suggests a year-2000 population of 22.175 million and a growth rate of 0.4 percent annually (with the growth rate decreasing substantially between 1990 and 2000), but uses a year-2000 base population of 20.221 million for the DPRK. While recognizing the extreme difficulty in estimating DPRK population, we continue to assume that year 1990 population was 22 million (as official estimates suggest) and adopt the figure provided by USDOE EIA as the year 2000 population. This suggests a modest decrease in population over the decade which is certainly consistent with food shortages and anecdotal but fairly widespread evidence of lack of proper food rations, as well as medical care, for the DPRK populace.

21 Assumption. There have been reports of forced migration from the cities to the rural areas, but none have been confirmed. World Bank projections suggest continued rural-to-urban migration. The overall pattern of migration remains undocumented. There is anecdotal evidence that residents of cities in the North of the DPRK, for example, are leaving for the countryside where they can forage, rather than remain in cities where food distribution is sporadic at best. We assume that there has been at least a modest net migration from urban to rural areas.

22 This lower population growth assumption represents an attempt on our part to take into account the effects of the food shortages of the 1990's on future population growth in the DPRK, but assumes that there would be at least a modest improvement in the food situation. Historical (pre-1990) population growth rates had been near 2 percent annually.

23 Visitors to the DPRK in 2000 describe electricity in Pyongyang as being generally available, but electricity in at least major portions of other cities being largely unavailable. Based on Korea Trade-Investment Promotion Agency (KOTRA) data (from http://www.kotra.or.kr/main/info/nk/eng/main.php3, visited 6/3/02) that lists the population of Pyongyang as 3.4 *million, assuming, based roughly on a record of of electrical outlet voltage collected in Pyongyang and covering most of 2000, that Pyongyang suffered from blackouts for about* 20% *of 2000, and further assuming that residents of cities other than Pyongyang had power only* 14% *of the time, we estimate that the average consumption of power per household was about* 32% *of that in 1990.*

24 Nautilus Institute's rural energy survey in the village of Unhari, (as reported on in "A RURAL ENERGY SURVEY IN UNHARI VILLAGE, THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK): METHODS, RESULTS, AND IMPLICATIONS", Asian Perspectives special issue, 2002.), suggested an annual average usage of 390 kWh per household per year, fairly close to the 1990 value estimated above. During our mission to Unhari in 2000, we determined that householders virtually never had electric power available in their homes during the day, especially in the winter months. As Unhari is relatively close to Pyongyang, it is our expectation that the situation there is likely, if anything, to be better than that in other rural areas. We therefore assume that the lack of availability of power limited rural residents to 10% *of 1990 levels of electricity consumption in the year 2000.*

25 Oil use in rural households increased for 2000 relative to 1996 to reflect more use of kerosene and diesel oil for lighting during the bulk of the year, when electricity for lighting is unavailable. On a national basis, the per-household rural oil consumption estimate shown here is approximately the same as that estimated for Unhari village (see reference in Note 24) based on a survey done in 1998. Other areas probably had less access to fuel supplies than Unhari, on average, but rural electricity availability in 2000 was worse than in 1998.

26 In earlier versions of this analysis, a much higher estimate of coal use per household (9 tonnes) was used. The results of the Nautilus Unhari survey, and input from recent DPRK visitors, have suggested that a substantial revision to this assumption is in order. Therefore, an average of 2.8 tonnes coal/HH year is assumed for households in rural areas in 1990 using coal (exclusively or nearly so) for cooking and heating. This is consistent with estimates from other documents in the authors files, and is consistent with the 2 tonnes/yr finding in (relatively temperate) Unhari, given that the Unhari survey was taken in 1998/2000, when supplies were not as adequate as in 1990 (by residents' estimation).

27 Initial assumption (in previous versions of analysis) for charcoal use in urban households reduced based on input from residents and recent visitors to the DPRK that charcoal use in urban households is not routine.

28 Initial assumption (in previous versions of analysis) for wood/biomass use in rural households reduced based on input from recent visitors and consideration of results of Unhari survey suggesting that coal use per household is lower than previously thought (see note 26 in this worksheet). The revised figure shown is calculated assuming that wood/biomass burns approximately 67% *as efficiently as coal, and takes into account the difference between the energy contents of coal and biomass fuels. By way of comparison, annual estimates of per-household woood/biomass fuel use in rural households vary from 9 to 13 or so tonnes per HH year, but in many cases the mass basis (wet or dry) of the biomass input was not specified (document in author's files).*

29 Assumed approximately the same as in urban households.

30 Assumed, based on input from observers, to be quite low, even in 1990.

31 Observers suggest that electricity supplies to residences and public/commercial buildings in the DPRK have improved somewhat by 2005, relative to 2000, though improvements, and the number of hours per day that residents can expect to have electricity services, vary substantially by region of the country, by proximity to power plants, and by time of year (allocation of electricity varies in seasons when agricultural uses have priority, and availability of *electricity varies seasonally as water flows affect hydroelectric output). Observers have reported levels of electricity availability ranging from an hour or two per day (intermittently) to nearly 24 hours per day.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
AGRICULTURAL SECTOR ENERGY DEMAND

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

				Sources/Notes:
Oil Use in Agricultural Sector				
Total Area of Field Crops:	1.70E+06	ha		*1*
Average Diesel use	41	l/ha		*2*
Conversion Factor	1149	l/te		
Conversion Factor	43.17888	GJ/te		
Oil Use: Agric. Machinery	2.62E+06	GJ		
Electricity Use in Agricultural Fields				
Total Area of All Crops:	2.00E+06	ha		*3,4*
Average electricity use	126	kWh/ha		*2*
Conversion Factor	0.0036	GJ/kWh		
Electricity Use: Agric./Fields	9.07E+05	GJ		
Coal Use: Processing/Other				
Area of Rice Cultivation	6.50E+05			*4*
Total Agr. Coal Use	1.50E+01	GJ/ha rice		*7*
Processing/Other Coal Use	9.75E+06	GJ		
Oil Use: Processing/Other				
Total Agr. Oil Use	7.70E+00	GJ/ha rice		*7*
Oil Use in Agric. Machinery	2.62E+06			
Net Oil Use, Processing/Other	2.39E+06	GJ		
Electricity Use: Processing/Other				
Total Agr. Electricity Use	4.44E+02	kgce/ha rice		*7*
Conversion Factor	4.04E+02	kgce/MWhe		
Conversion Factor	3.60E+00	GJ/MWHe		
Electricity Use: Agric./Fields	9.07E+05	GJ		
Net Elect Use, Processing/Other	1.66E+06	GJ		*9*
Wood/Biomass Use: Processing/Other				
Grain straws used in Crop drying	3.00E+06	te		*5*
Conversion Factor	14.5	GJ/te		*6*
Grain brans used in crop drying	1.00E+05	te		*5*
Conversion Factor	14.5	GJ/te		*6*
Wood used in Agricultural Sector	0		*No data*	
Conversion Factor	16	GJ/te		*6*
Total Wood/Biomass Use:	4.50E+07	GJ		

ESTIMATE OF CURRENT AND FUTURE ENERGY USE IN AGRICULTURAL SECTOR

(Notes 10, 15)

	1996	2000	2005		
Area Cropped Relative to 1990:	100%	100%	102%		*Assumption*
Use of Tractors, etc. Relative to 1990:	30%	25%	18%		*8*
Use of Electricity in Fields Relative to 1990:	90%	75%	65%		*11*
Coal Use, Processing/Other, Rel. to 1990:	53%	39%	51%		*8*
Oil Use, Processing/Other, Rel. to 1990:	30%	25%	18%		*8*
Elect. Use, Processing/Other, Rel. to 1990:	53%	37%	51%		*8*
Biomass Use, Processing/Other, Rel. to 1990:	53%	44%	54%		*8*

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Sources/Notes:

1 Total reported cropped area less fruit orchards (300,000 ha), which are assumed to be relatively less energy intensive to operate. From document in authors' files [KJ1, p. 7].

2 P.81: F Liu et al, "An Overview of Energy Supply and Demand in China", LBL, May 1992.

3 Assumption is that most electricity use will be for irrigation.

4 Crop area. From document in authors' files [KJ1, p. 7].

5 From document in authors' files [HT1, p. 10].

6 From document in authors' files [FC1, p. 7]. Air dried wood.

7 Based on 1987 Chinese values. Agricultural coal use from J. Sinton, Ed, "China Energy Databook 1992" (Revised June 1993), LBL, page IV-56. Rice area in China from FAO.

8 Intensity of fuels use relative to 1990 values (for example, use of field machinery per hectare).

9 On a per hectare of rice basis, the sum of the "field" and "other" electricity consumption estimates shown here are very similar to the approximately 3.6 GJ per ha of rice estimated during Nautilus' 1998 and 2000 rural energy survey in Unhari village, the DPRK, as (as reported in "A RURAL ENERGY SURVEY IN UNHARI VILLAGE, THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK): METHODS, RESULTS, AND IMPLICATIONS", Asian Perspectives special issue, 2002.).

10 Estimates of fuel use in 2005 and 2000 relative to 1990 are subjective, and are based on observations by Nautilus and others who have visited farms in the DPRK. Typically, supplies of electricity and coal seem to be provided to farms at a priority to other sectors during the growing and harvest seasons, so supplies of those fuels are barely sufficient to accomplish the necessary threshing and milling, but motor fuel supplies are considerably less than in 1990, so that tractors are used only for essential purposes, and much more labor is done by hand. This is probably even more the case in more remote areas of the country. The lack of spare parts for tractors and trucks also diminishes demand for motor fuels. Electricity use for agriculture is assumed to be slightly higher in 2000 than in 1996 because, though availability of electricity for agricultural requirements are similar, intensity per unit of output is assumed to be higher due to a lack of access to spare parts and a lack of other fuels for support vehicles (thus decreasing overall efficiency). One observer of DPRK energy use has suggested that mechanized inputs to agriculture may have fallen by over 85 percent from 1990 to 2005. Other observers report increased use of manual and animal labor in the fields, including the transfer of office and factor workers, students, others from the cities in 2005 in larger numbers than in previous years to help bring in the harvest. We have loosely interpreted this anecdotal information to point to a continued decline in diesel fuel for tractors and other farm implements, with the result being that oil use in agriculture was 20 percent of 1990 levels by 2005. For related analysis, see also Hugh Bentley, "Trends in the DPRK Agricultural Sector & Implications for Energy Use", as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). This presentation is available as http://www.nautilus.org/DPRKEnergyMeeting/papers/Bentley.ppt.

11 An article in KCNA in English (Pyongyang), dated 14 March, 2005, and entitled "Kaechon-Lake Thaesong Waterway Pays Off", suggests that the waterway carried 100 million cubic meters of water over two years, and displaced more than 500 water pumps that "had to consume more than 60,000 kW of electricity a year to supply needed water to [the areas served]. Assuming that this note referred to the power input to the displaced pumps as 60 *MW, and assuming an annual average capacity factor for those pumps of about* 20% *this implies a displacement of* 105.12 GWhrs, or 3.78E+05 GJ of electricity, about 42% *of estimated field use of electricity in 1990. On this basis we decrease estimated use of electricity in 2005, but by somewhat less than this estimate, assuming that there may still be additional pumping from the new aqueduct into the fields, and assuming that the KCNA article may present a somewhat optimistic account of the impacts of the waterway.*

12 China Customs Statistics reported imports of meat to the DPRK from China (meat imports were 90% pork by 2005) had increased more than 20-fold (by weight), on average, between 1995-1997 and 2003-2005. This may be indicative of continued decline in DPRK agricultural production. Import data as compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.

13 China Customs Statistics reported imports of fertilizers to the DPRK from China were 92,494 te in 2003 60,804 *te in 2004, and* 67,838 *te in 2005. 95 percent or more of these imports were in the "nitrogeneous fertilizer" category (HS # 3102). DPRK fertilzer imports from China appear to vary considerably by year, but the average imports for 2003 - 2005 was about five times the average imports in 1995 - 1997. Source as in Note 12, above.*

14 China Customs Statistics include reports of the following agricultural exports from the DPRK to China in 2005:

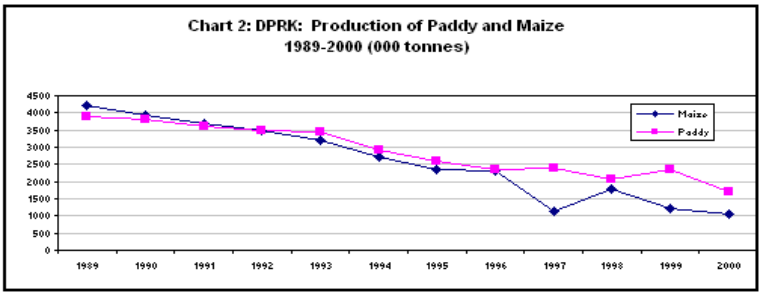
HS #	*Description*	*Tonnes*
12	MISC GRAIN,SEED,FRUIT	20,948
08	EDIBLE FRUIT AND NUTS	5,479
78	LEAD	4,666
14	OTHER VEGETABLE	3,903
07	VEGETABLES	1,912

The same compendium also notes exports from the DPRK to China of about 35 million live animals (types not specfied), up from about 21 million in 2004 and 7.8 million in 2003.
Source as in Note 12, above.

15 Coal and biomass use in crop drying, and electricity used in crop processing, are assumed to be roughly proportional to annual cereal-equivalent harvests, based on the following output statistics:

Year	Million tonnes cereal Equivalent production
1990	6.940
1996	4.077
2000	3.421
2005	4.129

Value for 1990 is estimated based on data from Chart 2 (shown below) in FAO GLOBAL INFORMATION AND EARLY WARNING SYSTEM ON FOOD AND AGRICULTURE and WORLD FOOD PROGRAMME, SPECIAL REPORT FAO/WFP CROP AND FOOD SUPPLY ASSESSMENT MISSION TO THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA, dated 16 November 2000. The ratios of 1990 and 1996 total paddy and *maize production were used with the 1996 value for cereal equivalent production below to create an estimated value for 1990 consistent with the other values in the time series shown in the table.*
Values for 1996 and 2000 are from page 17 of UN Food and Agriculture Organization and the World Food Programme, SPECIAL REPORT, FAO/WFP CROP AND FOOD SUPPLY ASSESSMENT MISSION TO THE DEMOCRATIC *PEOPLE'S REPUBLIC OF KOREA, dated 30 October 2003, and available as http://www.nautilus.org/DPRKBriefingBook/agriculture/fao-dprk-30oct.pdf*
Value for 2005 is from Randall Ireson, Food Security in North Korea: Designing Realistic Possibilities, dated February 2006, published by the Walter H. Shorenstein Asia-Pacific Research Center. Freeman Spogli Institute for International Studies, Stanford University, and available as http://iis-db.stanford.edu/pubs/21046/Ireson_FoodSecurity_2006.pdf. Table 2.



In addition, coal, electricity, and biomass use in processing per unit crop harvested were assumed to have decreased somewhat relative to 1990, due to lack of availability of fuel and other factors, as follows:

Coal Use, Processing/Other, Rel. to 1990:	90%	80%	85%
Elect. Use, Processing/Other, Rel. to 1990:	90%	75%	85%
Biomass Use, Processing/Other, Rel. to 1990:	90%	90%	90%

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
FISHERIES SECTOR ENERGY DEMAND

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

Sources/Notes:

Oil Use: Large Ships

Estimated Inventory of DPRK Larger Fishing Vessels (~1990s)

Average Displacement (tonnes)	Average Horsepower	Number	Description	*Composite estimate based on sources 1, 4, and 6*
10,000	2,250	8	Large Factory Ships	
485	400	554	"Multi-purpose"	
60	100	776	"Trap-fishing"	
200	200	215	Others (estimate)	
438,250	360,200	1,553	Total	

Total Engine horsepower of Larger Ships		360,200		*See above*
Average days at sea		200		*Estimate, consistent with data in 1 for collectives*
Operating hours/day		12		*Estimate*
Fraction of Ships in operation (as of 1990)		85%		*Estimate*
Average fraction of full power while operating		50%		*Estimate*
Total fishing fleet power use	3.67E+08	hp-hours		
Fuel consumption rate	0.18	kg/hp-hr		*7*
Conversion Factor	1.032	kg Diesel/kgoe		*From "Oil" Worksheet in this Workbook*
Conversion Factor	0.04184	GJ/kgce		
Total Oil Use, Larger Ships	2.68E+06	GJ		
Fraction of Oil Use as Diesel	95%			*Calculated*
Fraction of Oil Use as Heavy Fuel Oil	5%			*Assumes only large factory ships use Heavy Fuel Oil*
Diesel Oil Use in Large Ships	2.55E+06	GJ		
Heavy Fuel Oil Use in Large Ships	1.34E+05	GJ		

Oil Use: Fishing Collectives — *Placeholder estimate*

Number of fishing collectives	284			*5*
HP of motors on boats per collective	76			*8*
Average days at sea		200		*Estimate, consistent with data in 1 for collectives*
Operating hours/day		12		*Estimate*
Fraction of boats in operation (as of 1990)		75%		*Estimate*
Average fraction of full power while operating		25%		*Estimate*
Total collectives fishing fleet power use		9.71E+06	hp-hours	*Calculated*
Fuel consumption rate	0.2	kg/hp-hr		*Assumed somewhat higher than for larger boats*
Diesel Oil Use in Fishing Collectives	7.88E+04	GJ		

Oil Use: Processing/Other				*no data*
Fisheries product output, total	2.20E+06	tonnes		*1990 value from Table 2 from FAO source in note 6*
Fraction of product processed	60%			*Rough Estimate, assumes some not processed or minimally processsed*
Fuels consumption per unit output	1.14	GJ/tonne		*9*
Fraction of fuels consumption as heavy oil		15%		*Fough Estimate*
Fraction of fuels consumption as diesel oil		10%		*Fough Estimate*
Fraction of fuels consumption as coal		75%		*Fough Estimate*
Electricity Consumption per Unit output		110.32	GJ/tonne	*9*
	or	0.40	GJ/tonne	*9*
Heavy Oil Use, Processing/Other	2.26E+05	GJ		*Calculated*
Diesel Oil Use, Processing/Other	1.51E+05	GJ		*Calculated*
Total Oil Use, Fisheries Sector	3.14E+06	GJ		*Calculated*
Coal Use: Ships	0.00E+00	GJ		*no data*
Coal Use: Processing/Other	1.13E+06	GJ		*Calculated*
Total Coal Use, Fisheries Sector	1.13E+06	GJ		*Calculated*
Electricity Use: Processing/Other	5.24E+05	GJ		*Calculated*
Total Electricity Use, Fisheries Sector	5.24E+05	GJ		*Calculated*

ESTIMATE OF CURRENT AND FUTURE ENERGY USE IN FISHERIES SECTOR

(See Note 3)

	1996	2000	2005	2	
Large Ships Fishing Effort Relative to 1990:	30%	25%	28%		*Assumption*
Fishing Collectives Fishing Effort Relative to 1990:	30%	25%	28%		*Assumption*
Oil/Coal Use, Processing/Other Relative to 1990:	45%	37%	40%		*Assumption*
Elect. Use, Processing/Other Relative to 1990:	45%	37%	40%		*Assumption*

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS

Sources/Notes:

1 From document in authors' files [IF1].

2 Chinese data, c. 1990. From p. 23: "Energy of China, 1993" [provided by J. Sinton of LBL--Chinese language].

3 The Korea Trade-Investment Promotion Agency (KOTRA) suggests that DPRK marine products catch decreased substantially between 1996 and 1997, but increased somewhat between then and 2000. KOTRA data (from "Agriculture, Forestry, and Marine Products industries", available through http://www.kotra.or.kr/main/, visited 6/3/02) lists 1996 output of .876 million tonnes, and 1999 output of .664 million tonnes. A web page on "North Korea's Foreign Trade in 2000" from the same site listes the value of marine exports as having increased 9.4 % between 1999 and 2000. If all fisheries production tracked export earnings (which is not necessarily the case, but assumed for the sake of argument here), the implied ratio of fisheries output between 1996 and 2000 is 83% . We further assume that fisheries effort (as reflected in fuel use) is proportional to fisheries output. Alternatively, end of 1999 data based on the Economic and Social Comparison between the Two Koreas , published by the National Statistics Administration (December 2000) and provided on http://www.koreascope.org/english/sub/1/index3-h.htm, suggest that the DPRK fish catch in 1999 was 45.70% of the catch in 1990. This figure is very close to the 42 percent figure shown above. Further, data from source 6, below, shows 1996 total marine products production as 45% of 1990 production, but also shows a marked shift in production, with 68 percent of output from "marine capture" in 1989, to only 32 percent in 1996 (with the remainder being from aquaculture, 99% of which was marine aquaculture. Since marine aquaculture seems likely to require significantly less energy for boats and ships than "marine capture", we estimate that 1996 energy use for fishing was 30% of 1990 energy use, and that 1996 energy use for processing and other fisheries sector energy use was reduced by the same amount as fisheries output was reported to decrease between 1990 and 1996. For 2000, the ratio shown above between 2000 and 1996 marine products output was used to scale energy use. The ROK Ministry of Unification site http://www.unikorea.go.kr/en/index.jsp includes a listing of fisheries output suggesting that total marine products production in the DPRK had increased to 1.16 million tonnes by 2004, a significant jump from 2002 and 2003 (0.81 and 0.84 million tonnes). Pending receipt of 2005 information, we assume that fisheries output in 2005 was slightly lower than that in 1996.

4 The document Seoul T'ongil Kyongje , dated January 2002, pages 38-50, is an article by Hong Mi-ri entitled "North Korean Industries (Part IX): Fisheries Industry". This article includes the following information about the DPRK fishing fleet: As of 1988, 30,600 boats, of which 21,000 were motorized. Of about 1540 primary fishing boats, 766 were 30 to 100-ton "trap-fishing boats", 554 were "multipurpose" vessels of 450-485 tons, and 8 large vessels in the 10,000-ton class (80 meters or more long, 2250 horsepower). The percentages of the fleet in various categories as given in the article (trap fishing boats 60.0 % of total) do not quite match the totals provided, but are close. The article states that "recent, unofficial information" suggests that only 400 of 1400 "relatively large motorized fishing boats" were operable due to "fuel shortages, faulty equipment, supply difficulties, engine problems, and such things."

5 The document cited in Note 4 describes DPRK fisheries production in 1984 as 1.65 million tons, and 1.78 million tons in 1993, but falling to 0.698 million tonnes by 2000. The document describes 284 fisheries cooperatives of 70 - 100 households, owning 20 to 70 boats each. The document also estimates that no more than 10 percent of the West Coast production potential is being used, and "the operation rate of fishing and processing facilities on the east coast is only at about 30 percent". Cooperatives in 1998 are described as having 1500 motorized fishing boats, and 4000 non-motorized vessels, which is roughly consistent with information in Reference 1, above.

6 The document WORKING PAPER 6, DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA REPORT OF THE FISHERIES DEVELOPMENT PROGRAMMING MISSION, prepared for the Food and Agriculture Organization of the United Nations, dated November 1998, and available as http://www.fao.org/docrep/field/383547.htm#P108-15868, includes (as Table 1) a listing of the larger fishing boats in the DPRK fleet. This table is reproduced below. Some figures in this table correspond generally with the data from source 4, above, though there are some discrepencies (in particular, the 8 largest ships in the DPRK fleet are reported in various sources as 3750, 10,000, and 10,000 - 14,000 tonnes displacement) the reference in the table below to 1545 boats probably is meant to be a total number for all of the categories except the first.

Number of mechanized fishing boats classified by length and size of engine

Displacement Tonnage	Gross tons	Length (Metres)	HP of the Engine	Number
3 750	2 759	83	2 250	8
485	267	39	400	1 545
270	150	33	400	
140	77	23-25	200	
84	44	20-23	200	
30	18	16-18	30	

Original source for table cited:Ministry of Fisheries (DPRK)

7 Fuel consumption rate for diesels is assumed to average 0.18 kg/hp-hr, which is slightly higher than the (approximately) 1985 value for diesel-fueled boats in China cited on p. 18-6 in the chapter "Energy and Transport in China" in the document Energy Markets and the Future of Energy Demand, by Lawrence Berkeley National Laboratory (LBNL, USA), 1988. This figure is also similar to the fuel consumption estimate used for military ships elsewhere in this analysis.

8 Source 1 lists small collectives as having 150 member, and 2 boats with 28 hp engines plus 5 boats with 4 hp engines per collective. This is consistent with the lower end of the "20 - 70" boats per collective estimate provided in note 5, above, assuming that many boats counted in the total are not motorized.

9 In the document Improving Energy Use and Productivity in West Coast and Alaskan Seafood Processing Plants, by Greg Kelleher, Edward Kolbe, and Greg Wheeler (2001), the authors provide estimates of fuel consumption and output for five Alaskan seafood processing plants. The document is available as http://seagrant.oregonstate.edu/sgpubs/onlinepubs/t01004.pdf. Based on data in tables 1 and 2 of this document, per-unit output consumption of electricity and fuel oil can be calculated as follows:

Electricity Use	3.41	GWh (5 plants)
Fuels Use (oil, LPG)	33502	Million Btu (5 plants)
Output average	13.6	million lbs/yr per plant, or
	0.031	Million Te total
Implied electricity use per te output:	110.32	kWh.
Implied oil use per te output:	1,143,502	kJ.

The application of these intensities to the DPRK situation is admittedly inexact at best. Although Alaskan seafood processors certainly handle some of the same types of seafood as were and are handled in DPRK facilities, the compositions of the product lines will certainly be different (in fact, probably change year-to-year). Moreover, Alaskan seafood processing facilities are doubtless more efficient than DPRK facilities, but are also likely to be much more highly mechanized. As a result, these figures for electricity and thermal energy use, as applied to the DPRK situation, should be considered as initial estimates only, to be confirmed with better estimates when available.

10 China Customs Statistics report that the DPRK imported 5 fishing boats in 2004, and 11 in 2005. Based on the value of these shipments, however (and assuming that both the quantities and values reported in the China Customs Statistics are complete), these vessels, with average costs of $600 (2005) to $6000 (in 2004) US dollars each, would likely have been small in size. Import/export data as compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
BACK-UP CALCULATIONS AND DATA:
PUBLIC/COMMERCIAL SECTOR

Prepared By David Von Hippel
Date Last Modified: 3/12/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

				Sources/Notes:
Coal Use: Public/Commercial Sectors				
Urban Residential Floor Space:	1.34E+08	sq.m.		
Ratio of Res. Urban to Pub/Comml Space	29.60%			*1*
Commercial Floor Space	3.97E+07	sq.m.		*4*
Coal Use intensity	33	kgce/sq.m.		*2*
Conversion Factor	0.0293	GJ/kgce		
Total Coal Use, Public/Commercial Sectors	3.84E+07	GJ/yr		
Oil Use: Public/Commercial Sectors	1.92E+05	GJ/yr		*No Data*
Electricity Use: Public/Commercial Sectors				
Electricity Use intensity, Buildings	27.5	kWh/sq.m.		*3*
Conversion Factor	0.0036	GJ/kWh		
Electricity Use in Buildings	3.93E+06	GJ/yr		
Other Electricity Use, Public/Commercial	7.00E+06	GJ/yr		*5*
Total Elect. Use, Public/Commercial Sectors	1.09E+07	GJ/yr		
Wood/Biomass Use: Public/Commercial Sectors	1.92E+06	GJ/yr		*10*

ESTIMATE OF CURRENT AND FUTURE ENERGY USE IN PUBLIC/COMMERCIAL SECTORS
(See Note 8)

	1996	2000	2005	2			
Public/Commercial Floor space per unit residential floor space relative to 1990:	100%	95%	95%				*7*
Public/Commercial Floor space (sq.m.)	3.94E+07	3.53E+07	3.52E+07				7
Coal use per square meter relative to 1990:	75%	45%	40%				*12*
Elect. use per square meter relative to 1990:	55%	32%	44%				*13*
Other Public/Comm'l elect use rel to 1990.	55%	32%	44%				*13*
Wood/Biomass Use as a fraction of coal use:	10%	20%	30%				*10*
Oil use as a fraction of coal use:	0.5%	0.5%	1.5%	1.0%	1.0%	1.0%	*11*

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Sources/Notes:

1 Ratio of all commercial to urban resid. floor area, heating zone of China, 1989. From "Energy Use and Conservation in China's Residential and Commercial Sectors: Patterns, Problems, and Prospects", by Feng Liu, LBL, March, 1993, p.26.)
2 For centrally heated buildings. 10% higher than Chinese value from source as in 1, page 41.
3 Derived based on data in 1, pages 26 and 63.
4 Note that this is about twice current Chinese levels, but less than half of 1985 USSR levels.
5 Placeholder estimate to bring total Agric/Services/Military power demand up to 25% of electricity use as estimated in document in authors' files [EP1].
6 [Not Used]
7 Lower value in 2000 assumes the closure of some buildings no longer used.
8 Based on visits to the DPRK in 1998 and 2000, commercial/public space does not seem to be under construction at an unusual rate (when there is construction at all), so the ratio of residential to commercial/public space remains as in 1990. The reduction in electricity use relative to 1990 is a function of the same assumed average urban electricity outage rate used for the residential sector, namely that power outages in cities outside the Pyongyang area as of 2000 were by far the rule rather than the exception. The fraction of 1990 coal use per unit area assumed for 2000, 65%, reflects the assumption that coal availability is poor in many areas of the country.

9 China Customs Statistics reported imports of computers and computer components to the DPRK from China more than doubled, in both number and value, between 2004 and 2005. This increase in computer (HS #8471) imports may indicate or be a indicator of somewhat of an increase in public/commercial activity, including, possibly, in the information technology sector.
Import data as compiled by Nathanial Aden, 2006. For related analysis, see also N. Aden, North Korean Trade with China as Reported in Chinese Customs Statistics: Recent Energy Trends and Implications as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Dr. Aden's paper is available as http://www.nautilus.org/fora/security/0679Aden.pdf.

10 We have no direct data on use of wood and biomass as a heating and cooking fuel in the public/commercial sector in the DPRK as of 1990, but anecdotal evidence of widespread use of biomass fuels in at least some types of common public institutions in recent years suggests that at least some use of biomass fuels for heating and cooking occurred in at least rural areas as of 1990. Accordingly, we assume that public/commercial/institutional use of biomass was approximately 5% of coal use, in terms of energy content in 1990. *Given the lower heating efficiency of biomass relative to coal in most applications, this implies that biomass accounted for only a few percent of heating provided in 1990. Some observers note that the use of wood and other biomass fuels for heating (when used) and cooking in several types of public sector buildings has increased substantially since the mid-1990s, with wood often providing the bulk of fuel use.*

11 We have no direct data on oil use in the public/commercial sectors, but it seems clear that some oil (in the form of kerosene and LPG for cooking) was and is used in the sector. We make the nominal assumption that oil use in 1990 was 0.5 percent of coal use in the sector, remained at that level in 1996 and 2000, but increased in 2005 to a level equal to 1 percent of coal use in 2005 as a result of the growth in the number of restaurants, primarily in Pyongyang, but also elsewhere in the country. Oil use is assumed to be 50% *kerosene and* 50% *LPG in 1990, 1996, and 2000, but* 75% *LPG in 2005.*

12 Coal use is assume to decline substantially, particularly in 2000 and 2005, relative to 1990, based on observers reports that many public buildings, including most office buildings, have remained unheated in winter in recent years.

13 For 2000, public/commercial electricity use relative to 1990 is assumed similar to that for the residential sector. For 2005, some observers report a modest increase in the availability of electricity to public/commercial buildings, though the change in electricity availability varied substantially by area of the DPRK, including in relation to proximity to new or existing power plants, or to priority users of power.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

BACK-UP CALCULATIONS AND DATA: ENERGY USED IN MILITARY BUILDINGS AND OTHER FACILITIES

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

				Sources/Notes:
Coal Use: Military Sector				
	Military Installation Floor Space:	2.00E+07	sq.m.	*1*
	Coal Use intensity	33	kgce/sq.m.	*2*
	Conversion Factor	0.0293	GJ/kgce	
	Total Coal Use, Military Buildings	1.93E+07	GJ	
	Coal Use, Military Manufacturing	8.87E+05	GJ	*5, 8*
	Other Coal Use: Military Sector	9.60E+06	GJ	*1*
	Total Coal Use, Buildings and Other	2.98E+07	GJ	
Oil Use: Military Sector				
	Oil Use, Military Transport Vehicles	6.58E+06	GJ	*5*
	Oil Use, Heavy Armaments	2.63E+05	GJ	*5*
	Oil Use in Air Force	2.65E+06	GJ	*5*
	Oil Use in Navy	6.85E+06	GJ	*5*
	Oil Use, Buildings and Other	1.00E+05	GJ	*1*
	Total Oil Use, Military Sector	1.64E+07	GJ	
Electricity Use: Military Buildings and Other				
	Electricity Use intensity, Buildings	55	kWh/sq.m.	*4*
	Conversion Factor	0.0036	GJ/kWh	
	Other Electricity Use	1.00E+07		*1*
	Total Electricity Use, Buildings and Other:	1.40E+07	GJ	
	Electricity Use, Military Manufacturing	4.75E+04	GJ	*5*
	Total Electricity Use, Military:	1.40E+07	GJ	
Wood Use: Military Sector				
	Intensity of wood/biomass fuel use relative to coal use	200%		*10*
Energy Use in 1996, 2000 and 2005 Relative to 1990 for Subsectors/End-Uses Not Covered in Military Workbook				
	1996 Coal/Wood Use, Buildings and Other, relative to 1990	95%		*Assumption*
	2000 Coal/Wood Use, Buildings and Other, relative to 1990	85%		*Assumption*
	2005 Coal/Wood Use, Buildings and Other, relative to 1990	80%		*Assumption*
	1996 Oil Use, Buildings and Other, relative to 1990	95%		*Assumption*
	2000 Oil Use, Buildings and Other, relative to 1990	85%		*Assumption*
	2005 Oil Use, Buildings and Other, relative to 1990	80%		*Assumption*
	1996 Fraction of Coal and Wood Use as Wood	10%		*9*
	2000 Fraction of Coal and Wood Use as Wood	15%		*9*
	2005 Fraction of Coal and Wood Use as Wood	17%		*9, 11*
	1996 Elect. Use, Buildings and Other, relative to 1990	55%		*Assumption*
	2000 Elect. Use, Buildings and Other, relative to 1990 *(See Note 6)*	54%		*Assumption*
	2005 Elect. Use, Buildings and Other, relative to 1990 *(See Note 7)*	64.5%		*Assumption*

Sources/Notes:

1 Placeholder Estimate, but electricity comparable to estimates by KERI ("Analysis of Present Status and Future Supply /Demand Prospects for the DPRK Power System", by J.Y. Yoon, presented at the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA) that military sector electricity demand in the DPRK would be about 4.9 TWh/yr if unconstrained. Since electricity demand in 1990 in the DPRK was already somewhat constrained by supply, we assume that total military electricity use in that year was about 80% of the KERI (Korea Electrotechnical Research Institute) figure. Dr. Yoon's presentation is avaialble as http://www.nautilus.org/DPRKEnergyMeeting/Papers/Yoon.ppt.

2 Assumed to be 10% higher than value for centrally heated Commercial/Public buildings from "Energy Use and Conservation in China's Residential and Commercial Sectors: Patterns, Problems, and Prospects", by Feng Liu, LBL, March, 1993, p.41.)

3 Derived based on data in 1, pages 26 and 63.

4 Assumed to be 100% higher than the level in (other) public and commercial buildings due to use of specialized electrical equipment.

5 As estimated in other Military Energy Consumption sections.

6 Rough assumption, but as the electricity situation in the country has continued to worsen, it.seems unlikely that electricity use in military buildings in the DPRK is larger than in 1996, even considering the importance of the military sector in the DPRK

7 Rough assumption, taking into account that as the overall electricity situation in the country has improved slightly from 2000 to 2005, military sector electricity use should rise somewhat.

8 The journal Seoul T'ongil Kyongje, dated July 2002, contains an article (pages 28-36) by So Chu-sok entitled "North Korean Industries (Part X): Munitions Industry". Among the information in this article is the following: "…North Korean military power has not changed greatly since….the mid 1990s", apart from some missile development and "expanded forward deployment of long-range artillery". The article estimates the size of the military at 1.7 million people, consuming much more than 5% of food in the country, and more than 15 percent of fuel oil used in the DPRK. Military stockpiles of food and fuel are "100 to 120 days worth", but it is not stated whether. this refers to days under typical non-combat or combat conditions. The article states that there are about 180 munitions factories in the DPRK, including about 40 gun factories, 10 armored vehicle factories, 50 ammunitions factories, and 10 naval shipyards, producing a total of 25 percent of GNP. Exports of SCUD-C missiles in the early 1990s are estimated at 100 to 150 per year. Factories, largely based on Soviet/East Bloc technology, have become "technologically obsolete and their facilities are run down", resulting in "extremely low" efficiency and high rates of consumption of energy and materials that, coupled with fuel and materials shortages, have "caused production setbacks" in some factories. These trends are taken into account in the analysis of energy demand in the military manufacting sector (see military sector analysis workpapers).

9 The publication Seoul Wolgan Choson published an article by Kim Yon-kwang and Yi Sang-hun, dated 1 October, 2003 (pages 168-181), entitled "Kim Chong-il's Military is Hoarding All Rice Aid as Military Provision", which is based on an interview with a DPRK soldier named Chin Yon-kyu, who had defected to the ROK, but who was (or claimed to be) a driver for a high-ranking officer. This article contains one of a number of anecdotal reports, including reports by observers of and recent visitors to the DPRK, that suggest that soldiers, like many DPRK residents have in recent years, in many locales, been obliged to forage, in both the broad and specific senses of the word, for both food and fuel. Although no quantitative data are available to assist in estimating the impact of the need for military units to use wood fuel, we have assumed that the fraction of fuel for cooking and heating made up by wood has risen, starting at (near) zero, we assume, in 1990, rising substantially in 1996 and through 2000, and rising slightly between 2000 and 2005 as the DPRK economy improved somewhat.

10 Rough assumption, but considering that much biomass is probably burned in open fireplaces, and much of the biomass/wood fuel used is probably green (wet and unseasoned), it seems reasonable to assume the the efficiency of biomass fuel use might be half that (twice the intensity) of coal use for cooking and heating end-uses.

11 By way of comparison, the assumptions above for 2005 suggests military wood/biomass fuel use of approximately 4.06E+06 *GJ is approximately the amount of wood fuel energy needed to cook* 1.27E+08 *kilograms of rice, assuming the use of* 2 *kg of (dry) wood fuel per kg of rice. (Note that this is a highly variable quantity, depending on cooking methods and the type of fireplace/stove and pots used, but the figure cited is within the range of values provided in, for example, http://www.fao.org/docrep/006/AB780E/AB780E03.htm http://www.worldenergy.org/wec-geis/publications/reports/rural/energy_use_in_rural_areas/2_3.asp, and http://www.fao.org/docrep/x5400e/x5400e04.htm.) At an average daily ration of* 0.5 *kg per soldier (various accounts put soldiers rations at about 500 grams per day, sometimes somewhat lower or higher, depending on the soldier's tasks, duty station, and food availability), this implies that wood equivalent to the amount needed to cook rice for about* 694,565 *soldiers is used. Given that some wood will in fact be used for heating, or for cooking other foods this figure--the equivalent of somewhat more than half of the number of people the DPRK has in uniform, seems generally plausible.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

BACK-UP CALCULATIONS AND DATA: OTHER/NON-SPECIFIED SECTOR

Prepared By David Von Hippel
Date Last Modified: 3/6/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

			Sources/Notes:
Coal Use: Other/Non-Specified Sectors			
Diesel Oil Use: Other/Non-Specified Sectors	1.70E+06	GJ	*1*
Kerosene/Jet Fuel Use: Other/Non-Specified Sect.	4.20E+06	GJ	*1*
Electricity Use: Other/Non-Specified Sectors			
Wood/Biomass Use: Other/Non-Specified Sectors			
Heat from Yongbyon Nuclear Reactor used locally	4.73E+05	GJ	*2*

ESTIMATE OF CURRENT AND FUTURE ENERGY USE IN NON-SPECIFIED SECTORS

Values Relative to 1990	**1996**	**2000**	**2005**		
Oil used in unspecified/other sectors	0%	0%	0%		*Assumption*
Heat from Yongbyon Nuclear Reactor	0%	0%	100%		*3*

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Sources/Notes:

1 Included to account for remainder of refined products production in balance sheet, 1990.

2 See Note 13 in "ELECTRICITY GENERATION IN 1990" worksheet.

3 Yongbyon reactor not operating in 1996 or 2000. Capacity factor in 2005 assumed to be similar to that in 1990 (about 60 percent).

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

2006 UPDATE

BACK-UP CALCULATIONS AND DATA: NON-ENERGY RESOURCE USES

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

DERIVATION OF INFORMATION PASSED TO ENERGY BALANCE SHEET, 1990

			Sources/Notes:
Coal Use as feedstock: Fertilizer (Ammonia) production	1.83E+07	GJ/yr	*1*
Total Coal Use: Non-Energy Applications:	1.83E+07	GJ/yr	
Oil Use: Non-Energy Products excluding:	5.76E+06	GJ/yr	*4*
-- heavy oil for fertilizer production	9.15E+05	GJ/yr	*5*
-- naptha for fertilizer production	3.66E+06	GJ/yr	*5*
Wood/Biomass Use: Roundwood for Wood Products:	1.20E+07	GJ/yr	*2*
Wood/Biomass Use: Non-Energy Applications	1.20E+07	GJ/yr	

ESTIMATE OF CURRENT AND FUTURE NON-ENERGY USE OF FUELS

Values Relative to 1990	**1996**	**2000**	**2005**		
Coal, Oil feedstock for ammonia production	25%	8%	11%	THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS	*3*
Oil Use: Other Non-Energy Products	30%	15%	15%		*Assumption*
Wood/biomass used as roundwood:	60%	50%	50%		*Assumption*

Sources/Notes:

1 Imported from Industry sheet.
2 Imported from Biomass sheet.
3 Assumed same as production relative to 1990 for the fertilizer subsector; imported from "Industry--96-on" sheet.
4 Estimate based on estimated output of bitumen, petroleum coke, lubricants, and waxes in 1990. Some of these products were probably exported (to Russia and possibly China).
5 For Nitrogen fertilizer manufacture. See "Industry-96-on" worksheet in this workbook, note 3.

Additional Summary Figures and Tables

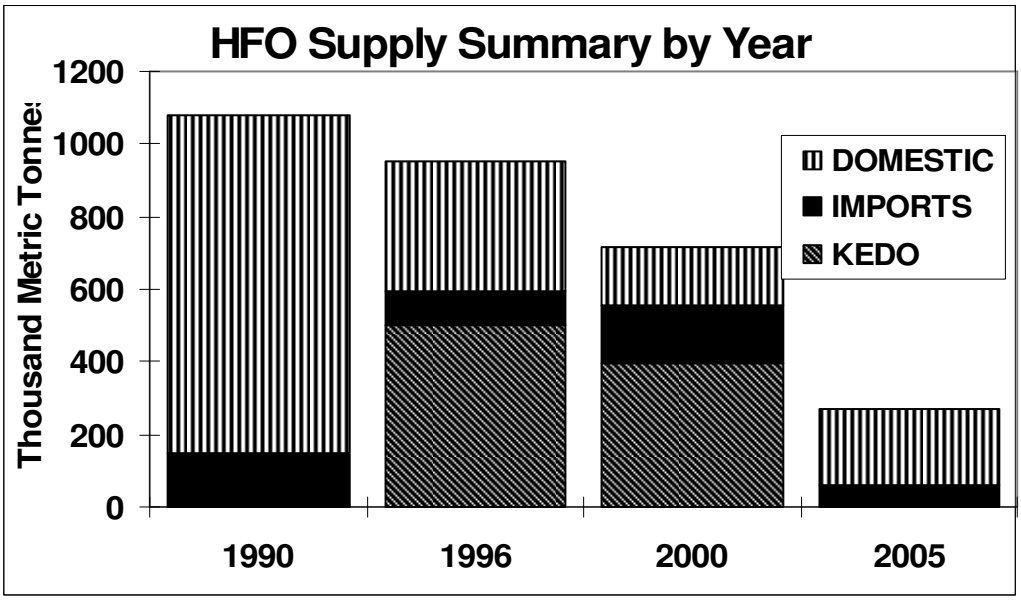
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)
2006 UPDATE
ADDITIONAL GRAPHS AND FIGURES

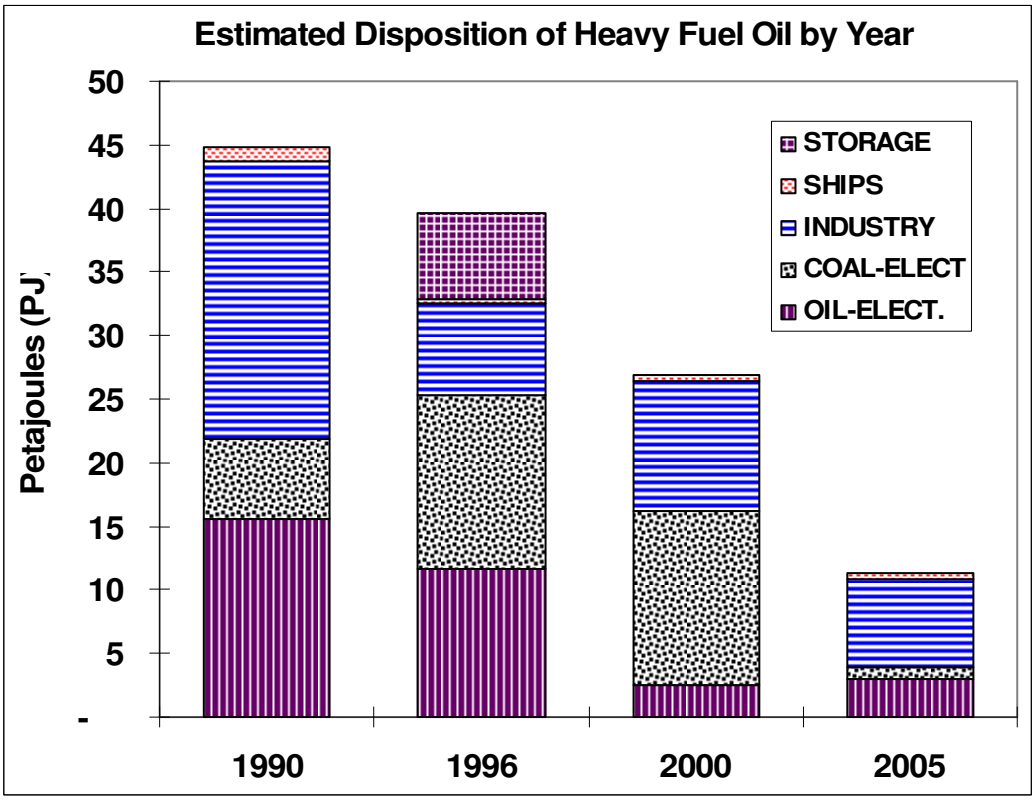
HFO Supply Summary: Thousand tonnes

	YEAR			
SOURCE	**1990**	**1996**	**2000**	**2005**
KEDO	**0**	500	395	-
IMPORTS	150	94	160	60
DOMESTIC	**930.4**	356	160	211
TOTAL	1,080	950	714	271
KEDO	0%	53%	55%	0%
IMPORTS	14%	10%	22%	22%
DOMESTIC	86%	37%	22%	78%
TOTAL	100%	100%	100%	100%

HFO Demand Summary: Petajoules (PJ)

	YEAR			
CONSUMER	**1990**	**1996**	**2000**	**2005**
OIL-ELECT.	15.6	11.7	2.6	3
COAL-ELECT	6.3	13.6	13.6	1
INDUSTRY	21.8	7.1	10.3	7
SHIPS	1.0	0.4	0.4	0.4
STORAGE	**-**	6.7	-	-
TOTAL	**44.8**	**39.6**	**26.8**	11
OIL-ELECT.	35%	30%	10%	26%
COAL-ELECT	14%	34%	51%	8%
INDUSTRY	49%	18%	38%	62%
SHIPS	2%	1%	1%	4%
STORAGE	0%	17%	0%	0%
TOTAL	100%	100%	100%	100%
HFO Supply Summary				
KEDO	-	22.0	17.3	-
Net Non-KEDO Imports	6.2	2.9	2.8	2.5
Domestic Refining	38.6	14.8	6.6	8.8
TOTAL	**44.8**	**39.6**	**26.8**	**11.3**


HFO Supply Summary by Year
Thousand Metric Tonne
1200
1000
800
600
400
200
0
1990
1996
2000
2005
DOMESTIC
IMPORTS
KEDO

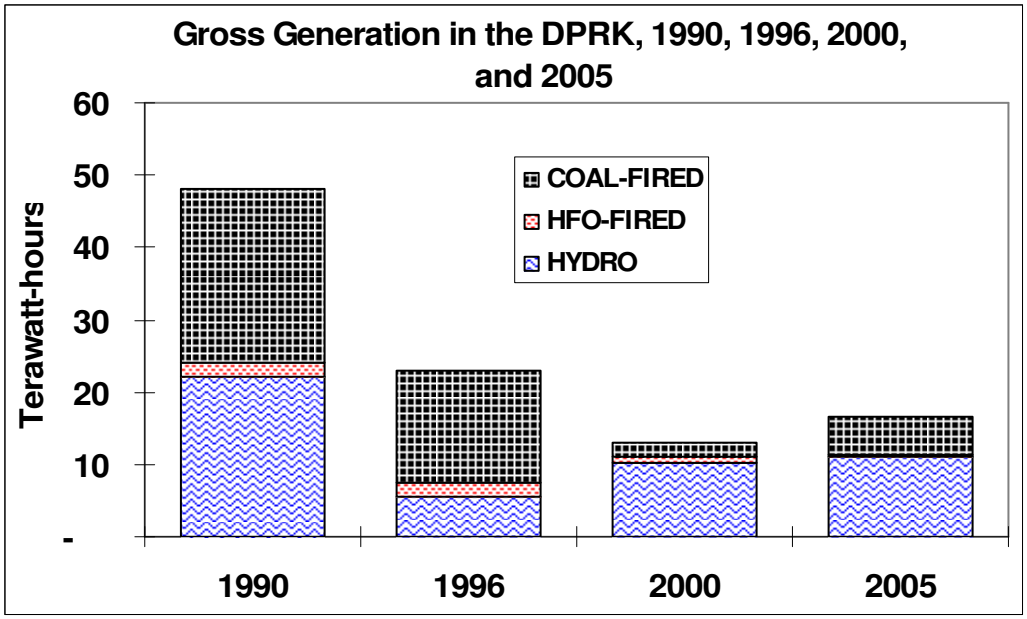

Estimated Disposition of Heavy Fuel Oil by Year
Petajoules (PJ
50
45
40
35
30
25
20
15
10
5
-
1990
1996
2000
2005
STORAGE
SHIPS
INDUSTRY
COAL-ELECT
OIL-ELECT.

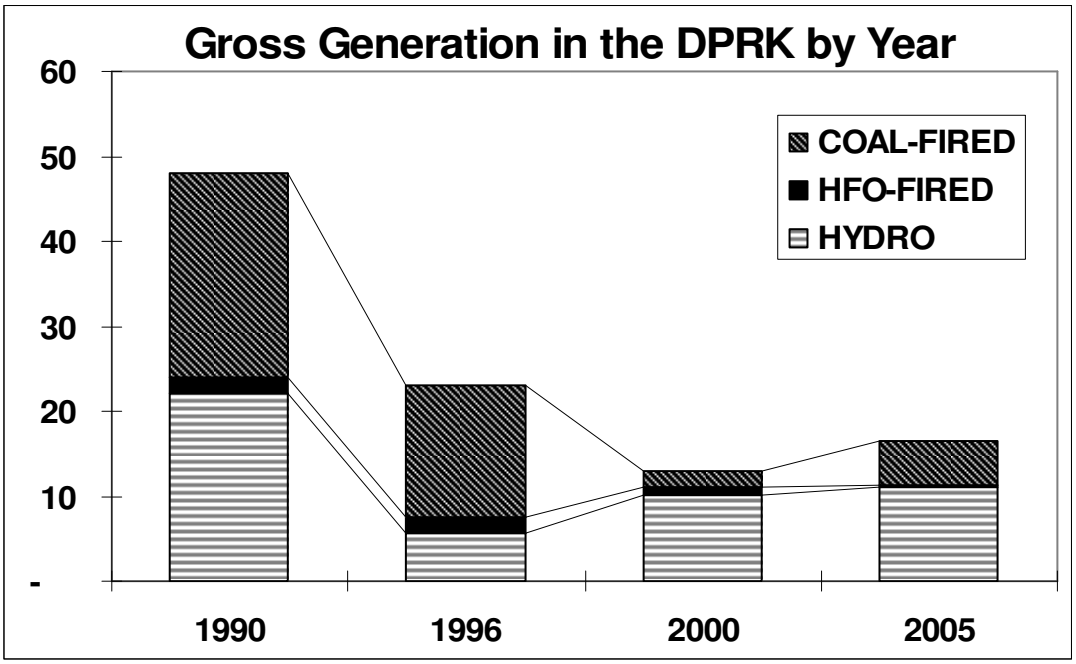
Demand Summary for Other Refined Products: Terajoules

	DIESEL OIL				GASOLINE				KERO/JET FUEL/LPG			
SECTOR	1990	1996	2000	2005	1990	1996	2000	2005	1990	1996	2000	2005
INDUSTRIAL	3,000	660	623	336	-	-	-	-	-	-	-	-
TRANSPORT	12,906	5,022	4,298	4,839	23,171	10,244	3,738	3,346	399	320	379	618
RESIDENTIAL	-	-	-	-	-	-	-	-	6,600	1,946	2,869	1,694
AGRICULTURAL	5,005	1,502	1,251	919	-	-	-	-	-	-	-	-
FISHERIES	2,777	856	710	796	-	-	-	-	-	-	-	-
MILITARY	6,859	5,248	5,623	5,506	7,386	6,451	5,675	5,152	1,798	1,199	974	899
NON-SPECIFIED/OTHER	1,700	-	-	-	-	-	-	-	4,200	-	-	-
TOTAL	32,246	13,287	12,506	12,396	30,558	16,694	9,413	8,498	12,997	3,464	4,222	3,211
INDUSTRIAL	9%	5%	5%	3%	0%	0%	0%	0%	0%	0%	0%	0%
TRANSPORT	40%	38%	34%	39%	76%	61%	40%	39%	3%	9%	9%	19%
RESIDENTIAL	0%	0%	0%	0%	0%	0%	0%	0%	51%	56%	68%	53%
AGRICULTURAL	16%	11%	10%	7%	0%	0%	0%	0%	0%	0%	0%	0%
FISHERIES	9%	6%	6%	6%	0%	0%	0%	0%	0%	0%	0%	0%
MILITARY	21%	39%	45%	44%	24%	39%	60%	61%	14%	35%	23%	28%
NON-SPECIFIED/OTHER	5%	0%	0%	0%	0%	0%	0%	0%	32%	0%	0%	0%
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Supply Summary for Electricity: Terawatt-hours of Gross Generation

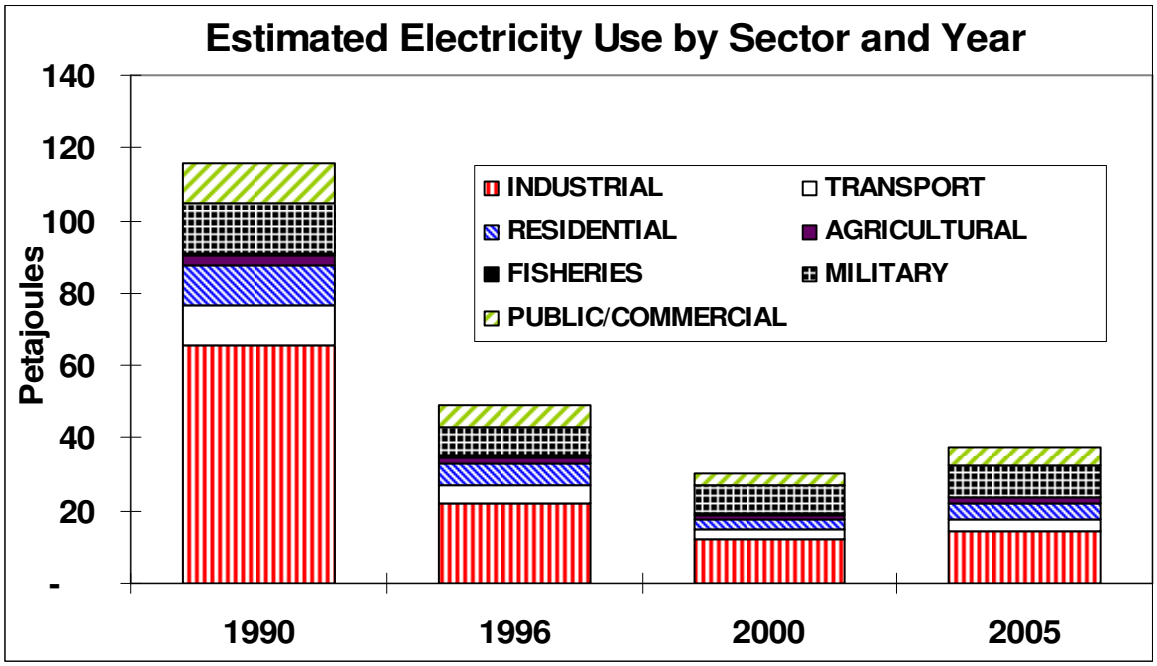
	YEAR			
GENERATION	1990	1996	2000	2005
HYDRO	22.2	5.6	10.2	11
HFO-FIRED	1.8	1.9	0.9	0.2
COAL-FIRED	24.0	15.5	1.8	5
TOTAL	48	23	13	17
HYDRO	46%	24%	79%	67%
HFO-FIRED	4%	8%	7%	1%
COAL-FIRED	50%	67%	14%	31%
TOTAL	100%	100%	100%	100%

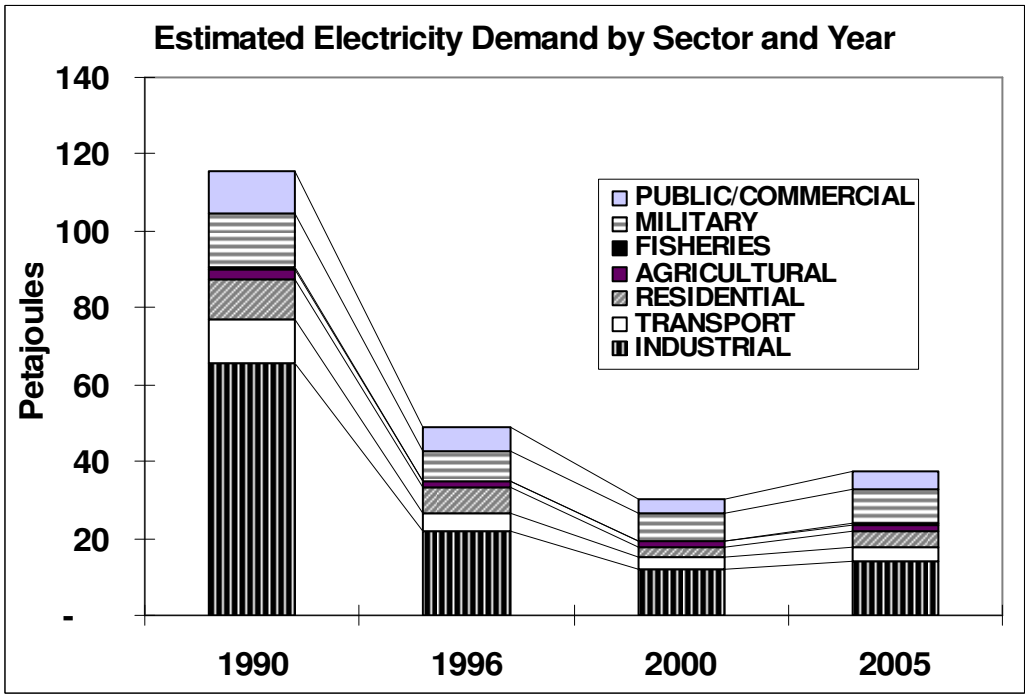




Demand Summary for Electricity: Petajoules

	ELECTRICITY			
SECTOR	**1990**	**1996**	**2000**	**2005**
INDUSTRIAL	65	22	12	14
TRANSPORT	11	5	3	4
RESIDENTIAL	11	6	3	4
AGRICULTURAL	3	2	1	1
FISHERIES	1	0	0	0
MILITARY	14	8	8	9
PUBLIC/COMMERCIAL	11	6	3	5
TOTAL	116	49	30	37
INDUSTRIAL	57%	45%	40%	38%
TRANSPORT	10%	10%	10%	10%
RESIDENTIAL	9%	13%	9%	11%
AGRICULTURAL	2%	3%	4%	4%
FISHERIES	0%	0%	1%	1%
MILITARY	12%	16%	25%	24%
PUBLIC/COMMERCIAL	9%	12%	11%	12%
TOTAL	100%	100%	100%	100%


Estimated Electricity Use by Sector and Year
Petajoules
140
120
100
80
60
40
20
-
1990
1996
2000
2005
INDUSTRIAL
TRANSPORT
RESIDENTIAL
AGRICULTURAL
FISHERIES
MILITARY
PUBLIC/COMMERCIAL


Estimated Electricity Demand by Sector and Year
Petajoules
140
120
100
80
60
40
20
-
1990
1996
2000
2005
PUBLIC/COMMERCIAL
MILITARY
FISHERIES
AGRICULTURAL
RESIDENTIAL
TRANSPORT
INDUSTRIAL

SUMMARY TABLE OF ELECTRICTY SUPPLY AND DEMAND
Units: TWh

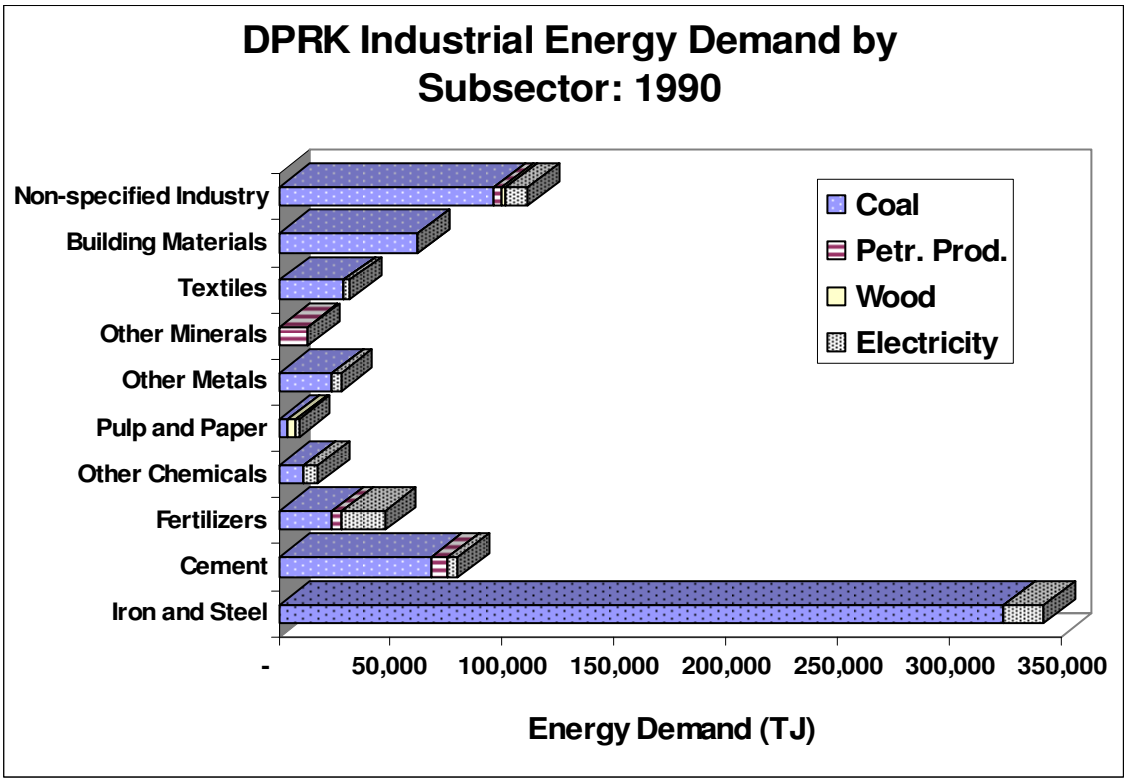
	YEAR			
GENERATION	**1990**	**1996**	**2000**	**2005**
HYDRO	22.2	5.6	10.2	11.1
HFO-FIRED	1.8	1.9	0.9	0.2
COAL-FIRED	24.0	15.5	1.8	5.2
NUCLEAR	-	-	-	
TOTAL	48.0	23.0	13.0	65.4
EXPORTS	(3.4)	(1.0)	(0.0)	(0.1)
COAL PROD.	(2.4)	(1.2)	(0.6)	(0.9)
OWN USE	(3.6)	(2.8)	(0.5)	(1.0)
LOSSES	(6.3)	(4.4)	(3.5)	(4.3)
TOTAL DEMAND	32.1	13.6	8.4	10.4
INDUSTRIAL	18.2	6.1	3.3	3.9
TRANSPORT	3.2	1.3	0.9	1.0
RESIDENTIAL	3.0	1.8	0.7	1.2
AGRICULTURAL	0.7	0.5	0.4	0.4
FISHERIES	0.1	0.1	0.1	0.1
MILITARY	3.9	2.1	2.1	2.5
PUBLIC/COMM'L	3.0	1.7	0.9	1.3

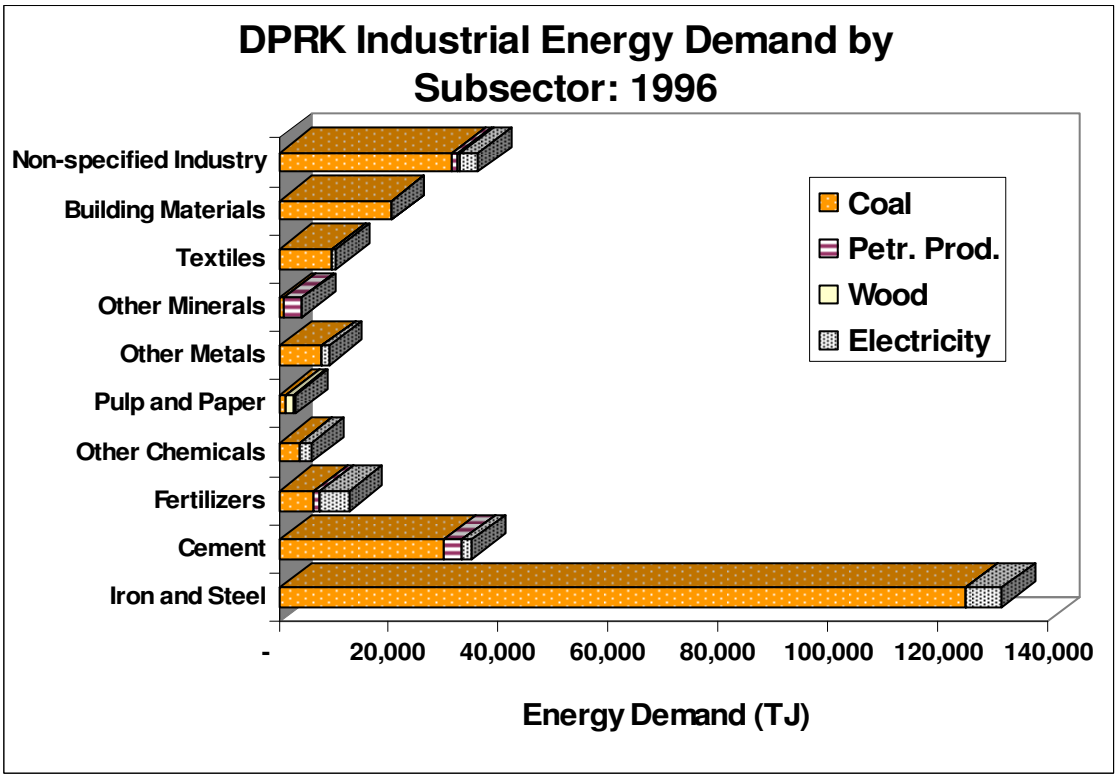
DPRK Industrial Energy Demand By Subsector: 1990 and 1996

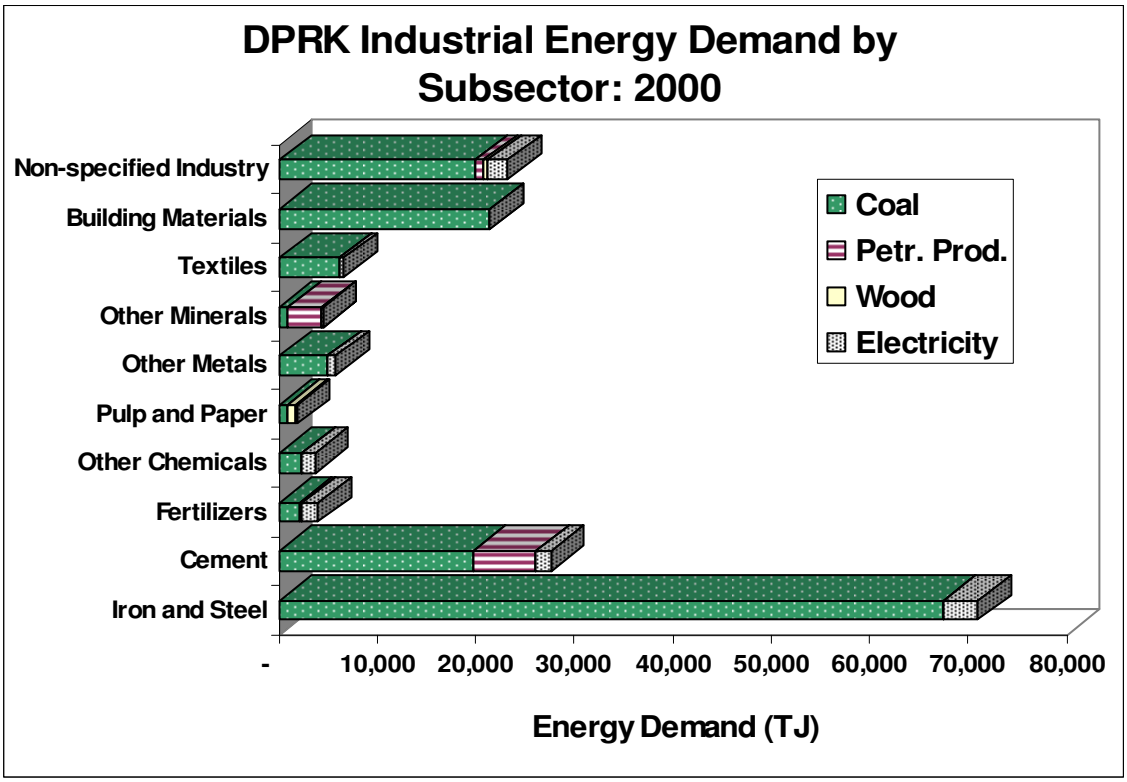
Units: Terajoules (TJ)	**1990**				**1996**			
Subsector	Coal	Petr. Prod.	Wood	Electricity	Coal	Petr. Prod.	Wood	Electricity
Iron and Steel	324,615	-	-	17,388	124,977	-	-	6,694
Cement	68,139	7,571	-	4,356	29,981	3,331	-	1,917
Fertilizers	23,994	4,573	-	18,891	6,515	1,129	-	5,130
Other Chemicals	11,203	-	-	6,616	3,697	-	-	2,183
Pulp and Paper	4,026	-	4,026	932	1,329	-	1,329	308
Other Metals	23,720	-	-	4,126	7,828	-	-	1,362
Other Minerals	-	12,600	-	396	832	3,326	-	131
Textiles	29,385	-	-	2,497	9,697	-	-	824
Building Materials	61,980			189	20,453	-	-	62
Non-specified Industry	96,000	3,750	1,600	10,000	31,680	908	528	3,300
TOTAL	643,061	28,493	5,626	65,392	236,988	8,694	1,857	21,910

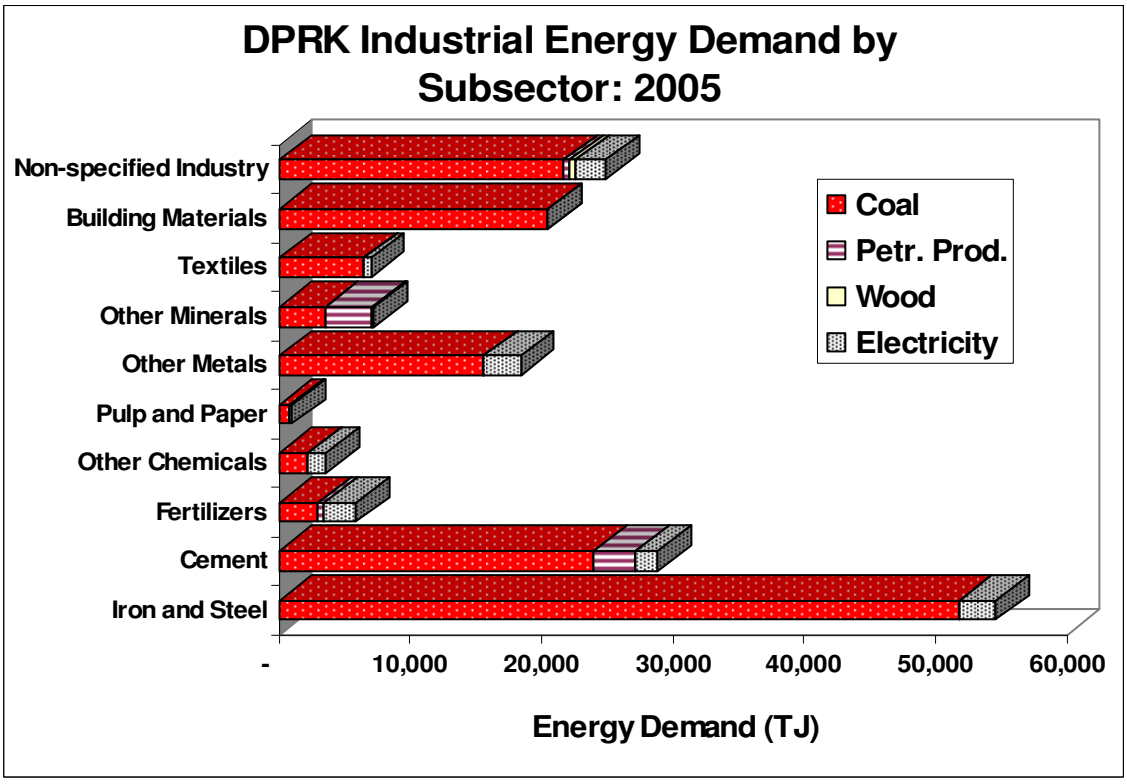
DPRK Industrial Energy Demand By Subsector: 2000 and 2005

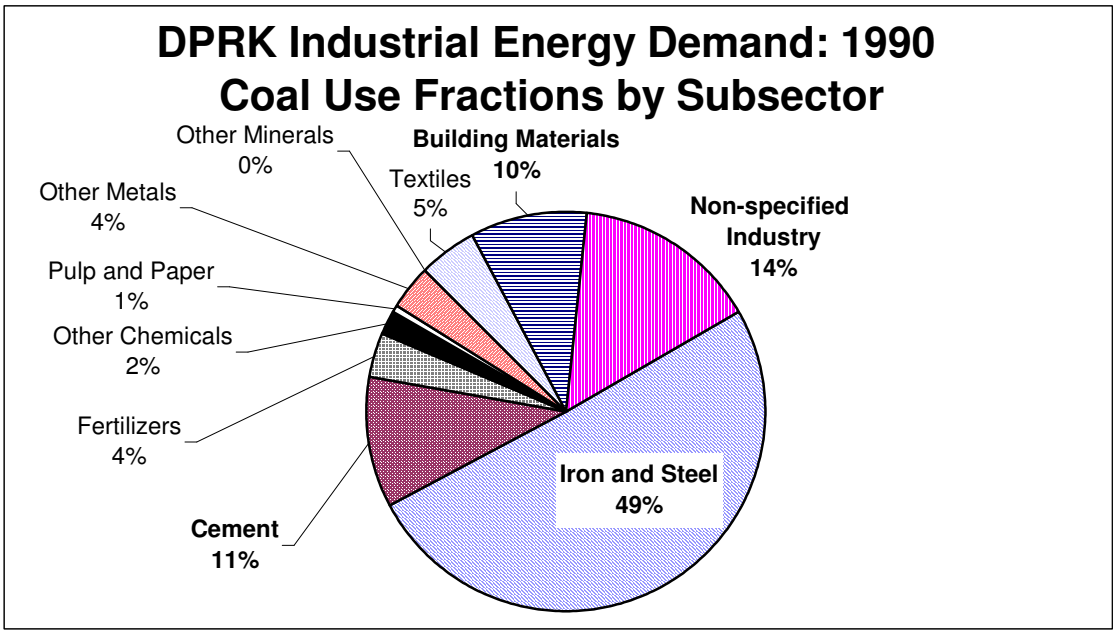
Units: Terajoules (TJ)	**2000**				**2005**			
Subsector	Coal	Petr. Prod.	Wood	Electricity	Coal	Petr. Prod.	Wood	Electricity
Iron and Steel	67,382	-	-	3,609	51,776	-	-	2,824
Cement	19,720	6,399	-	1,503	23,985	3,256	-	1,561
Fertilizers	2,070	343	-	1,629	2,956	512	-	2,370
Other Chemicals	2,325	-	-	1,373	2,224	-	-	1,338
Pulp and Paper	836	-	836	194	799	-	-	188
Other Metals	4,924	-	-	857	15,655	-	-	2,773
Other Minerals	869	3,478	-	137	3,528	3,528	-	222
Textiles	6,100	-	-	518	6,465	-	-	559
Building Materials	21,383			65	20,453			64
Non-specified Industry	19,927	934	332	2,076	21,754	462	369	2,307
TOTAL	145,536	11,154	1,168	11,961	149,595	7,758	369	14,206

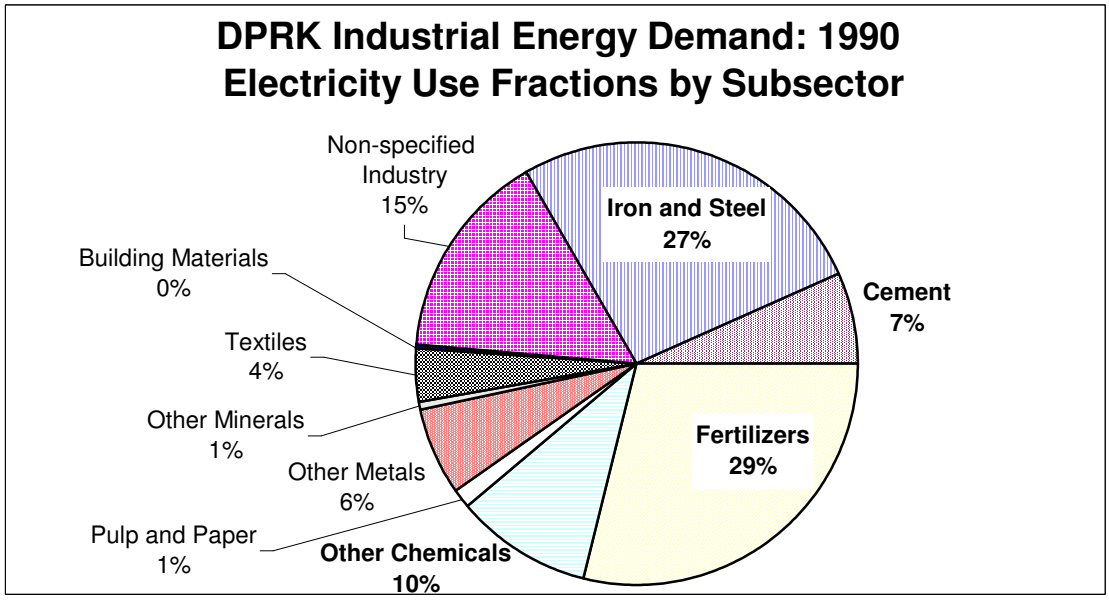

DPRK Industrial Energy Demand by Subsector: 1990
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
50,000
100,000
150,000
200,000
250,000
300,000
350,000
Energy Demand (TJ)

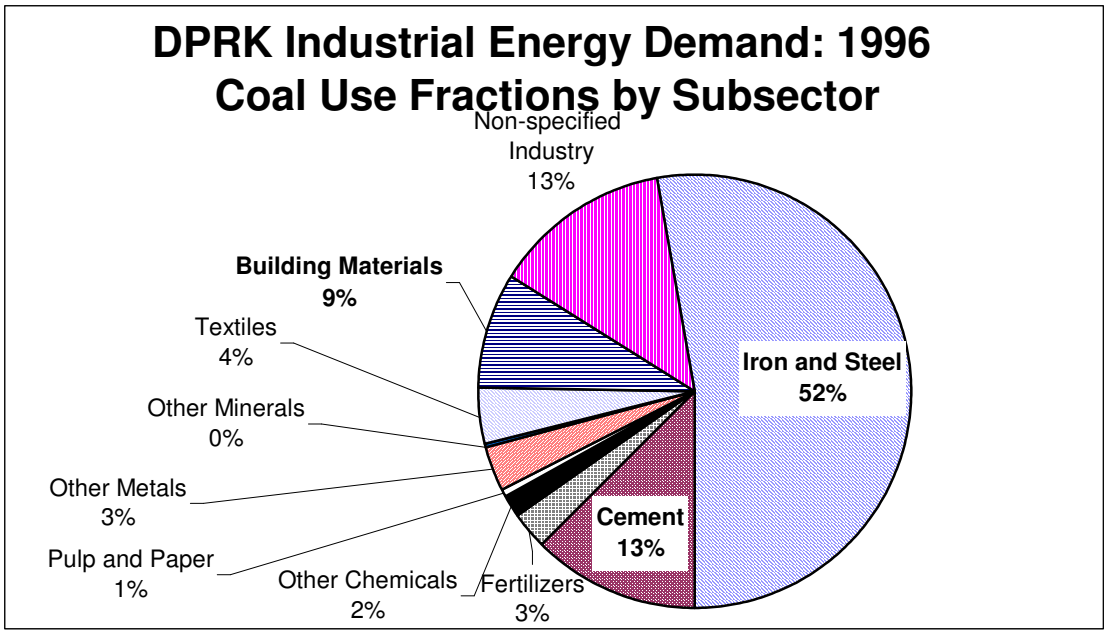

DPRK Industrial Energy Demand by Subsector: 1996
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Energy Demand (TJ)

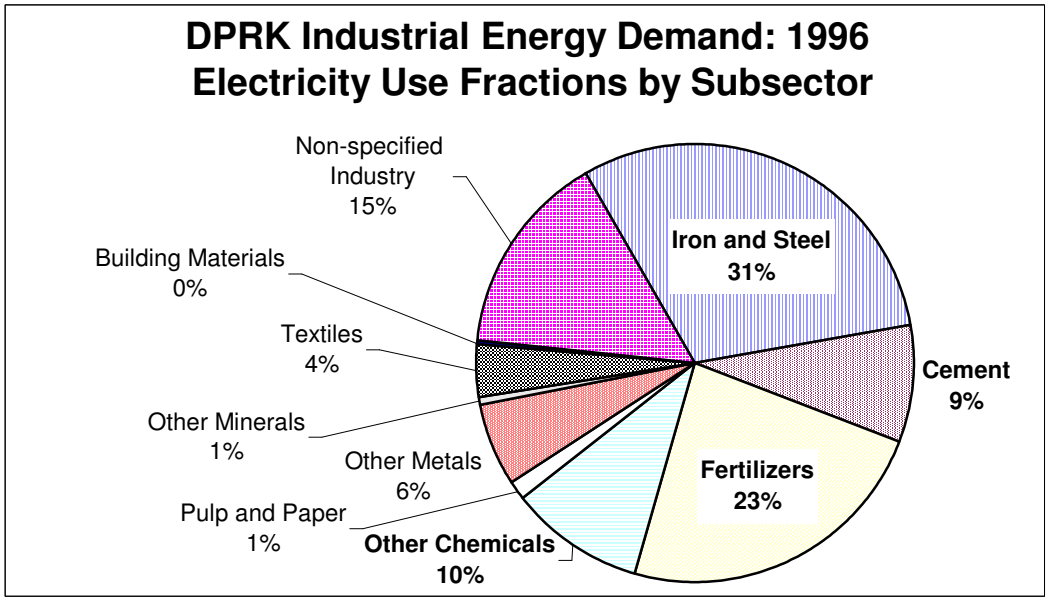

DPRK Industrial Energy Demand by Subsector: 2000
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
Energy Demand (TJ)


DPRK Industrial Energy Demand by Subsector: 2005
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
10,000
20,000
30,000
40,000
50,000
60,000
Energy Demand (TJ)


DPRK Industrial Energy Demand: 1990
Coal Use Fractions by Subsector
Other Minerals 0%
Building Materials 10%
Textiles 5%
Other Metals 4%
Non-specified Industry 14%
Pulp and Paper 1%
Other Chemicals 2%
Fertilizers 4%
Iron and Steel 49%
Cement 11%

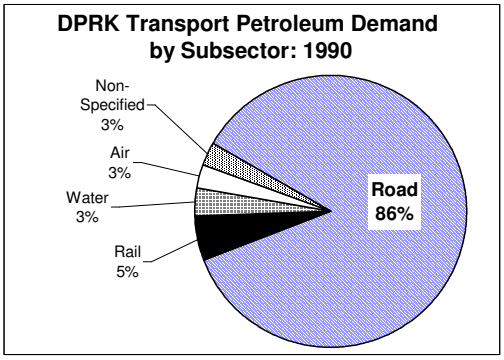

DPRK Industrial Energy Demand: 1990
Electricity Use Fractions by Subsector
Non-specified Industry 15%
Iron and Steel 27%
Building Materials 0%
Cement 7%
Textiles 4%
Other Minerals 1%
Fertilizers 29%
Other Metals 6%
Pulp and Paper 1%
Other Chemicals 10%

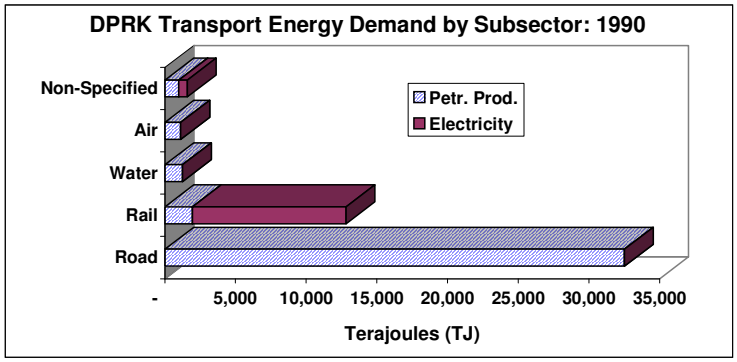


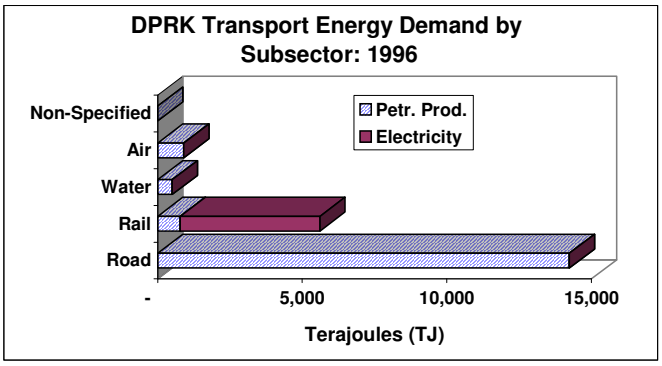


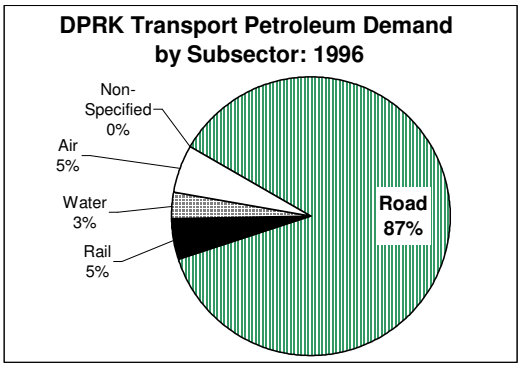
DPRK Transport Energy Demand By Subsector: 1990, 1996, 2000, annd 2005

Units: Terajoules (TJ)	**1990**		**1996**		**2000**		**2005**	
Subsector	Petr. Prod.	Electricity	Petr. Prod.	Electricity	Petr. Prod.	Electricity	Petr. Prod.	Electricity
Road	32,502	-	14,235	-	7,220	-	7,336	-
Rail	1,949	10,870	779	4,828	585	3,153	604	3,587
Water	1,253	-	501	-	464	-	489	-
Air	1,123	-	899	-	843	-	944	-
Non-Specified	1,000	600	-	-	-	-	-	-







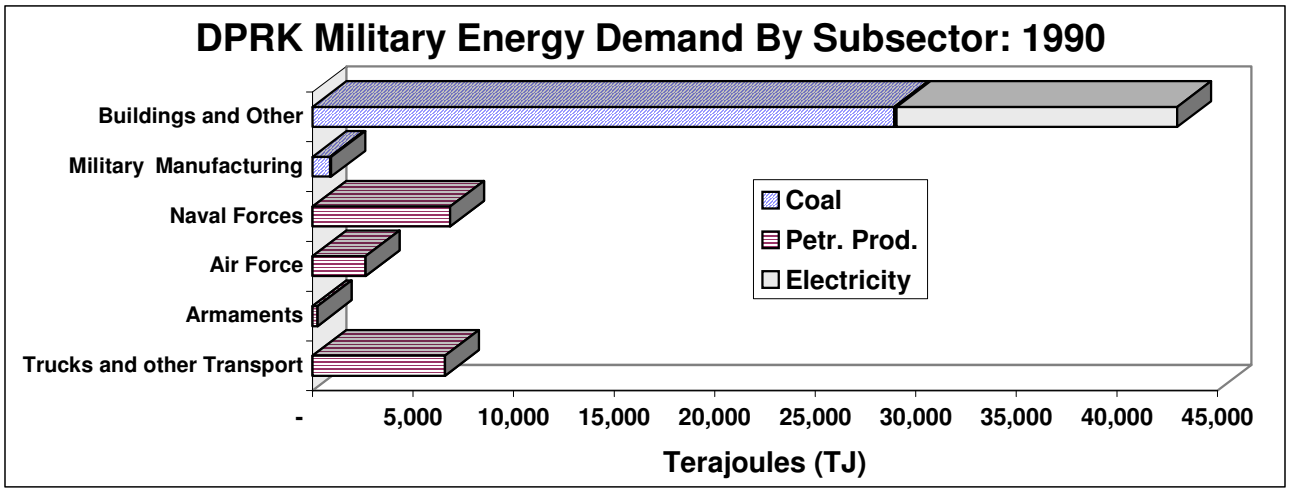


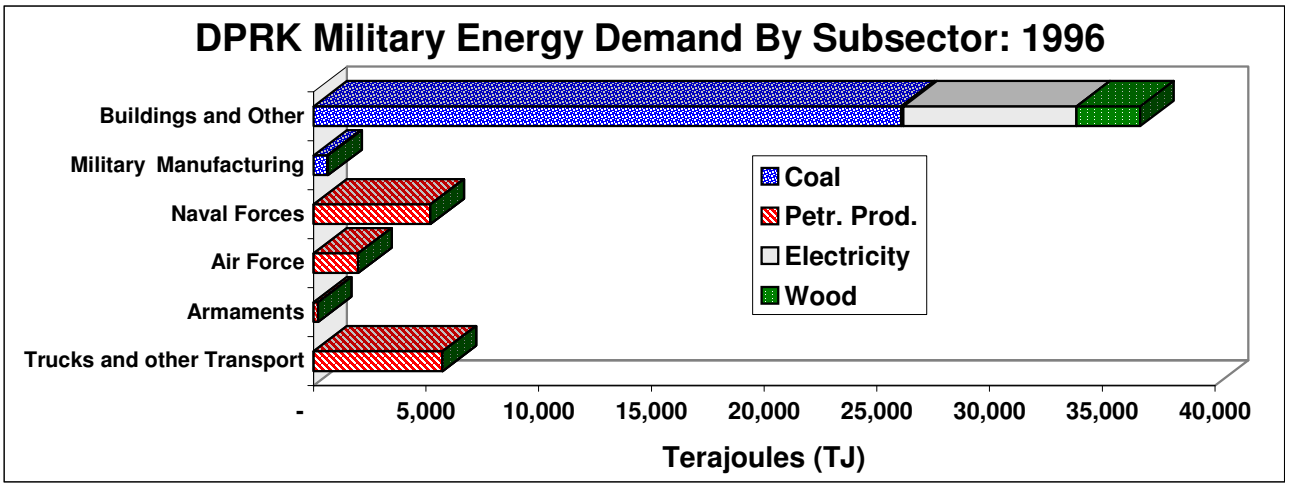
DPRK Military Energy Demand By Subsector: 1990, 1996, 2000, and 2005

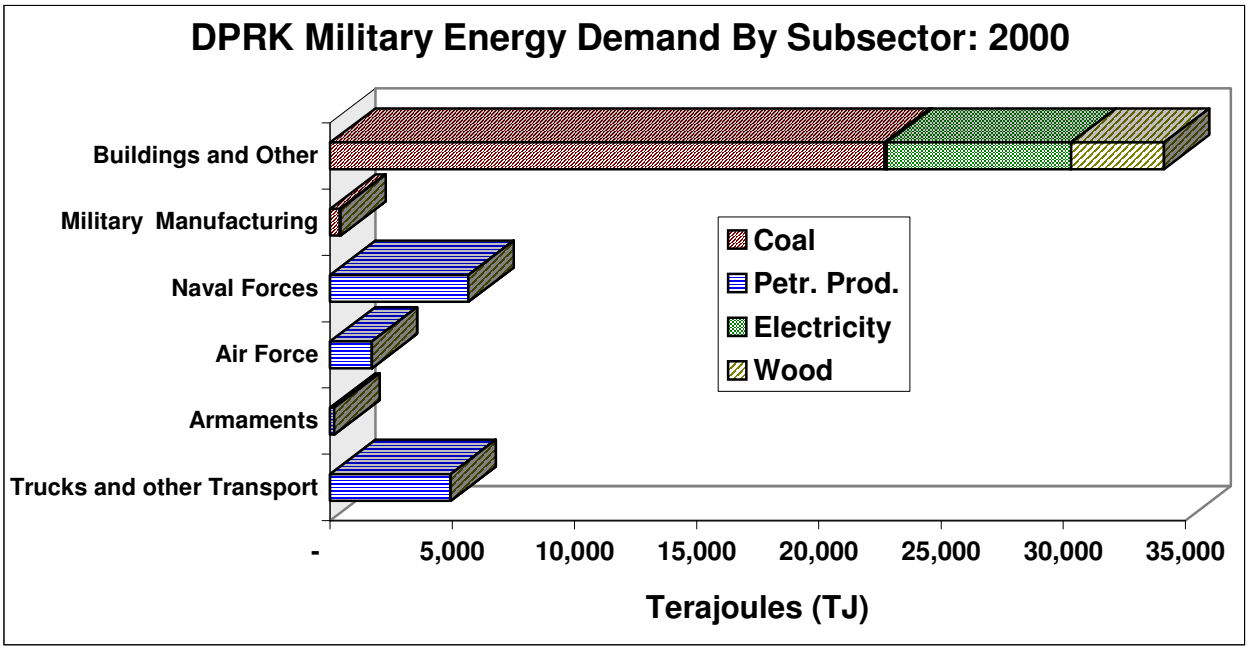
Units: Terajoules (TJ)	**1990**		
Subsector	Coal	Petr. Prod.	Electricity
Trucks and other Transport	-	6,585	-
Armaments	-	263	-
Air Force	-	2,648	-
Naval Forces	-	6,847	-
Military Manufacturing	887	-	48
Buildings and Other	28,938	100	13,960

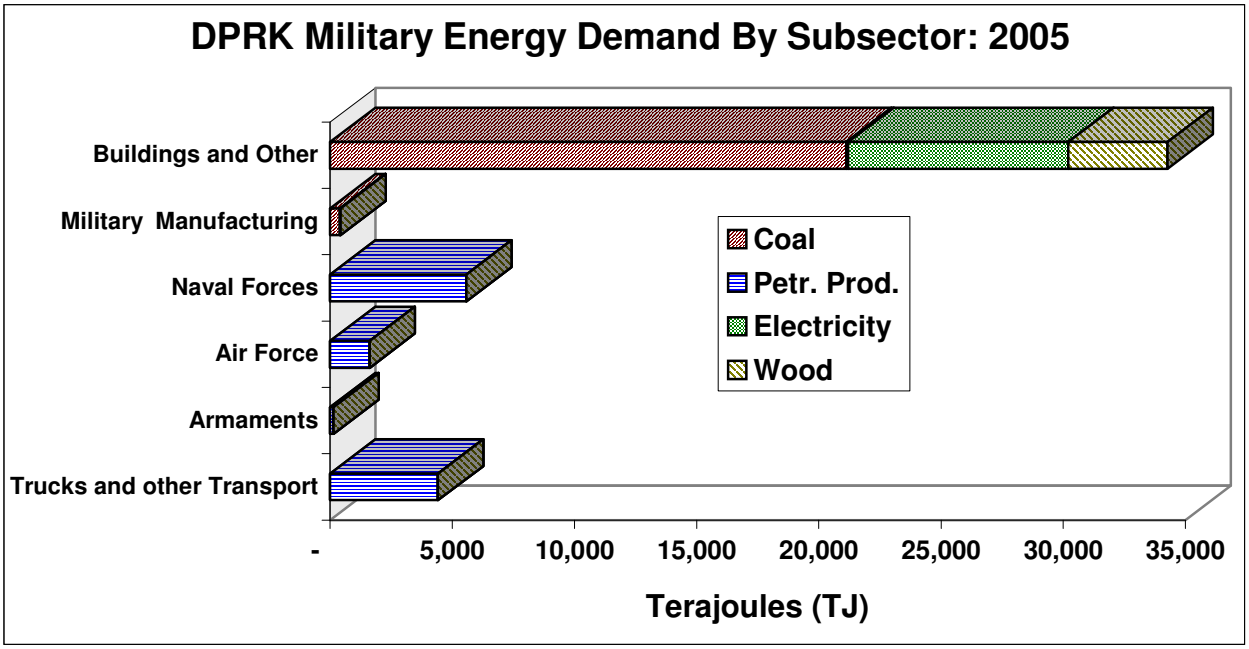
	1996			
	Coal	Wood	Petr. Prod.	Electricity
Trucks and other Transport	-	-	5,734	-
Armaments	-	-	211	-
Air Force	-	-	1,985	-
Naval Forces	-	-	5,198	-
Military Manufacturing	621	-	-	33
Buildings and Other	26,074	2,833	95	7,678

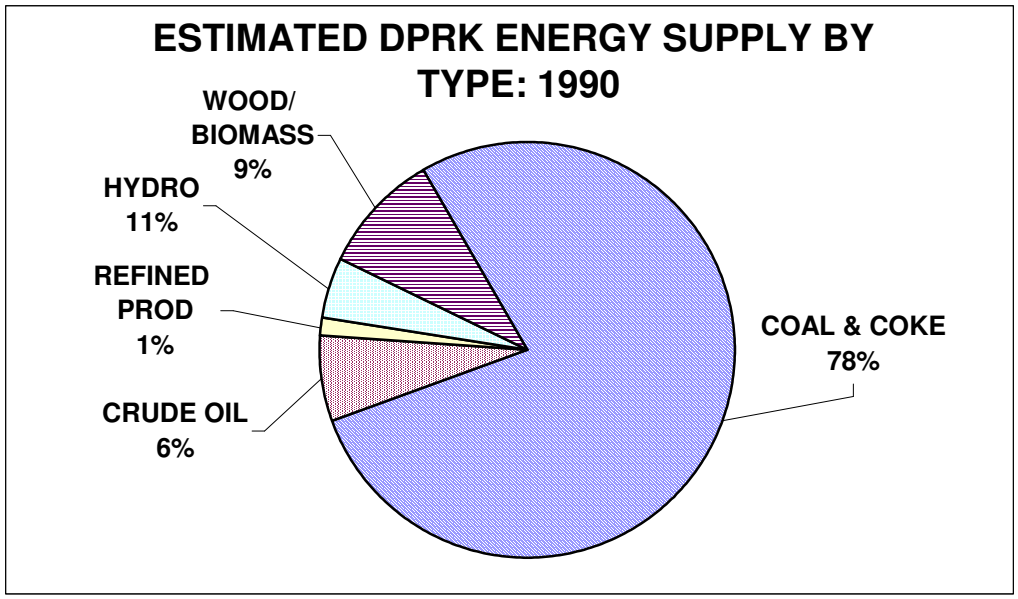
	2000				**2005**			
Subsector	Coal	Wood	Petr. Prod.	Electricity	Coal	Wood	Petr. Prod.	Electricity
Trucks and other Transport	-	-	4,926	-	-	-	4,405	-
Armaments	-	-	172	-	-	-	141	-
Air Force	-	-	1,703	-	-	-	1,615	-
Naval Forces	-	-	5,654	-	-	-	5,572	-
Military Manufacturing	399	-	-	21	399	-	-	21
Buildings and Other	22,696	3,803	85	7,538	21,122	4,056	80	9,004

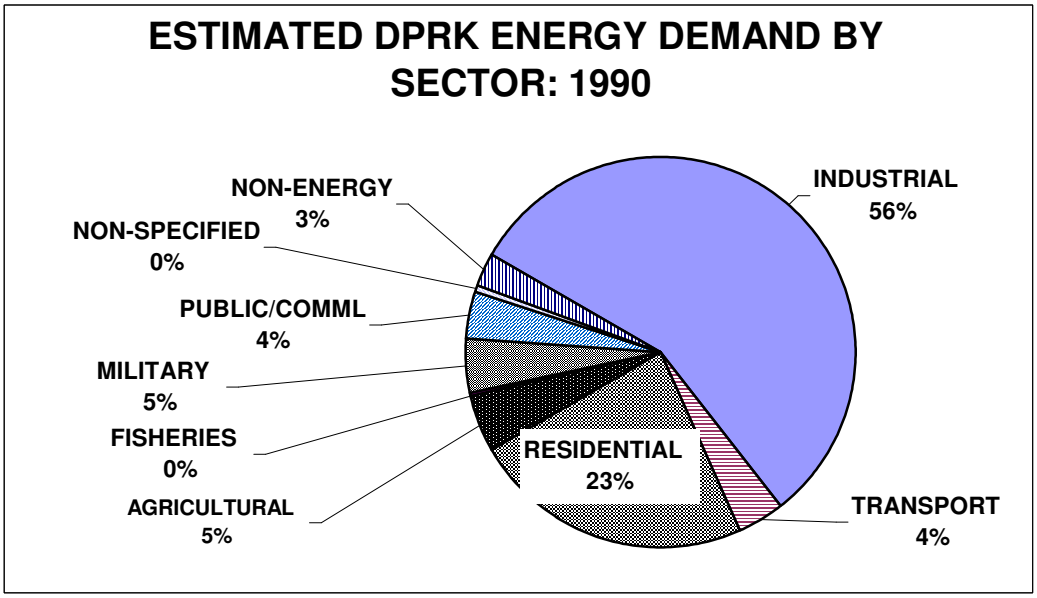

DPRK Military Energy Demand By Subsector: 1990
Buildings and Other
Military Manufacturing
Naval Forces
Air Force
Armaments
Trucks and other Transport
Coal
Petr. Prod.
Electricity
-
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Terajoules (TJ)

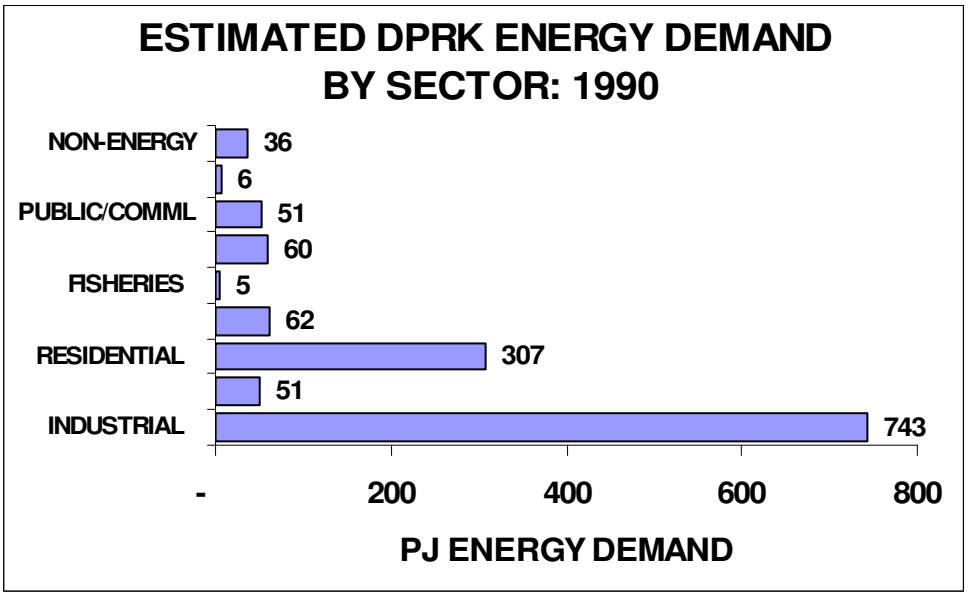

DPRK Military Energy Demand By Subsector: 1996
Buildings and Other
Military Manufacturing
Naval Forces
Air Force
Armaments
Trucks and other Transport
Coal
Petr. Prod.
Electricity
Wood
-
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
Terajoules (TJ)

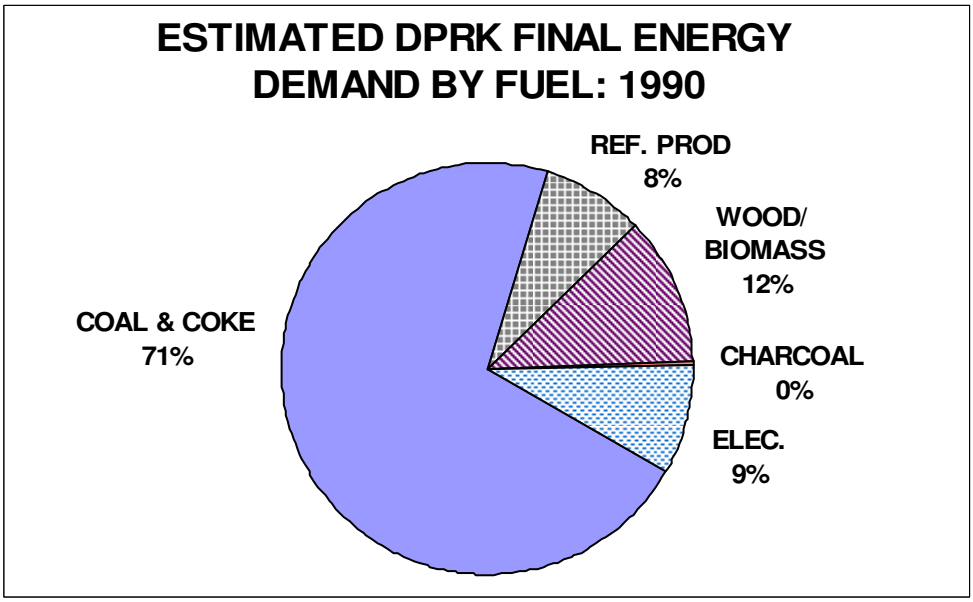

DPRK Military Energy Demand By Subsector: 2000
Buildings and Other
Military Manufacturing
Naval Forces
Air Force
Armaments
Trucks and other Transport
Coal
Petr. Prod.
Electricity
Wood
-
5,000
10,000
15,000
20,000
25,000
30,000
35,000
Terajoules (TJ)

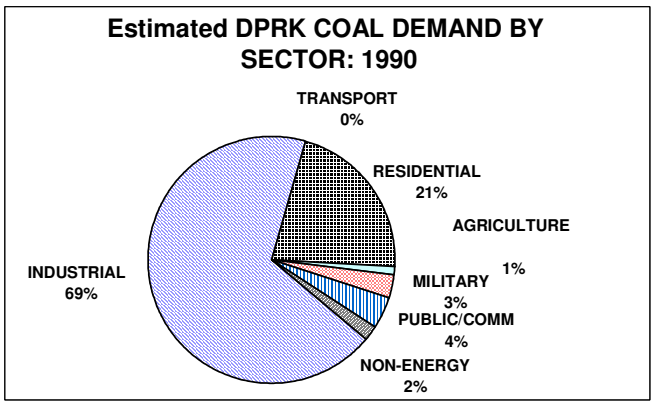

DPRK Military Energy Demand By Subsector: 2005
Buildings and Other
Military Manufacturing
Naval Forces
Air Force
Armaments
Trucks and other Transport
Coal
Petr. Prod.
Electricity
Wood
-
5,000
10,000
15,000
20,000
25,000
30,000
35,000
Terajoules (TJ)

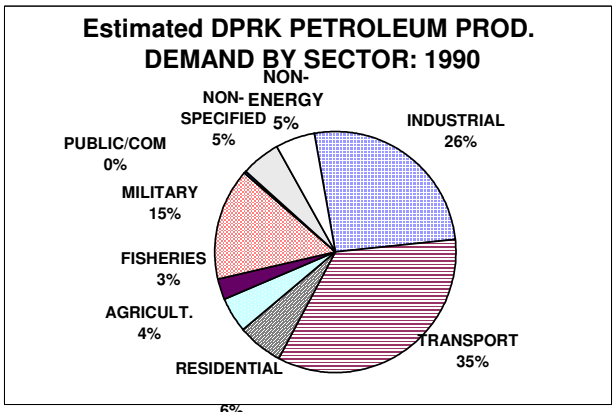

ESTIMATED DPRK ENERGY SUPPLY BY TYPE: 1990
WOOD/ BIOMASS 9%
HYDRO 11%
REFINED PROD 1%
CRUDE OIL 6%
COAL & COKE 78%

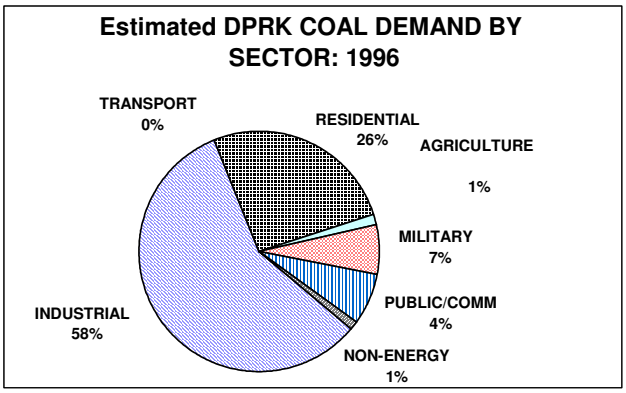

ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 1990
NON-ENERGY 3%
NON-SPECIFIED 0%
PUBLIC/COMML 4%
MILITARY 5%
FISHERIES 0%
AGRICULTURAL 5%
RESIDENTIAL 23%
INDUSTRIAL 56%
TRANSPORT 4%

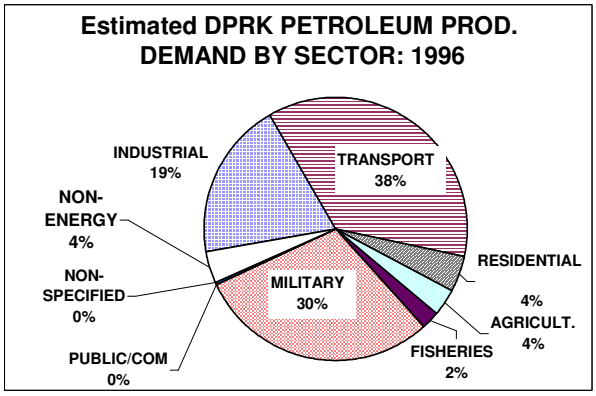

ESTIMATED DPRK ENERGY DEMAND BY SECTOR: 1990
NON-ENERGY
36
6
PUBLIC/COMML
51
60
FISHERIES
5
62
RESIDENTIAL
307
51
INDUSTRIAL
743
-
200
400
600
800
PJ ENERGY DEMAND

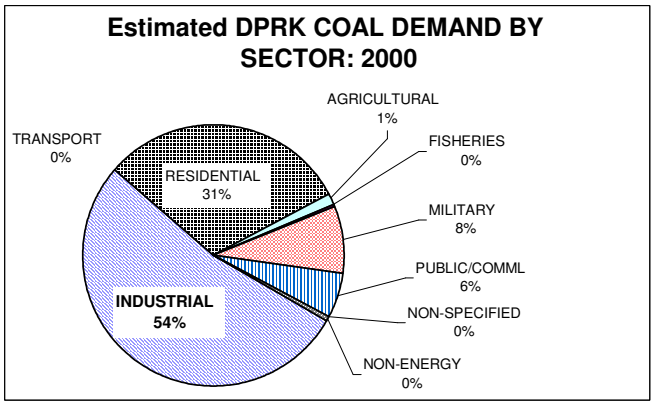

ESTIMATED DPRK FINAL ENERGY DEMAND BY FUEL: 1990
REF. PROD
8%
WOOD/
BIOMASS
12%
CHARCOAL
0%
ELEC.
9%
COAL & COKE
71%

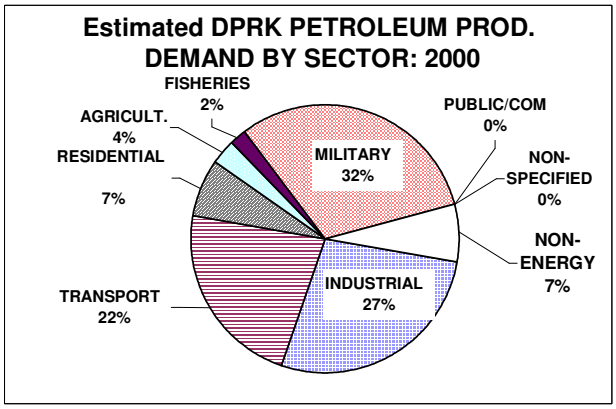

Estimated DPRK COAL DEMAND BY SECTOR: 1990
TRANSPORT
0%
RESIDENTIAL
21%
AGRICULTURE
1%
MILITARY
3%
PUBLIC/COMM
4%
NON-ENERGY
2%
INDUSTRIAL
69%

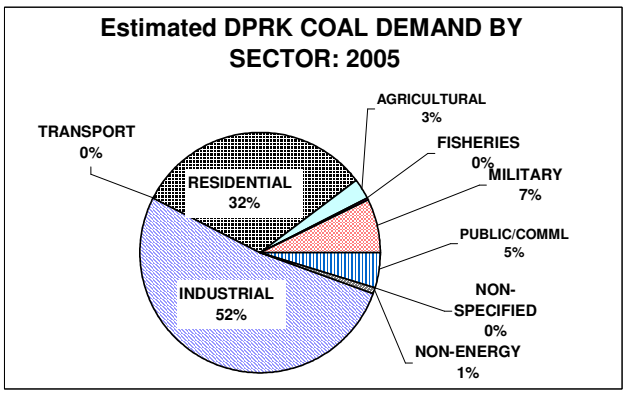

Estimated DPRK PETROLEUM PROD. DEMAND BY SECTOR: 1990
NON-
ENERGY
5%
NON-
SPECIFIED
5%
INDUSTRIAL
26%
PUBLIC/COM
0%
MILITARY
15%
FISHERIES
3%
AGRICULT.
4%
TRANSPORT
35%
RESIDENTIAL
6%

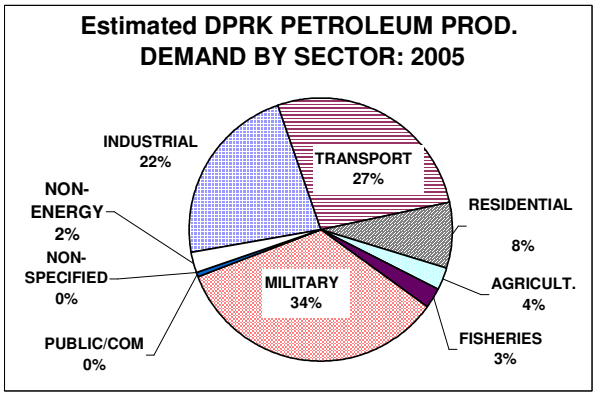

Estimated DPRK COAL DEMAND BY SECTOR: 1996
TRANSPORT 0%
RESIDENTIAL 26%
AGRICULTURE 1%
MILITARY 7%
PUBLIC/COMM 4%
NON-ENERGY 1%
INDUSTRIAL 58%

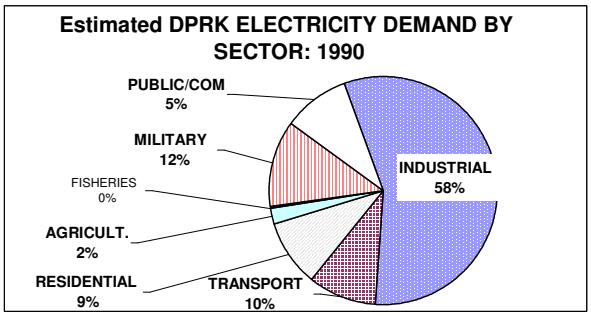

Estimated DPRK PETROLEUM PROD. DEMAND BY SECTOR: 1996
INDUSTRIAL 19%
TRANSPORT 38%
NON-ENERGY 4%
RESIDENTIAL 4%
NON-SPECIFIED 0%
MILITARY 30%
AGRICULT. 4%
PUBLIC/COM 0%
FISHERIES 2%

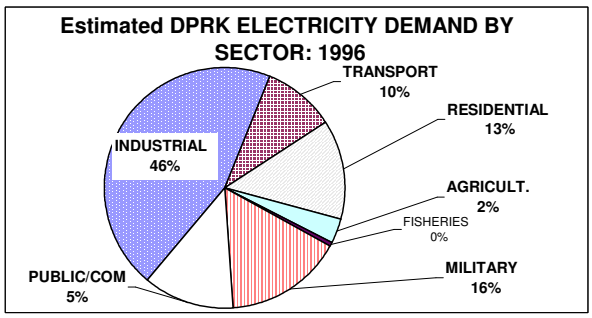

Estimated DPRK COAL DEMAND BY SECTOR: 2000
AGRICULTURAL 1%
TRANSPORT 0%
FISHERIES 0%
RESIDENTIAL 31%
MILITARY 8%
PUBLIC/COMML 6%
INDUSTRIAL 54%
NON-SPECIFIED 0%
NON-ENERGY 0%

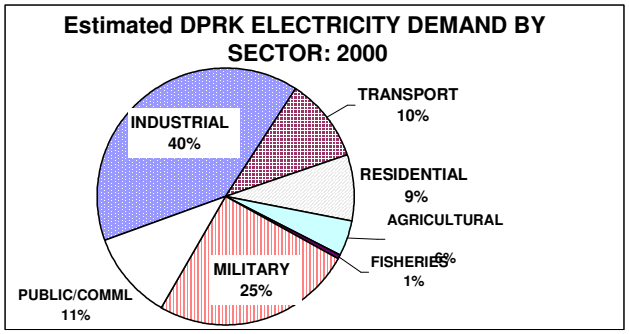

Estimated DPRK PETROLEUM PROD. DEMAND BY SECTOR: 2000
FISHERIES 2%
AGRICULT. 4%
PUBLIC/COM 0%
RESIDENTIAL 7%
MILITARY 32%
NON-SPECIFIED 0%
NON-ENERGY 7%
TRANSPORT 22%
INDUSTRIAL 27%

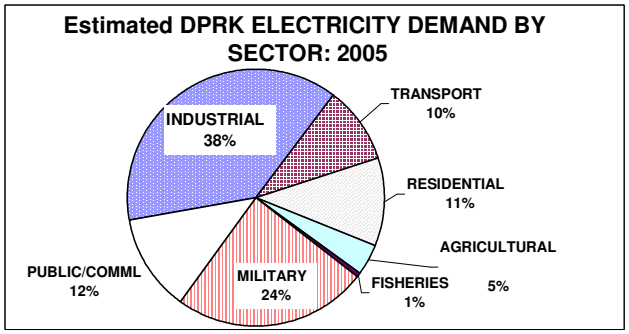

Estimated DPRK COAL DEMAND BY SECTOR: 2005
AGRICULTURAL 3%
TRANSPORT 0%
FISHERIES 0%
RESIDENTIAL 32%
MILITARY 7%
PUBLIC/COMML 5%
INDUSTRIAL 52%
NON-SPECIFIED 0%
NON-ENERGY 1%


Estimated DPRK PETROLEUM PROD. DEMAND BY SECTOR: 2005
INDUSTRIAL 22%
TRANSPORT 27%
NON-ENERGY 2%
RESIDENTIAL 8%
NON-SPECIFIED 0%
MILITARY 34%
AGRICULT. 4%
PUBLIC/COM 0%
FISHERIES 3%


Estimated DPRK ELECTRICITY DEMAND BY SECTOR: 1990
PUBLIC/COM 5%
MILITARY 12%
INDUSTRIAL 58%
FISHERIES 0%
AGRICULT. 2%
RESIDENTIAL 9%
TRANSPORT 10%


Estimated DPRK ELECTRICITY DEMAND BY SECTOR: 1996
TRANSPORT 10%
RESIDENTIAL 13%
INDUSTRIAL 46%
AGRICULT. 2%
FISHERIES 0%
PUBLIC/COM 5%
MILITARY 16%





DPRK Energy Supply By Fuel and Source: 1990
Units:Petajoules (PJ)

Source	Coal	Crude Oil	Ref. Prod.	Hydro	Wood
Domestic Production	1,292	-	-	80	147
Imports	68	111	27	-	12
Exports	(30)	-	-	-	-

DPRK Energy Supply By Fuel and Source: 1996
Units:Petajoules (PJ)

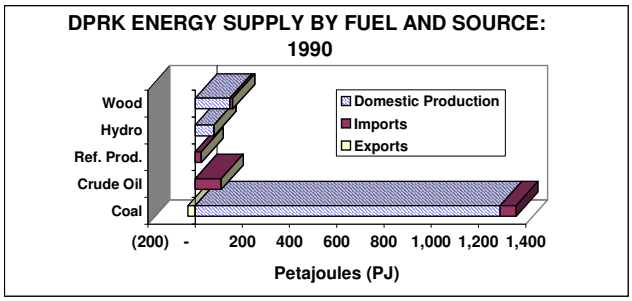
Source	Coal	Crude Oil	Ref. Prod.	Hydro	Wood
Domestic Production	643	-	-	20	135
Imports	12	40	39	-	12
Exports	(1)	-	-	-	(0)

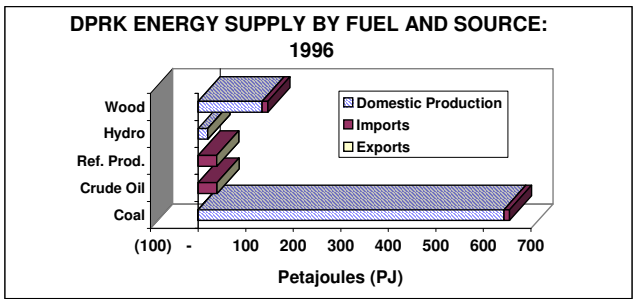
DPRK Energy Supply By Fuel and Source: 2000
Units:Petajoules (PJ)

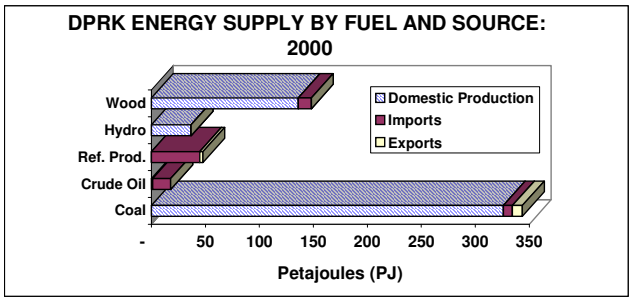
Source	Coal	Crude Oil	Ref. Prod.	Hydro	Wood
Domestic Production	326	1	-	37	136
Imports	8	17	45	-	12
Exports	9	-	3	-	0

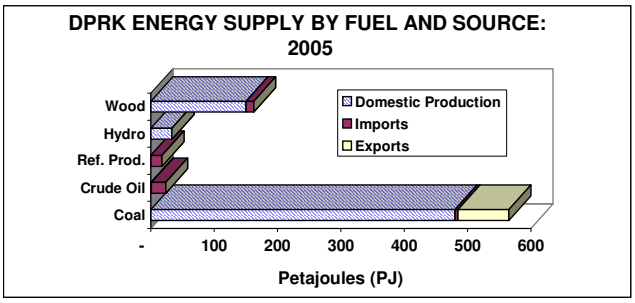
DPRK Energy Supply By Fuel and Source: 2005
Units:Petajoules (PJ)

Source	Coal	Crude Oil	Ref. Prod.	Hydro	Wood
Domestic Production	480	1	-	33	150
Imports	5	22	17	-	12
Exports	80	-	0	-	0







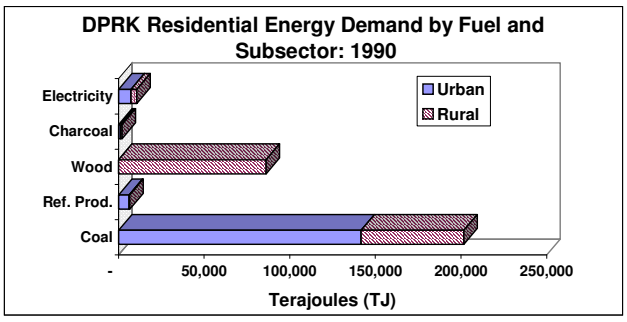


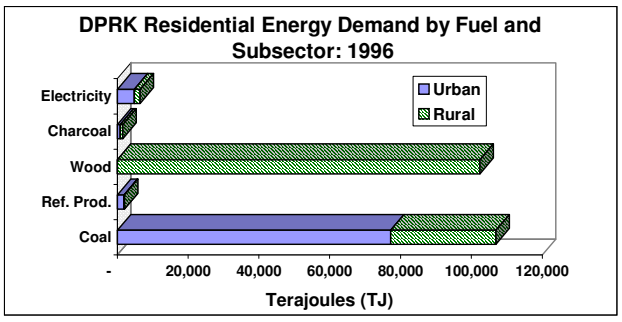
DPRK Residential Sector Energy Demand By Fuel and Subsector: 1990 and 1996

Units:Terajoules (TJ)	**1990**					**1996**				
Source	Coal	Ref. Prod.	Wood	Charcoal	Electricity	Coal	Ref. Prod.	Wood	Charcoal	Electricity
Urban	141,547	6,256	-	1,134	7,420	77,175	1,861	-	843	4,781
Rural	60,119	344	86,140	928	3,298	29,799	85	102,471	690	1,635

DPRK Residential Sector Energy Demand By Fuel and Subsector: 2000 and 2005

Units:Terajoules (TJ)	**2000**					**2005**				
Source	Coal	Ref. Prod.	Wood	Charcoal	Electricity	Coal	Ref. Prod.	Wood	Charcoal	Electricity
Urban	59,639	2,577	-	637	2,239	65,995	2,508	-	634	3,667
Rural	25,478	291	109,518	590	349	27,520	295	118,296	637	566





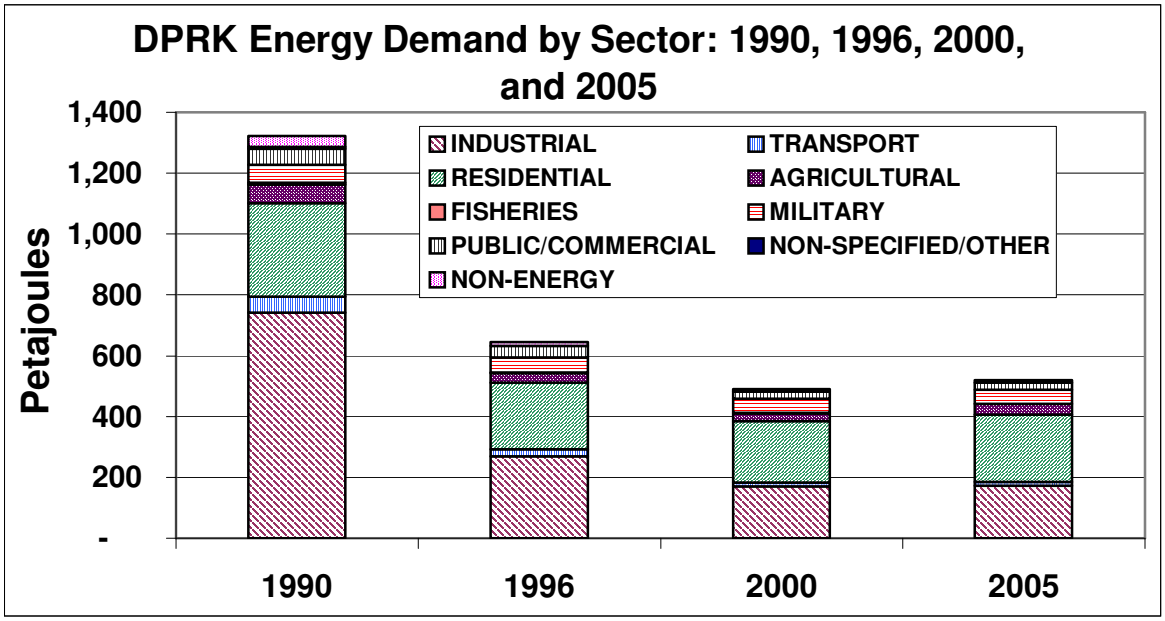
DPRK Energy Demand By Sector: 1990, 1996, 2000, and 2005

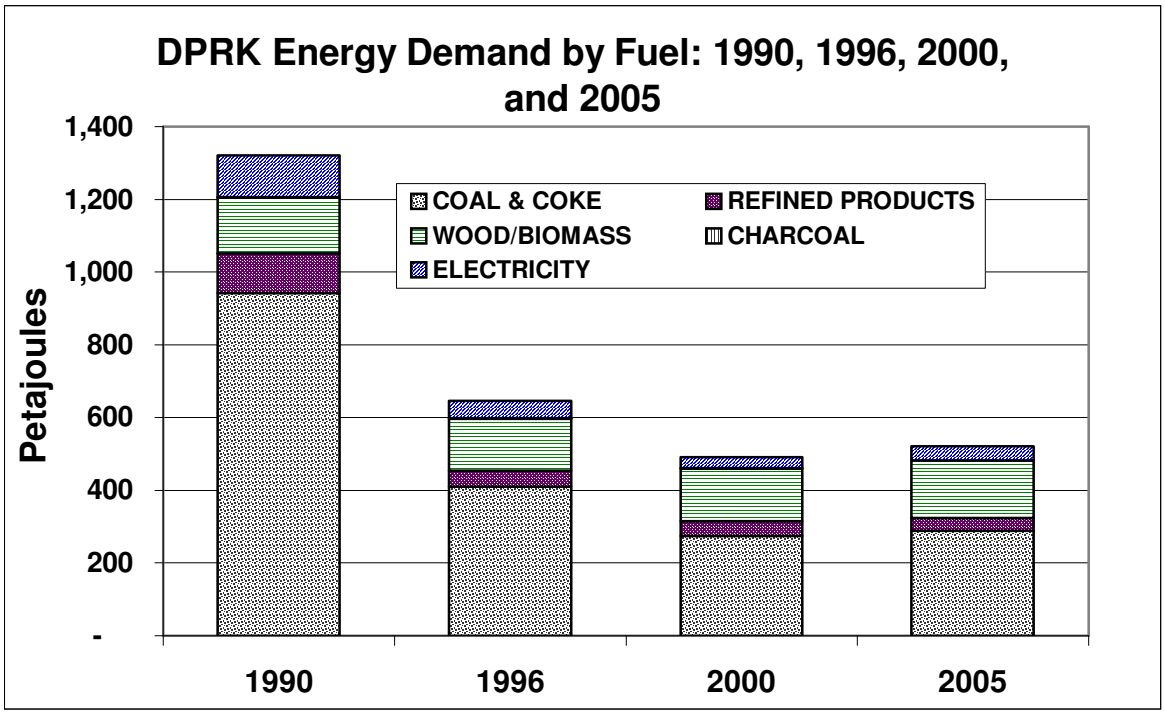
Units: Petajoules (PJ)

SECTOR	**1990**	**1996**	**2000**	**2005**
INDUSTRIAL	743	269	170	172
TRANSPORT	51	22	13	14
RESIDENTIAL	307	219	201	220
AGRICULTURAL	62	32	26	35
FISHERIES	5	2	1	2
MILITARY	60	50	47	46
PUBLIC/COMMERCIAL	51	38	22	23
NON-SPECIFIED/OTHER	6	-	-	-
NON-ENERGY	36	13	10	9
TOTAL	**1,322**	**646**	**491**	**520**

DPRK Energy Demand By Fuel Category: 1990, 1996, 2000, and 2005
Units: Petajoules (PJ)

SECTOR	1990	1996	2000	2005
COAL & COKE	942	409	275	289
REFINED PRODUCTS	109	45	41	35
WOOD/BIOMASS	152	142	144	158
CHARCOAL	2	2	1	1
ELECTRICITY	116	49	30	37
TOTAL	**1,322**	**646**	**491**	**520**





Estimates of Cost and Savings of Selected Energy Efficiency Measures

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

BACK-UP CALCULATIONS AND DATA: POTENTIAL ENERGY EFFICIENCY IMPROVEMENTS: END-USERS

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

BASED ON YEAR 2005 CONSUMPTION

Sources/Notes:

GENERAL ASSUMPTIONS/CONVERSION FACTORS			
Currency Conversion: 1990 Yuan to 1990 $US:	4.755		*Note 3*
Fraction of total investment represented by annualized CCE:	15%		*Note 4*
Inflator to convert 1990 costs to 2005 costs:	149%		*Note 18*
Energy Conversion Factor:	29.3	GJ/tce	
Energy Conversion Factor:	0.0036	GJ/kWh	

Sources/Notes:

Efficiency Improvements in Coal Fired Boilers: Industrial

Coal Use (Fuel) by Industrial Subsector

Subsector	Total TJ/yr	Fraction in Boilers & Furnaces	Total TJ/yr Boilers & Furnaces	
		Note 5		
Iron and Steel	51,776	60%	31,066	
Cement	23,985	100%	23,985	
Fertilizers	2,956	100%	2,956	*1*
Other Chemicals	2,224	100%	2,224	
Pulp and Paper	799	100%	799	
Other Metals	15,655	100%	15,655	
Other Minerals	3,528	100%	3,528	
Textiles	6,465	100%	6,465	
Non-specified Industry	21,754	100%	21,754	
Agricultural Processing	7,800	100%	7,800	
Military Manufacturing	399	100%	399	

TOTAL EST COAL USE IN BOILERS AND FURNACES		116,631	TJ/yr	
Fractional Savings Potential, Boilers and Furnaces:		37.5%		*6, 19*
ESTIMATED POTENTIAL COAL SAVINGS		43,737	TJ/yr	
Per Unit Upgrade Costs, Boilers and Furnaces		537	Yuan/(tce/yr)	*7*
Per Unit Upgrade Costs, Boilers and Furnaces	$	5.75	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$	251,337,262		

Coal Use in Small/Medium Boilers and Furnaces:

(Assumes that essentially all coal use is in boilers and furnaces)

Sector/Subsector	Total TJ/yr	Fraction in Boilers & Furnaces	TJ/yr in Boilers & Furnaces	
		Note 5		
Residential/Urban	59,639	90%	53,675	*2*
Public/Commercial	22,696	100%	22,696	
Military Buildings	15,373	100%	15,373	

TOTAL EST COAL USE IN BOILERS AND FURNACES		91,744	TJ/yr	
Fractional Savings Potential, Boilers and Furnaces:		23.0%		*8, 19*
ESTIMATED POTENTIAL COAL SAVINGS		21,101	TJ/yr	
Per Unit Upgrade Costs, Boilers and Furnaces		300	Yuan/(tce/yr)	*8*
Per Unit Upgrade Costs, Boilers and Furnaces	$	3.21	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$	67,700,723		
Fract. Savings Potent., Building Envelope Improvements:		20%		*12*
ESTIMATED POTENTIAL COAL SAVINGS		14,129	TJ/yr	
Per Unit Upgrade Costs, Building Envelope Improvements:		275	Yuan/(tce/yr)	*12*
Per Unit Upgrade Costs, Building Envelope Improvements:	$	2.94	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$	41,552,545		

Coal Use in Household cooking and heating stoves:

Residential/Rural Coal Use (TJ)		27,520	TJ/yr	
Residential/Urban Cooking Coal Use		5,964	TJ/yr	
TOTAL EST COAL USE IN DOMESTIC STOVES		33,484	TJ/yr	
Fractional Savings Potential, Domestic Stoves:		25.0%		*9*
ESTIMATED POTENTIAL COAL SAVINGS		8,371	TJ/yr	
Per Unit Upgrade Costs, Domestic Stoves		100	Yuan/(tce/yr)	*9*
Per Unit Upgrade Costs, Domestic Stoves	$	1.07	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$	8,952,534		

Electricity Use by Industrial Subsector: Motors and Drives

Subsector	Total TJ/yr	Fraction in Motors & Drives	Total TJ/yr Motors & Drives
		Note 10	
Iron and Steel	2,824	50%	1,412
Cement	1,561	95%	1,483
Fertilizers	2,370	50%	1,185
Other Chemicals	1,338	50%	669
Pulp and Paper	188	95%	179
Other Metals	2,773	20%	555
Other Minerals	222	95%	211
Textiles	559	95%	531
Non-specified Industry	2,307	80%	1,846
Agricultural Processing	1,443	95%	1,154
Military Manufacturing	21	80%	20

TOTAL EST ELECT USE, IND. MOTORS & DRIVES		9,245	TJ/yr	
Fractional Savings Potential, Motor Improvements		15.0%		*11, 19*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS		1,387	TJ/yr	
Per Unit Upgrade Costs, Electric Motors		0.10	Yuan/kWh	*11*
Per Unit Upgrade Costs, Electric Motors	$	58.03	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$	80,470,054		

Electricity Use in Other Sectors: Motors and Drives

Sector/Subsector	Total TJ/yr	Fraction in Motors & Drives	Total TJ/yr Motors & Drives
	Note 10		
Residential/Urban	2,239	10%	224
Public/Commercial	7,538	30%	2,262
Military Buildings	3,383	30%	1,015

TOTAL EST ELECT USE, IND. MOTORS & DRIVES	3,500	TJ/yr	
Fractional Savings Potential, Motor Improvements	15.0%		*11*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS	525	TJ/yr	
Per Unit Upgrade Costs, Electric Motors	0.10	Yuan/kWh	*11*
Per Unit Upgrade Costs, Electric Motors	$ 58.03	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$ 30,468,941		

Electricity Use: Lighting

Sector/Subsector	Total TJ/yr	Fraction in Lighting	Total TJ/yr Lighting
	Note 13		
Industrial (All)	11,961	5%	598
Residential/Rural	349	40%	140
Residential/Urban	2,239	40%	896
Public/Commercial	7,538	50%	3,769
Military Buildings	3,383	50%	1,692

TOTAL EST ELECT USE, RESIDENTIAL LIGHTING	1,035	TJ/yr	
Fractional Savings Potential, Lighting Improvements	48.0%		*14*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS	497	TJ/yr	
Per Unit Costs: CFL Replacement of Incandescent	0.10	Yuan/kWh	*14*
Per Unit Upgrade Costs, Residential Lighting	$ 58.03	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$ 28,840,921		
TOTAL EST ELECT USE, NON-RESIDENTIAL LIGHTING	6,059	TJ/yr	
Fractional Savings Potential, Lighting Improvements	50.0%		*15*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS	3,029	TJ/yr	
Per Unit Costs: CFL Replacement of Incandescent	0.015	Yuan/kWh	*15*
Per Unit Upgrade Costs, Residential Lighting	$ 41.39	/(GJ/yr) ($2005)	
TOTAL EST. ENERGY EFFICIENCY INVESTMENT	$ 125,386,277		

Petroleum Fuel Use: Medium-Sized Trucks

Fuel Use: Civilian Transport/Freight (gasoline trucks only)	1,832	TJ/yr	
Freight transported by gasoline trucks	3.40E+08	te-km	
Average tonne-km per vehicle/yr	15,000	te-km	*Rough Est.*
Implied number of 2.5 tonne trucks in use (civilian):	22,680		
Fuel Use: Military Trucks (2 1/2 tonne only)	4,957	TJ/yr	
Total number 2 1/2 tonne military trucks in active service	46,261		
Total number of 2.5 tonne trucks in service:	68,941		
Fraction of trucks to be replaced	66%		*Rough Est.*
Fraction of energy use represented by trucks replaced	90%		*Rough Est.*
Fractional energy savings by replacing trucks	43%		*16*
TOTAL ENERGY SAVED	2,651	TJ/yr	
Cost per truck to replace	$ 20,000		*17*
TOTAL COST OF NEW TRUCKS	$ 910,015,011		

Sources/Notes:

1 *Total coal use shown here does not include coal used as a non-energy feedstock in carbide production.*

2 *Assumes 10 percent or less of urban coal use is burned in individual cooking stoves*

3 *1990 Value from Microsoft Encarta, 1994.*

4 *Assumes 12 percent discount rate and average 15 year lifetime for energy efficiency investments. J. Sathaye (1992), "Economics of Improving Efficiency of China's Electricity Supply and Use: Are Efficiency Investments Cost-effective?" (LBL--In draft form as of May 1992).*

5 *End-use fractions are rough assumptions*

6 *Assumes the following measures: Microcomputer control (8% increase in efficiency), insulation of piping (responsible for heat loss equal to 10% of energy use), and rennovation of boilers & furnaces (10 -15% increase in efficiency). Overall, assumes increase in average boiler energy efficiency from 50% to 65 or 70%, plus additional savings from other measures. 50% initial (existing boiler) efficiency estimate from document in authors' files [R1]. Savings fractions and costs for measures taken from China studies: M.Levine, L.Xueyi, "Energy Conservation Programs in the PRC", Aug, 1990, LBL-29211; D. Yande, "An Analysis of the Potential in Investment-Cum-Energy Conservation in Chemical Industry in China"; and Levine et al, "China's Energy System: Historical Evolution, Current Issues, and Prospects", Ann. Rev Energy Environ., 1992, 17:405-435. Note that the savings potential assumed here, 37.5%, comports with the estimate (UN document) that the conservation potential in DPRK is 30 to 50% (and further, up to 20% can be saved at "little or no cost").*

7 *Assumes (based on sources in 6) 8% increase in efficiency from microprocessor controls at investment of 1200 Y/tce-yr, 10% increase for insulation of piping (and similar furnace improvements) at 412 Y/tce-yr, and 12% increase for boiler and furnace rennovation at 200 Y/tce-yr.*

8 *Assumes (based roughly on sources in 6) that a 15% efficiency increase with general boiler rennovations, starting from an average efficiency of 50%, is available for an investment of 250 Y/(tce/yr) (20 percent higher than value estimated for industrial boilers in Levine et al).*

9 *Various estimates place the efficiency of chinese coal stoves/heaters at anywhere from 20 to 50 percent. We have assumed that efficiency measures can increase the thermal efficiency of individual rural stove/heaters and urban stoves from ave. of 30% to 40%, for a 25% reduction in coal use. Doc. in authors' files [R1] cites an estimated DPRK residential coal-fired heating stove efficiency of 30%, and cooking stove efficiency of 20%. Efficiency investment of 100 Y/tce for domestic coal burning improvements from Levine et al (1992--see note 6). It is not clear exactly which measures these improvements include; likely candidates include coal briquetting and stove technology improvements.*

10 *Values are rough estimates. By way of comparison, 65 percent of the electricity used in the entire Chinese economy has been estimated to be consumed in electric motors (Sathaye, 1992).*

11 *Assumes (based on Chinese experience) that motors can be upgraded from an average efficiency of 75% to an efficiency of 88% (the latter is close to standard US motors) at a (per unit) cost of 0.1 Y/kWh. Costs and efficiency improvements from Sathaye, 1992. Note that other improvements such as variable speed electronic drives, improved valving and gearing, piping retrofits represent substantial additional savings potential.*

12 *Based on Chinese studies, assumes a 20% increase in thermal performance through two measures:* a 30mm perlite cement mortar coat on inside of walls plus double glazing. Costs based on estimated *Payback of 2-3 years and market coal price of 110Y/tce. Source: S. Lang et al, "Energy Conservation Standards for Spare Heating in Chinese Residential Buildings", 1992, LBL. Note that these two simple measures do not begin to exhaust the cost effective measures available for building shell improvements. Other estimates based on the Chinese situation show that 30 percent improvements in building energy efficiency are possible for a modest 5% increase in building costs. (Source: "An Overview of Energy Demand and Supply in China", F. Liu et al, 1992 (LBL).)*

13 *Rough estimates. For comparison, lighting comprises about 28% of household electricity use in Thailand, and 33% in the FSU, but in both cases use of household appliances, including cooling, refrigeration, and electric water and space heating, probably account for a larger fraction of energy use than in DPRK homes. Nautilus' 1998 rural energy survey suggested that lighting comprised over 50 percent of total electricity use in the households in one rural village.*

14 Assumes that 80% of residential lighting energy is used in incandescent bulbs, that compact fluorescent (CFL) bulbs save 75% of the energy of incandescent bulbs, and that CFLs can be used to replace incandescent bulbs for roughly 80 percent of residential incandescent bulb lighting use. Costs based on Sathaye, 1992, and are based on setting up CFL factory in China at an investment cost of $5M to produces 3 million CFLs per year at roughly 6.9Y/unit. Note that extensive use of CFLs will require that DPRK power grid be upgraded to reduce voltage fluctuations and improve power factors. An addendum to this estimate is that the DPRK apparently has placed CFLs, reportedly made in the DPRK, in virtually all DPRK households during approximately 2005 - 2006. The DPRK reportedly deployed both imported bulbs, including bulbs made by Phillips, but over time have developed DPRK-based manufacturing. News of this program is based on a report provided by the DPRK delegation attending the 2006 "Asian Energy Security" workshop organized by Nautilus with EETC of Tsinghua University, Beijing (November, 2006).

15 Assumption based primarily on industrialized-country costs (as in Von Hippel and Verzola, 1994).

16 Estimated based on our estimates for the fuel economy of 2 1/2 tonne trucks in the DPRK military and quoted estimate from US Isuzu truck vendor for average fuel economy of new 2 1/2 tonne Isuzu (diesel) truck (11 miles per gallon). Adjustment has been made for higher fuel energy content of diesel (vs. gasoline).

17 Cost of 2 1/2 tonne Isuzu truck in US was approximately $30,000 in the mid-1990s, but is likely at least double that as of 2005. Assuming that a large portion of the price is profit for the vendor, import duties, and profit for Isuzu, and further, that the cost of producing similar trucks in the DPRK (for example, under license to Isuzu) will be lower than in Japan due to lower wage rates and factor prices, we have estimated a cost per truck of $20,000 US (2005 dollars). This may still be too high, as the average value of trucks imported to the DPRK from China in 2005 was under $10,000 (though some or many of these units may have been used).

18 See, for example, "Inflation Calculator" on http://data.bls.gov/cgi-bin/cpicalc.pl.

19 The savings figures shown here may well be conservative (low) for DPRK conditions. In his presentation "Energy Efficiency Activities in the DPRK and Opportunities for Rationalization of Energy Use", prepared as prepared for the DPRK Energy Experts Working Group Meeting, June 26th and 27th, 2006, Palo Alto, CA, USA). Prof. Jan Jasiewicz notes the results of energy audits in industrial installations in the DPRK where potential savings were found to be between 15 and 60 percent, with payback times (presumably under market prices for energy commodities) of less than three years.

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

BACK-UP CALCULATIONS AND DATA: POTENTIAL ENERGY EFFICIENCY IMPROVEMENTS: ELECTRICITY SUPPLY

Prepared By David Von Hippel
Date Last Modified: 3/8/2007

BASED ON YEAR 2005 ACTIVITIES

GENERAL ASSUMPTIONS/CONVERSION FACTORS			
Currency Conversion: 1990 Yuan to 1990 $US:	4.755		*Note 1*
Fraction of total investment represented by annualized CCE:	15%		*Note 2*
Inflator to convert 1990 costs to 2005 costs:	149%		*Note 10*
Energy Conversion Factor:	29.3	GJ/tce	
Energy Conversion Factor:	0.0036	GJ/kWh	

Sources/Notes:

Electricity Supply Improvements:

Coal and HFO Consumption in Electricity Generation Boilers	92,675	TJ/yr	
Fractional Savings Potential, Boilers:	30.0%		*3*
ESTIMATED POTENTIAL COAL/HFO SAVINGS	27,803	TJ/yr	
Per Unit Upgrade Costs, Boilers	537	Yuan/(tce/yr)	*3*
Per Unit Upgrade Costs, Boilers	$ 5.75	/(GJ/yr) ($2005)	
ESTIMATED ENERGY EFFICIENCY INVESTMENT: Boilers	$ 159,770,366		

Own Use of electricity in Coal and HFO-Fired Power Plants	898	TJ/yr	
Potential reduction in "Own Use" in Coal/HFO-Fired Plants:	50.0%		*4*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS	449	TJ/yr	
Per Unit Upgrade Costs, Plant Self-Use	0.12	Yuan/kWh	
Per Unit Upgrade Costs, Plant Self-Use	$ 69.63	/(GJ/yr) ($2005)	
ESTIMATED ENERGY EFFICIENCY INVESTMENT: Self Use	$ 46,605,034		

Emergency Losses of electricity in Coal/HFO-Fired Power Plants	891	TJ/yr	
Potential red. in Emergency Losses in Coal-Fired Plants:	90%		*6*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS	802	TJ/yr	
Per Unit Upgrade Costs, Reduction in Emergency Losses	0.075	Yuan/kWh	*6*
Per Unit Upgrade Costs, Reduction in Emergency Losses	$ 43.52	/(GJ/yr) ($2005)	
EST. ENERGY EFFICIENCY INVESTMENT: Emer. Losses	$ 34,914,913		

Transmission and Distribution Losses of Electricity	12,464	TJ/yr	*7*
Potential reduction in Transmission and Distribution Losses:	37.5%		*5*
ESTIMATED POTENTIAL ELECTRICITY SAVINGS	4,674	TJ/yr	
Per Unit Upgrade Costs, Electricity T&D	0.075	Yuan/kWh	*5*
Per Unit Upgrade Costs, Electricity T&D	$ 43.52	/(GJ/yr) ($2005)	
ESTIMATED ENERGY EFFICIENCY INVESTMENT: T&D	$ 203,415,501		

DPRK Wind Power Resource	???	MW	
Total Wind Power Generation Implemented, 2003 to 2012	500	MW	
Capacity factor of Wind generators	25%		*7*
Energy Produced by Wind Generators (year 10)	1,095	GWhe/yr	
Energy Produced by Wind Generators (year 10)	3,942	TJ/yr	
Capital Cost of Wind Generators (per unit capacity)	$ 596	per kW	*8*
Variable Operations and Maintenance Costs	$ 0.015	per KWhe	*9*
Total Capital Costs of installed Wind Generators	$ 298,000,000		
Total of Other Generation Costs (year 10)	$ 16,315,500	per yr ($2005)	

Sources/Notes:

1 *1990 Value from Microsoft Encarta, 1994.*

2 *Assumes 12 percent discount rate and average 15 year lifetime for energy efficiency investments. J. Sathaye (1992), "Economics of Improving Efficiency of China's Electricity Supply and Use: Are Efficiency Investments Cost-effective?" (LBL--In draft form as of May 1992).*

3 *Assumes the following measures: Microcomputer control (8% increase in efficiency), insulation of piping (responsible for heat loss equal to 10% of energy use), and rennovation of boilers (10 -15% increase in efficiency). Overall, assumes increase in average boiler energy efficiency from 55-60% to 75-80%. Savings fractions and costs for measures taken from China studies on industrial boilers; we assume similar savings will be available for DPRK utility boilers (probably at a lower price, due to economies of scale). Sources: M.Levine, L.Xueyi, "Energy Conservation Programs in the PRC", Aug, 1990, LBL-29211; D. Yande, "An Analysis of the Potential in Investment-Cum-Energy Conservation in Chemical Industry in China"; and Levine et al, "China's Energy System: Historical Evolution, Current Issues, and Prospects", Ann. Rev Energy Environ., 1992, 17:405-435.*
Note that the savings potential assumed here, 30%, comports with the estimate (UN document) that the conservation potential in DPRK is 30 to 50% (and further, up to 20% can be saved at "little or no cost").

4 *Assumes Own use can be reduced from current (estimated) 9.0% to 4.5% of gross generation. Savings fraction range and cost range from Sathaye, 1992.*

5 *Assumes Transmission and Distribution losses can be reduced from current (reported) 16% to 10% of net generation. Savings fraction range and cost range from Sathaye, 1992.*

6 *Assumes that emergency losses can be nearly eliminated by plant and T&D improvements, and that measures to reduce emergency losses will be available at a cost per kWh saved similar to that for transmission and distribution improvements. In fact, reduction in emergency losses may occur as a result of boiler and T&D improvements even without any additional outlay.*

7 *Rough estimate. By way of comparison, Cavallo, Hock and Smith ("Wind Energy: Technology and Economics", in Renewable Energy, Sources for Fuels and Electricity, T.B. Johansson et al, 1993. Island Press, Washington, DC) cite capacity figures of 25 and 26.7 percent for California and Denmark, respectively.*

8 *Assumes that wind machines can be produced in DPRK under license to an existing manufacturer, or can be imported from manufacturers i n developing or former East Bloc nations. For comparison, Martinot (draft dissertation summary ,1994) cites a cost of about $280/kW for 110 kW machines manufactured under license in the Ukraine, and Cavallo, Hook, and Smith (source as in 7) give a figure of $760/kW for US manufactured machines.*

9 *Based on data from California (source as above). Since much of the O&M required on wind machines is labor-intensive as opposed to material-intensive, these costs may well be less in the DPRK.*

10 *See, for example, "Inflation Calculator" on http://data.bls.gov/cgi-bin/cpicalc.pl.*

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

BACK-UP CALCULATIONS AND DATA:
POTENTIAL ENERGY EFFICIENCY IMPROVEMENTS: SUMMARY

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

BASED ON YEAR 2005 ACTIVITIES

Inflator for 2005 to 2005 (*Note 1*):	1.000

MEASURES TO SAVE COAL:

Measure	Estimated Energy Energy Savings Potential, TJ/yr		Total Estimated Investment Cost, $US 2005
Industrial Boiler and Furnace Improvements	43,737		$ 251,337,262
Residential and Public/Commercial/Military Boiler Impr.	21,101		$ 67,700,723
Building Envelope Improvements	14,129		$ 41,552,545
Domestic Stove/Heater Improvements	8,371		$ 8,952,534
Electric Utility Boiler Improvements	27,803		$ 159,770,366
TOTALS	115,140	TJ/yr	$ 529,313,431
Avoided Losses of Coal During Transport:	1,151	TJ/yr	
TOTAL COAL SUPPLY SAVINGS	116,291	TJ/yr	
Fraction of 2005 Total Coal Supply	28.7%		
Investment required, $ per GJ/yr of Coal Supply Savings			**$ 4.55**
Investment required, $ per tce/yr of Coal Supply Savings			**$ 133**

MEASURES TO SAVE/GENERATE ELECTRICITY:

Measure	Estimated Energy Energy Savings Potential, TJ/yr		Total Estimated Investment Cost, $US 2005
Industrial Motors and Drives	1,317		$ 76,400,152
Motors and Drives in other Sectors	525		$ 30,468,941
Residential Lighting	497		$ 28,840,921
Non-residential Lighting	3,029		$ 125,386,277
Own Use reduction in Power Plants	449		$ 46,605,034
Reduction of Emergency Use in Power Plants	802		$ 34,914,913
Transmission and Distribution Improvements	4,674		$ 203,415,501
Wind-powered Electricity Generation	3,942		$ 298,000,000
TOTALS	15,235	TJ/yr	$ 844,031,739
Additional Avoided T&D Losses (based on 2005 Rates)	1,488	TJ/yr	
TOTAL ELECTRICITY SUPPLY SAVINGS/GENERATION	16,724	TJ/yr	
Fraction of 2005 Total Electricity Generation	28.1%		
Investment required, $ per GJ/yr of Electricity Supply Savings/Generation			**$ 50.47**
Investment required, $ per MWh/yr of Electricity Supply Savings/Generation			**$ 182**

MEASURE TO SAVE PETROLEUM PRODUCTS:

Measure	Estimated Energy Energy Savings Potential, TJ/yr	Total Estimated Investment Cost, $US 2005
Improvements in 2 1/2 tonne truck fleet	2,651	$ 910,015,011
Fraction of 2005 Total Refined Products Use	7.6%	
Fract. of 2005 Total Refined Prod. Use in Road Transport	36.1%	
Investment required, $ per GJ/yr of refined products Savings		**$ 343.30**
Investment required, $ per toe/yr of petroleum products Savings		**$ 14,364**

ESTIMATED EMISSIONS REDUCTION (Rough Calculations)

	Sulfur Oxides (tonnes)	Nitrogen Oxides (tonnes)	Carbon Dioxide (tonnes)
MEASURES TO SAVE COAL	47,438	29,552	7,404,117
MEASURES TO SAVE ELECTRICITY	15,446	9,708	2,450,004

Sources/Notes:

1 *Not used--costs already updated to 2005 USD in efficiency estimates worksheets.*

Estimates of Acid Gas and Greenhouse Gas Emissions

NAUTILUS INSTITUTE

ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

ESTIMATED GHG AND ACID GAS EMISSIONS FROM FUELS PRODUCTION AND COMBUSTION FOR THE YEAR 1990

Prepared By David Von Hippel
Date Last Modified: 3/12/2007

EMISSION FACTORS: kg/GJ fuel combustion/production

GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	*Notes*
Carbon Dioxide from Combustion	95.3	73.08	0	0	*1,4*
Methane from Combustion	0.0017	0.01	0.016	0.001867	*1,2*
Methane from Production	0.534	0	0	0.084	*1,3*
Nitrous Oxide from Combustion	0.0045	0.0035	0.007	0.007	*1,2*
Sulfur Oxides from Combustion	0.611	0.299	0	0	*4,5*
Nitrogen Oxides from Combustion	0.38	0.24	0.121	0.121	*1,2,6*

SUMMARY EMISSIONS RESULTS: Tonnes of Emissions by Fuel

	1990				
GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	TOTAL
Carbon Dioxide from Combustion	**1.18E+08**	**8.72E+06**	**0.00E+00**	**0.00E+00**	**1.26E+08**
Methane from Combustion	**2.10E+03**	**1.19E+03**	**2.18E+03**	**3.85E+00**	**5.48E+03**
Methane from Production	**7.10E+05**	**0.00E+00**	**0.00E+00**	**1.75E+02**	**7.10E+05**
Nitrous Oxide from Combustion	**5.55E+03**	**4.18E+02**	**9.55E+02**	**4.84E+01**	**6.97E+03**
Sulfur Oxides from Combustion	**7.53E+05**	**3.57E+04**	**0.00E+00**	**0.00E+00**	**7.89E+05**
Nitrogen Oxides from Combustion	**4.69E+05**	**2.85E+04**	**1.65E+04**	**8.37E+02**	**5.15E+05**

Tonnes of Emissions by Balance Category

	CARBON DIOXIDE	METHANE	NITROUS OXIDE	SULFUR OXIDES	NITROGEN OXIDES
TOTAL	**1.26E+08**	**7.15E+05**	**6.97E+03**	**7.89E+05**	**5.15E+05**
ENERGY SUPPLY	0.00E+00	7.10E+05	0.00E+00	0.00E+00	0.00E+00
Domestic Production	0.00E+00	6.89E+05	0.00E+00	0.00E+00	0.00E+00
Imports	0.00E+00	3.65E+04	0.00E+00	0.00E+00	0.00E+00
Exports	0.00E+00	1.62E+04	0.00E+00	0.00E+00	0.00E+00
ENERGY TRANSF.	3.15E+07	9.78E+02	1.52E+03	1.97E+05	1.25E+05
Electricity Generation	3.10E+07	7.44E+02	1.47E+03	1.95E+05	1.23E+05
Petroleum Refining	4.35E+05	5.96E+01	2.08E+01	1.78E+03	1.42E+03
Coal Prod./Prep.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Charcoal Production	0.00E+00	1.75E+02	3.40E+01	0.00E+00	5.87E+02
Own Use	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Losses	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENERGY DEMAND	9.48E+07	4.67E+03	5.45E+03	5.92E+05	3.90E+05
INDUSTRIAL	6.25E+07	1.28E+03	2.96E+03	3.98E+05	2.49E+05
TRANSPORT	2.76E+06	4.07E+02	1.45E+02	1.13E+04	9.26E+03
RESIDENTIAL	1.97E+07	1.79E+03	1.55E+03	1.25E+05	8.90E+04
AGRICULTURAL	1.30E+06	7.86E+02	3.76E+02	7.45E+03	1.03E+04
FISHERIES	3.37E+05	3.33E+01	1.61E+01	1.63E+03	1.18E+03
MILITARY	4.05E+06	2.15E+02	1.92E+02	2.31E+04	1.53E+04
PUBLIC/COMML	3.68E+06	9.79E+01	1.87E+02	2.35E+04	1.49E+04
NON-SPECIFIED	4.31E+05	5.90E+01	2.07E+01	1.77E+03	1.41E+03
NON-ENERGY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes/Sources:

1 *Carbon dioxide emission factors for coal and refined products, and all wood and charcoal factors From Greenhouse Gas Inventory Workbook: IPCC Draft Guidelines for National Greenhouse Gas Inventories, Volume 2. IPCC/OCED Joint Programme, published by UNEP/WMO. "Final Draft" Version*

2 *Most non-CO_2 emission factors derived from a variety of sources used by the authors in earlier work.*

3 *Production of methane from coal mining assumes a mid range estimate (from source 1) for production and post-mining emissions of 14 cubic meters methane per tonne of coal.*

4 *SO_x, CO_2 emission factors for wood/biomass and charcoal considered to be zero on the assumption that biomass fuels are used sustainably in the DPRK and have negligible sulfur contents.*

5 *SO_x emission factor for petroleum products estimated as shown below. SO_x emission factor for coal combustion assumes that lignite coal is 0.5% sulfur, anthracite is 0.75% sulfur by weight. Analyses of coal from the Anju field (lignite) show sulfur contents ranging from 0.2 to 1.2 %S (Document in authors' files [HA1-VO1]). All of the sulfur in both oil-based and coal fuels is assumed to be emitted as SO_x. Sulfur contents for petroleum products are generally taken from Kato, et al (1991) Analysis of the Structure of Energy Consumption and the Dynamics of Emissions of Atmospheric Species Related to the Global Environmental Change (SO_x, NO_x, and CO_2) in Asia. NISTEP Report No. 21, page 37.*

6 *NO_x emission factors for coal are derived from Kato et al, 1991 (reference as in 5, p. 39) assuming NO_x factors of 7.5 kg/te for anthracite, 6.38 kg/te for brown coal. These are listed as factors for industry, and are assumed to be representative. NO_x factors for coal-fired utility boilers are shown in the source document as somewhat higher than these figures, and factors for residential coal consumption are lower. NO_x emission factors for petroleum products were assumed to be 10 kg/te. NO_x emission factors vary considerably by fuel type and usage (NO_x from transport fuels is an order of magnitude higher than from residential fuels, for example); the figure used here is a central estimate of factors listed in Kato et al, 1991, page 41.*

ESTIMATE OF AGGREGATE SOx EMISSION FACTOR FOR REFINED PRODUCTS

Product	kTOE	TE/TOE	kTE	%S
Gasoline	730	1.07	781	0.12
Diesel	770	1.035	797	0.4
Heavy Oil	1,070	0.96	1027	1.5
Kerosene/Jet Fuel	262	1.045	274	0.032
LPG	278	1.13	314	0.00016
Aviation Gasoline	26	1.07	28	0.04
Weighted Average: Sulfur content in kg/GJ				**0.150**
Fraction of Sulfur emitted as SO_x				100%
Mass ratio of SO_x (as SO_2) to S				2
Weighted Average SO_x emission factor: kg/GJ				**0.299**

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

ESTIMATED GHG AND ACID GAS EMISSIONS FROM FUELS PRODUCTION AND COMBUSTION FOR THE YEAR 1996

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

EMISSION FACTORS: kg/GJ fuel combustion/production

GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	*Notes*
Carbon Dioxide from Combustion	95.3	73.82	0	0	*1,4*
Methane from Combustion	0.0017	0.01	0.016	0.001867	*1,2*
Methane from Production	0.534	0	0	0.084	*1,3*
Nitrous Oxide from Combustion	0.0045	0.0035	0.007	0.007	*1,2*
Sulfur Oxides from Combustion	0.611	0.377	0	0	*4,5*
Nitrogen Oxides from Combustion	0.38	0.24	0.121	0.121	*1,2,6*

SUMMARY EMISSIONS RESULTS: Tonnes of Emissions by Fuel

	1996				
GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	TOTAL
Carbon Dioxide from Combustion	**5.83E+07**	**4.61E+06**	**0.00E+00**	**0.00E+00**	**6.29E+07**
Methane from Combustion	**1.04E+03**	**6.27E+02**	**2.09E+03**	**2.86E+00**	**3.76E+03**
Methane from Production	**3.49E+05**	**0.00E+00**	**0.00E+00**	**1.28E+02**	**3.49E+05**
Nitrous Oxide from Combustion	**2.75E+03**	**2.20E+02**	**9.13E+02**	**3.57E+01**	**3.92E+03**
Sulfur Oxides from Combustion	**3.73E+05**	**2.09E+04**	**0.00E+00**	**0.00E+00**	**3.94E+05**
Nitrogen Oxides from Combustion	**2.33E+05**	**1.50E+04**	**1.58E+04**	**6.17E+02**	**2.64E+05**

Tonnes of Emissions by Balance Category

	CARBON DIOXIDE	METHANE	NITROUS OXIDE	SULFUR OXIDES	NITROGEN OXIDES
TOTAL	**6.29E+07**	**3.53E+05**	**3.92E+03**	**3.94E+05**	**2.64E+05**
ENERGY SUPPLY	0.00E+00	3.49E+05	0.00E+00	0.00E+00	0.00E+00
Domestic Production	0.00E+00	3.43E+05	0.00E+00	0.00E+00	0.00E+00
Imports	0.00E+00	6.20E+03	0.00E+00	0.00E+00	0.00E+00
Exports	0.00E+00	4.68E+02	0.00E+00	0.00E+00	0.00E+00
ENERGY TRANSF.	2.17E+07	7.55E+02	1.05E+03	1.36E+05	8.56E+04
Electricity Generation	2.15E+07	6.04E+02	1.02E+03	1.36E+05	8.46E+04
Petroleum Refining	1.67E+05	2.26E+01	7.92E+00	8.52E+02	5.41E+02
Coal Prod./Prep.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Charcoal Production	0.00E+00	1.28E+02	2.50E+01	0.00E+00	4.32E+02
Own Use	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Losses	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENERGY DEMAND	4.12E+07	3.13E+03	2.87E+03	2.58E+05	1.78E+05
INDUSTRIAL	2.27E+07	4.20E+02	1.07E+03	1.45E+05	9.05E+04
TRANSPORT	1.20E+06	1.78E+02	6.36E+01	4.91E+03	4.03E+03
RESIDENTIAL	1.03E+07	1.84E+03	1.22E+03	6.59E+04	5.38E+04
AGRICULTURAL	6.01E+05	4.04E+02	1.95E+02	3.60E+03	5.20E+03
FISHERIES	1.21E+05	1.08E+01	5.78E+00	6.10E+02	4.32E+02
MILITARY	3.51E+06	1.78E+02	1.66E+02	2.03E+04	1.33E+04
PUBLIC/COMML	2.73E+06	9.57E+01	1.49E+02	1.75E+04	1.12E+04
NON-SPECIFIED	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NON-ENERGY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes/Sources:

1 *Carbon dioxide emission factors for coal and refined products, and all wood and charcoal factors From Greenhouse Gas Inventory Workbook: IPCC Draft Guidelines for National Greenhouse Gas Inventories, Volume 2. IPCC/OCED Joint Programme, published by UNEP/WMO. "Final Draft" Version*

2 *Most non-CO2 emission factors derived from a variety of sources used by the authors in earlier work.*

3 *Production of methane from coal mining assumes a mid range estimate (from source 1) for production and post-mining emissions of 14 cubic meters methane per tonne of coal.*

4 *SOx, CO2 emission factors for wood/biomass and charcoal considered to be zero on the assumption that biomass fuels are used sustainably in the DPRK and have negligible sulfur contents.*

5 *SOx emission factor for petroleum products estimated as shown below. SOx emission factor for coal combustion assumes that lignite coal is 0.5% sulfur, anthracite is 0.75% sulfur by weight. Analyses of coal from the Anju field (lignite) show sulfur contents ranging from 0.2 to 1.2 %S (Document in authors' files [HA1-VO1]). All of the sulfur in both oil-based and coal fuels is assumed to be emitted as SOx. Sulfur contents for petroleum products are generally taken from Kato, et al (1991) Analysis of the Structure of Energy Consumption and the Dynamics of Emissions of Atmospheric Species Related to the Global Environmental Change (COx, NOx, and CO2) in Asia. NISTEP Report No. 21, page 37.*

6 *NOx emission factors for coal are derived from Kato et al, 1991 (reference as in 5, p. 39) assuming NOx factors of 7.5 kg/te for anthracite, 6.38 kg/te for brown coal. These are listed as factors for industry, and are assumed to be representative. NOx factors for coal-fired utility boilers are shown in the source document as somewhat higher than these figures, and factors for residential coal consumption are lower. NOx emission factors for petroleum products were assumed to be 10 kg/te. NOx emission factors vary considerably by fuel type and usage (NOx from transport fuels is an order of magnitude higher than from residential fuels, for example); the figure used here is a central estimate of factors listed in Kato et al, 1991, page 41.*

ESTIMATE OF SOx EMISSION FACTOR FOR REFINED PRODUCTS

Product	kTOE	TE/TOE	kTE	%S
Gasoline	399	1.07	427	0.12
Diesel	317	1.035	328	0.4
Heavy Oil	786	0.96	755	1.5
Kerosene/Jet Fuel	51	1.045	53	0.032
LPG	98	1.13	111	0.00016
Aviation Gasoline	21	1.07	22	0.04
Weighted Average: Sulfur content in kg/GJ				**0.188**
Fraction of Sulfur emitted as SO_x				100%
Mass ratio of SO_x (as SO_2) to S				2
Weighted Average SO_x emission factor: kg/GJ				**0.377**

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

ESTIMATED GHG AND ACID GAS EMISSIONS FROM FUELS PRODUCTION AND COMBUSTION FOR THE YEAR 2000

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

EMISSION FACTORS: kg/GJ fuel combustion/production

GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	*Notes*
Carbon Dioxide from Combustion	95.3	73.74	0	0	*1,4*
Methane from Combustion	0.0017	0.01	0.016	0.0018667	*1,2*
Methane from Production	0.534	0	0	0.084	*1,3*
Nitrous Oxide from Combustion	0.0045	0.0035	0.007	0.007	*1,2*
Sulfur Oxides from Combustion	0.611	0.380	0	0	*4,5*
Nitrogen Oxides from Combustion	0.38	0.24	0.121	0.121	*1,2,6*

SUMMARY EMISSIONS RESULTS: Tonnes of Emissions by Fuel

GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	TOTAL
Carbon Dioxide from Combustion	**2.90E+07**	**3.34E+06**	**0.00E+00**	**0.00E+00**	**3.24E+07**
Methane from Combustion	**5.17E+02**	**4.56E+02**	**2.13E+03**	**2.29E+00**	**3.11E+03**
Methane from Production	**1.74E+05**	**0.00E+00**	**0.00E+00**	**1.03E+02**	**1.74E+05**
Nitrous Oxide from Combustion	**1.37E+03**	**1.60E+02**	**9.34E+02**	**2.86E+01**	**2.49E+03**
Sulfur Oxides from Combustion	**1.86E+05**	**1.51E+04**	**0.00E+00**	**0.00E+00**	**2.01E+05**
Nitrogen Oxides from Combustion	**1.16E+05**	**1.09E+04**	**1.61E+04**	**4.95E+02**	**1.43E+05**

SUMMARY EMISSIONS RESULTS: Tonnes of Emissions by Balance Category

	CARBON DIOXIDE	METHANE	NITROUS OXIDE	SULFUR OXIDES	NITROGEN OXIDES
TOTAL	**3.24E+07**	**1.77E+05**	**2.49E+03**	**2.01E+05**	**1.43E+05**
ENERGY SUPPLY	0.00E+00	1.74E+05	0.00E+00	0.00E+00	0.00E+00
Domestic Production	0.00E+00	1.74E+05	0.00E+00	0.00E+00	0.00E+00
Imports	0.00E+00	4.48E+03	0.00E+00	0.00E+00	0.00E+00
Exports	0.00E+00	4.97E+03	0.00E+00	0.00E+00	0.00E+00
ENERGY TRANSF.	4.27E+06	3.35E+02	2.22E+02	2.57E+04	1.64E+04
Electricity Generation	4.20E+06	2.22E+02	1.98E+02	2.53E+04	1.58E+04
Petroleum Refining	7.48E+04	1.01E+01	3.55E+00	3.85E+02	2.42E+02
Coal Prod./Prep.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Charcoal Production	0.00E+00	1.03E+02	2.00E+01	0.00E+00	3.46E+02
Own Use	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Losses	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENERGY DEMAND	2.81E+07	2.88E+03	2.27E+03	1.75E+05	1.27E+05
INDUSTRIAL	1.39E+07	2.62E+02	6.61E+02	8.92E+04	5.56E+04
TRANSPORT	6.66E+05	9.98E+01	3.57E+01	2.73E+03	2.24E+03
RESIDENTIAL	8.32E+06	1.93E+03	1.17E+03	5.28E+04	4.65E+04
AGRICULTURAL	4.58E+05	3.38E+02	1.61E+02	2.72E+03	4.18E+03
FISHERIES	1.01E+05	9.00E+00	4.80E+00	5.06E+02	3.59E+02
MILITARY	3.12E+06	1.65E+02	1.48E+02	1.79E+04	1.18E+04
PUBLIC/COMML	1.47E+06	7.61E+01	9.10E+01	9.41E+03	6.24E+03
NON-SPECIFIED	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NON-ENERGY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes/Sources:

1 *Carbon dioxide emission factors for coal and refined products, and all wood and charcoal factors From Greenhouse Gas Inventory Workbook: IPCC Draft Guidelines for National Greenhouse Gas Inventories, Volume 2. IPCC/OCED Joint Programme, published by UNEP/WMO. "Final Draft" Version*

2 *Most non-CO2 emission factors derived from a variety of sources used by the authors in earlier work.*

3 *Production of methane from coal mining assumes a mid range estimate (from source 1) for production and post-mining emissions of 14 cubic meters methane per tonne of coal.*

4 *SOx, CO2 emission factors for wood/biomass and charcoal considered to be zero on the assumption that biomass fuels are used sustainably in the DPRK and have negligible sulfur contents.*

5 *SOx emission factor for petroleum products estimated as shown below. SOx emission factor for coal combustion assumes that lignite coal is 0.5% sulfur, anthracite is 0.75% sulfur by weight. Analyses of coal from the Anju field (lignite) show sulfur contents ranging from 0.2 to 1.2 %S (Document in authors' files [HA1-VO1]). All of the sulfur in both oil-based and coal fuels is assumed to be emitted as SOx. Sulfur contents for petroleum products are generally taken from Kato, et al (1991) Analysis of the Structure of Energy Consumption and the Dynamics of Emissions of Atmospheric Species Related to the Global Environmental Change (COx, NOx, and CO2) in Asia. NISTEP Report No. 21, page 37.*

6 *NOx emission factors for coal are derived from Kato et al, 1991 (reference as in 5, p. 39) assuming NOx factors of 7.5 kg/te for anthracite, 6.38 kg/te for brown coal. These are listed as factors for industry, and are assumed to be representative. NOx factors for coal-fired utility boilers are shown in the source document as somewhat higher than these figures, and factors for residential coal consumption are lower. NOx emission factors for petroleum products were assumed to be 10 kg/te. NOx emission factors vary considerably by fuel type and usage (NOx from transport fuels is an order of magnitude higher than from residential fuels, for example); the figure used here is a central estimate of factors listed in Kato et al, 1991, page 41.*

ESTIMATE OF SOx EMISSION FACTOR FOR REFINED PRODUCTS

Product	kTOE	TE/TOE	kTE	%S
Gasoline	225	1.07	241	0.12
Diesel	299	1.035	309	0.4
Heavy Oil	640	0.96	615	1.5
Kerosene/Jet Fuel	51	1.045	53	0.032
LPG	125	1.13	141	0.00016
Aviation Gasoline	17	1.07	18	0.04
Weighted Average: Sulfur content in kg/GJ				**0.190**
Fraction of Sulfur emitted as SO_x				100%
Mass ratio of SO_x (as SO_2) to S				2
Weighted Average SO_x emission factor: kg/GJ				**0.380**

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

ESTIMATED GHG AND ACID GAS EMISSIONS FROM FUELS PRODUCTION AND COMBUSTION FOR THE YEAR 2005

Prepared By David Von Hippel
Date Last Modified: 4/4/2007

EMISSION FACTORS: kg/GJ fuel combustion/production

GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	*Notes*
Carbon Dioxide from Combustion	95.3	73.15	0	0	*1,4*
Methane from Combustion	0.0017	0.01	0.016	0.0018667	*1,2*
Methane from Production	0.534	0	0	0.084	*1,3*
Nitrous Oxide from Combustion	0.0045	0.0035	0.007	0.007	*1,2*
Sulfur Oxides from Combustion	0.611	0.280	0	0	*4,5*
Nitrogen Oxides from Combustion	0.38	0.24	0.121	0.121	*1,2,6*

SUMMARY EMISSIONS RESULTS: Tonnes of Emissions by Fuel

GHG/POLLUTANT	COAL & COKE	REFINED PROD.	WOOD/ BIOMASS	CHAR-COAL	TOTAL
Carbon Dioxide from Combustion	**3.57E+07**	**2.71E+06**	**0.00E+00**	**0.00E+00**	**3.84E+07**
Methane from Combustion	**6.37E+02**	**3.70E+02**	**2.37E+03**	**2.37E+00**	**3.38E+03**
Methane from Production	**2.16E+05**	**0.00E+00**	**0.00E+00**	**1.07E+02**	**2.16E+05**
Nitrous Oxide from Combustion	**1.68E+03**	**1.30E+02**	**1.04E+03**	**2.96E+01**	**2.88E+03**
Sulfur Oxides from Combustion	**2.29E+05**	**1.10E+04**	**0.00E+00**	**0.00E+00**	**2.40E+05**
Nitrogen Oxides from Combustion	**1.42E+05**	**8.85E+03**	**1.79E+04**	**5.12E+02**	**1.70E+05**

SUMMARY EMISSIONS RESULTS: Tonnes of Emissions by Balance Category

	CARBON DIOXIDE	METHANE	NITROUS OXIDE	SULFUR OXIDES	NITROGEN OXIDES
TOTAL	**3.84E+07**	**2.20E+05**	**2.88E+03**	**2.40E+05**	**1.70E+05**
ENERGY SUPPLY	0.00E+00	2.16E+05	0.00E+00	0.00E+00	0.00E+00
Domestic Production	0.00E+00	2.56E+05	0.00E+00	0.00E+00	0.00E+00
Imports	0.00E+00	2.59E+03	0.00E+00	0.00E+00	0.00E+00
Exports	0.00E+00	4.27E+04	0.00E+00	0.00E+00	0.00E+00
ENERGY TRANSF.	8.90E+06	3.26E+02	4.41E+02	5.57E+04	3.55E+04
Electricity Generation	8.73E+06	1.97E+02	4.12E+02	5.50E+04	3.46E+04
Petroleum Refining	1.66E+05	2.26E+01	7.92E+00	6.34E+02	5.41E+02
Coal Prod./Prep.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Charcoal Production	0.00E+00	1.07E+02	2.07E+01	0.00E+00	3.58E+02
Own Use	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Losses	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENERGY DEMAND	2.95E+07	3.16E+03	2.44E+03	1.84E+05	1.34E+05
INDUSTRIAL	1.46E+07	3.00E+02	6.90E+02	9.26E+04	5.79E+04
TRANSPORT	6.85E+05	1.05E+02	3.79E+01	2.81E+03	2.33E+03
RESIDENTIAL	9.12E+06	2.08E+03	1.27E+03	5.80E+04	5.07E+04
AGRICULTURAL	8.11E+05	4.15E+02	2.10E+02	5.04E+03	6.16E+03
FISHERIES	1.11E+05	1.00E+01	5.27E+00	5.53E+02	3.93E+02
MILITARY	2.91E+06	1.55E+02	1.38E+02	1.67E+04	1.10E+04
PUBLIC/COMML	1.31E+06	9.05E+01	9.05E+01	8.37E+03	5.72E+03
NON-SPECIFIED	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NON-ENERGY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes/Sources:

1 *Carbon dioxide emission factors for coal and refined products, and all wood and charcoal factors From Greenhouse Gas Inventory Workbook: IPCC Draft Guidelines for National Greenhouse Gas Inventories, Volume 2. IPCC/OCED Joint Programme, published by UNEP/WMO. "Final Draft" Version*

2 *Most non-CO2 emission factors derived from a variety of sources used by the authors in earlier work.*

3 *Production of methane from coal mining assumes a mid range estimate (from source 1) for production and post-mining emissions of 14 cubic meters methane per tonne of coal.*

4 *SOx, CO2 emission factors for wood/biomass and charcoal considered to be zero on the assumption that biomass fuels are used sustainably in the DPRK and have negligible sulfur contents.*

5 *SOx emission factor for petroleum products estimated as shown below. SOx emission factor for coal combustion assumes that lignite coal is 0.5% sulfur, anthracite is 0.75% sulfur by weight. Analyses of coal from the Anju field (lignite) show sulfur contents ranging from 0.2 to 1.2 %S (Document in authors' files [HA1-VO1]). All of the sulfur in both oil-based and coal fuels is assumed to be emitted as SOx. Sulfur contents for petroleum products are generally taken from Kato, et al (1991) Analysis of the Structure of Energy Consumption and the Dynamics of Emissions of Atmospheric Species Related to the Global Environmental Change (COx, NOx, and CO2) in Asia. NISTEP Report No. 21, page 37.*

6 *NOx emission factors for coal are derived from Kato et al, 1991 (reference as in 5, p. 39) assuming NOx factors of 7.5 kg/te for anthracite, 6.38 kg/te for brown coal. These are listed as factors for industry, and are assumed to be representative. NOx factors for coal-fired utility boilers are shown in the source document as somewhat higher than these figures, and factors for residential coal consumption are lower. NOx emission factors for petroleum products were assumed to be 10 kg/te. NOx emission factors vary considerably by fuel type and usage (NOx from transport fuels is an order of magnitude higher than from residential fuels, for example); the figure used here is a central estimate of factors listed in Kato et al, 1991, page 41.*

ESTIMATE OF SOx EMISSION FACTOR FOR REFINED PRODUCTS

Product	kTOE	TE/TOE	kTE	%S
Gasoline	203	1.07	217	0.12
Diesel	296	1.035	306	0.4
Heavy Oil	269	0.96	258	1.5
Kerosene/Jet Fuel	78	1.045	81	0.032
LPG	61	1.13	68	0.00016
Aviation Gasoline	13	1.07	14	0.04
Weighted Average: Sulfur content in kg/GJ				**0.140**
Fraction of Sulfur emitted as SO_x				100%
Mass ratio of SO_x (as SO_2) to S				2
Weighted Average SO_x emission factor: kg/GJ				**0.280**

NAUTILUS INSTITUTE
ESTIMATED/PROJECTED ENERGY SUPPLY/DEMAND BALANCES
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA (DPRK)

SUMMARY GHG AND ACID GAS EMISSIONS FROM FUELS PRODUCTION AND COMBUSTION FOR THE YEARS 1996, 2000, AND 2005

Estimate of Sulfur Oxide Emissions, Thousand Tonnes of Sulfur Dioxide

	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Electricity Generation	195.2	135.6	25.3	55.0
Petroleum Refining	1.8	0.9	0.4	0.6
Industrial Sector	397.7	145.0	89.2	92.6
Transport Sector	11.3	4.9	2.7	2.8
Residential Sector	125.2	65.9	52.8	58.0
Agricultural Sector	7.5	3.6	2.7	5.0
Fisheries Sector	1.6	0.6	0.5	0.6
Military Sector	23.1	20.3	17.9	16.7
Public/Commercial	23.5	17.5	9.4	8.4
TOTAL	786.8	394.3	201.0	239.6

Estimate of Nitrogen Oxide Emissions, Thousand Tonnes

	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Electricity Generation	122.7	84.6	15.8	34.6
Petroleum Refining	1.4	0.5	0.2	0.5
Charcoal Production	0.6	0.4	0.3	0.4
Industrial Sector	248.8	90.5	55.6	57.9
Transport Sector	9.3	4.0	2.2	2.3
Residential Sector	89.0	53.8	46.5	50.7
Agricultural Sector	10.3	5.2	4.2	6.2
Fisheries Sector	1.2	0.4	0.4	0.4
Military Sector	15.3	13.3	11.8	11.0
Public/Commercial	14.9	11.2	6.2	5.7
TOTAL	513.5	264.0	143.3	169.7

Estimate of Carbon Dioxide Emissions, Million Tonnes

	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Electricity Generation	31.0	21.5	4.2	8.7
Petroleum Refining	0.4	0.2	0.1	0.2
Industrial Sector	62.5	22.7	13.9	14.6
Transport Sector	2.8	1.2	0.7	0.7
Residential Sector	19.7	10.3	8.3	9.1
Agricultural Sector	1.3	0.6	0.5	0.8
Fisheries Sector	0.3	0.1	0.1	0.1
Military Sector	4.0	3.5	3.1	2.9
Public/Commercial	3.7	2.7	1.5	1.3
TOTAL	125.8	62.9	32.4	38.4

Estimate of Methane Emissions, Thousand Tonnes

	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Coal Mining	709.7	349.2	173.6	216.3
Electricity Generation	0.7	0.6	0.2	0.2
Petroleum Refining	0.1	0.0	0.0	0.0
Charcoal Production	0.2	0.1	0.1	0.1
Industrial Sector	1.3	0.4	0.3	0.3
Transport Sector	0.4	0.2	0.1	0.1
Residential Sector	1.8	1.8	1.9	2.1
Agricultural Sector	0.8	0.4	0.3	0.4
Fisheries Sector	0.0	0.0	0.0	0.0
Military Sector	0.2	0.2	0.2	0.2
Public/Commercial	0.1	0.1	0.1	0.1
TOTAL	715.3	353.1	176.8	219.7

Estimate of Methane Emissions, Thousand Tonnes

	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Coal Mining	709.7	349.2	173.6	216.3
Electricity Generation	0.7	0.6	0.2	0.2
Petroleum Refining	0.1	0.0	0.0	0.0
Charcoal Production	0.2	0.1	0.1	0.1
Industrial Sector	1.3	0.4	0.3	0.3
Transport Sector	0.4	0.2	0.1	0.1
Residential Sector	1.8	1.8	1.9	2.1
Agricultural Sector	0.8	0.4	0.3	0.4
Fisheries Sector	0.0	0.0	0.0	0.0
Military Sector	0.2	0.2	0.2	0.2
Public/Commercial	0.1	0.1	0.1	0.1
TOTAL	715.3	353.1	176.8	219.7

Estimate of Nitrous Oxide Emissions, Thousand Tonnes

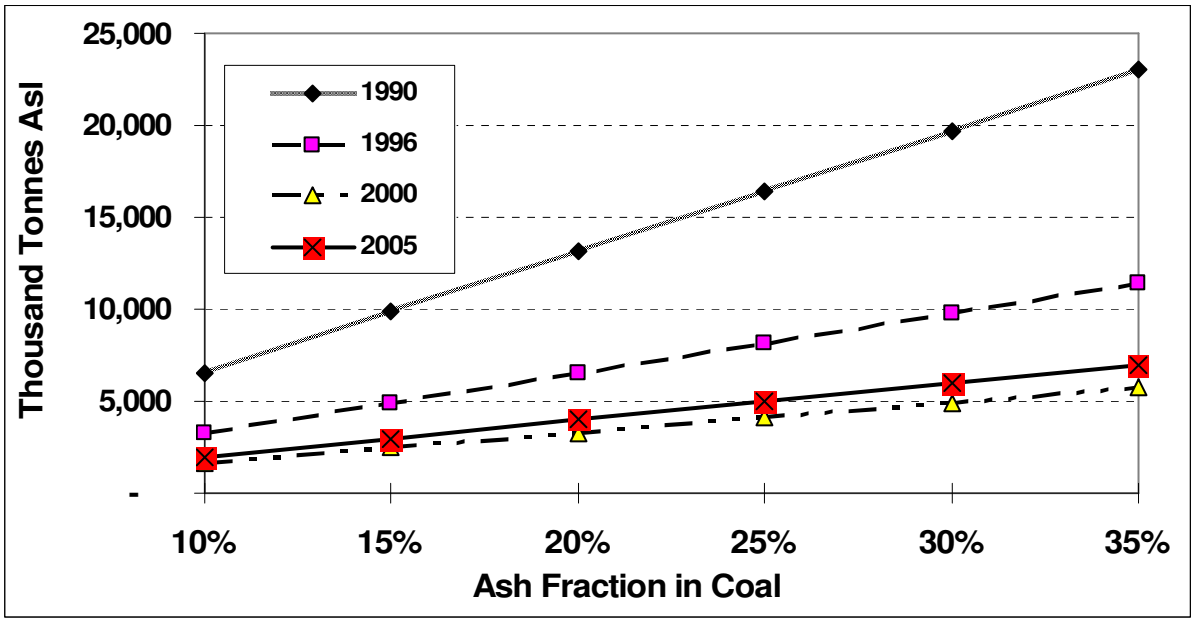
	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Electricity Generation	1.47	1.02	0.20	0.412
Petroleum Refining	0.02	0.01	0.00	0.008
Charcoal Production	0.03	0.02	0.02	0.021
Industrial Sector	2.96	1.07	0.66	0.690
Transport Sector	0.15	0.06	0.04	0.038
Residential Sector	1.55	1.22	1.17	1.268
Agricultural Sector	0.38	0.19	0.16	0.210
Fisheries Sector	0.02	0.01	0.00	0.005
Military Sector	0.19	0.17	0.15	0.138
Public/Commercial	0.19	0.15	0.09	0.091
TOTAL	6.95	3.92	2.49	2.88

Estimate of Coal Ash Production, Thousand Tonnes

Assumes that coal is on average		**20%** ash		
	YEAR			
Source of Emissions	**1990**	**1996**	**2000**	**2005**
Electricity Generation	3,347	2,192	328	934
Industrial Sector	6,831	2,517	1,546	1,589
Residential Sector	2,142	1,136	904	993
Agricultural Sector	104	55	41	83
Military Sector	317	284	245	229
Public/Commercial	408	303	163	145
TOTAL	13,148	6,488	3,228	3,972

Sensitivity Analysis: Total Coal Ash (Thousand Tonnes) vs. Ash Fraction Assumed

	YEAR			
Ash Fraction	**1990**	**1996**	**2000**	**2005**
10%	6,574	3,263	1,635	1,986
15%	9,861	4,894	2,453	2,979
20%	13,148	6,526	3,270	3,972
25%	16,435	8,157	4,088	4,966
30%	19,722	9,789	4,905	5,959
35%	23,009	11,420	5,723	6,952



SUMMARY OF ACID GAS AND CO_2 EMISSIONS

YEAR	Sulfur Oxides (thousand tonnes)	Nitrogen Oxides (thousand tonnes)	Carbon Dioxide (million tonnes)
1990	789	515	126
1996	394	264	63
2000	201	143	32
2005	240	170	38

SUMMARY OF SO_x and NO_x Emissions, 1990, 1996, 2000, and 2005

Units: Thousand Tonnes	SULFUR OXIDES				NITROGEN OXIDES			
	1990	1996	2000	2005	1990	1996	2000	2005
TOTAL	**788.6**	**394.3**	**201.0**	**239.6**	**514.9**	**264.0**	**143.3**	**169.7**
ENERGY TRANSFORMATION	196.9	136.4	25.7	55.7	124.7	85.6	16.4	35.5
Electricity Generation	195.2	135.6	25.3	55.0	122.7	84.6	15.8	34.6
Petroleum Refining	1.8	0.9	0.4	0.6	1.4	0.5	0.2	0.5
Charcoal Production	-	-	-	-	0.6	0.4	0.3	0.4
ENERGY DEMAND	591.6	257.8	175.2	184.0	390.1	178.4	126.9	-
INDUSTRIAL	397.7	145.0	89.2	92.6	248.8	90.5	55.6	57.9
TRANSPORT	11.3	4.9	2.7	2.8	9.3	4.0	2.2	2.3
RESIDENTIAL	125.2	65.9	52.8	58.0	89.0	53.8	46.5	50.7
AGRICULTURAL	7.5	3.6	2.7	5.0	10.3	5.2	4.2	6.2
FISHERIES	1.6	0.6	0.5	0.6	1.2	0.4	0.4	0.4
MILITARY	23.1	20.3	17.9	16.7	15.3	13.3	11.8	11.0
PUBLIC/COMML	23.5	17.5	9.4	8.4	14.9	11.2	6.2	5.7
NON-SPECIFIED	1.8	-	-	-	1.4	-	-	-

SUMMARY OF GHG Emissions, 1990, 1996, 2000, and 2005

Units: Thousand Tonnes	CARBON DIOXIDE				METHANE			
	1990	1996	2000	2005	1990	1996	2000	2005
TOTAL	126,229	62,878	32,353	38,402	715.36	353.09	176.80	219.74
ENERGY SUPPLY	-	-	-	-	709.71	349.21	173.59	216.25
Domestic Production	-	-	-	-	689.43	343.47	174.08	256.33
Imports	-	-	-	-	36.51	6.20	4.48	2.59
Exports	-	-	-	-	16.23	0.47	4.97	42.67
ENERGY TRANSFORMATION	31,473	21,713	4,273	8,895	0.98	0.76	0.34	0.33
Electricity Generation	31,038	21,545	4,198	8,730	0.74	0.60	0.22	0.20
Petroleum Refining	435	167	75	166	0.06	0.02	0.01	0.02
Charcoal Production	-	-	-	-	0.17	0.13	0.10	0.11
ENERGY DEMAND	94,756	41,166	28,081	29,507	4.67	3.13	2.88	3.16
INDUSTRIAL	62,500	22,659	13,943	14,553	1.28	0.42	0.26	0.30
TRANSPORT	2,764	1,200	666	685	0.41	0.18	0.10	0.11
RESIDENTIAL	19,708	10,340	8,324	9,120	1.79	1.84	1.93	2.08
AGRICULTURAL	1,295	601	458	811	0.79	0.40	0.34	0.42
FISHERIES	337	121	101	111	0.03	0.01	0.01	0.01
MILITARY	4,045	3,511	3,118	2,915	0.22	0.18	0.16	0.15
PUBLIC/COMML	3,675	2,733	1,471	1,312	0.10	0.10	0.08	0.09
NON-SPECIFIED	431	-	-	-	0.06	-	-	-

ATTACHMENT 2

WORKPAPERS AND DETAILED RESULTS:

ESTIMATES AND PROJECTIONS OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK: UPDATE FOR THE YEAR 2005

ESTIMATES AND PROJECTIONS OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK UPDATE 2006

SUMMARY: FUEL USE IN EQUIPMENT AND MILITARY MANUFACTURING, 1990, 1996, 2000, AND 2005

		1990			1996	2000	2005
MILITARY BRANCH **Equipment**	Est. Number in Service	Fuel Cons GJ	Fraction of Branch	Fraction of Total	Fuel Cons GJ	Fuel Cons GJ	Fuel Cons GJ
GROUND FORCES							
Tanks	5,832	2.05E+05	3.0%	1.2%	1.64E+05	1.34E+05	1.10E+05
Amphibious Vehicles	900	1.04E+04	0.2%	0.1%	8.35E+03	6.82E+03	5.58E+03
Armored Fighting Vehicles	4,015	4.50E+04	0.7%	0.3%	3.60E+04	2.95E+04	2.41E+04
Truck/Tank-Mounted Guns, Missiles	516	2.64E+03	0.0%	0.0%	2.12E+03	1.74E+03	1.42E+03
Jeeps and Motorcycles	9,045	2.15E+05	3.1%	1.2%	1.87E+05	1.61E+05	1.44E+05
2 1/2 Ton Trucks	72,403	6.23E+06	90.9%	36.0%	5.42E+06	4.65E+06	4.16E+06
Other Trucks and Utility Equipment	1,632	1.44E+05	2.1%	0.8%	1.30E+05	1.11E+05	9.97E+04
TOTAL: Ground Forces	94,343	6.85E+06	100.0%	39.6%	5.94E+06	5.10E+06	4.55E+06
AIR FORCE							
Fighters	748	1.76E+06	66.4%	10.2%	1.17E+06	9.52E+05	8.79E+05
Bombers	82	3.96E+04	1.5%	0.2%	2.64E+04	2.14E+04	1.98E+04
Transport	308	2.76E+05	10.4%	1.6%	2.32E+05	1.88E+05	1.76E+05
Helicopters	275	8.03E+04	3.0%	0.5%	6.02E+04	4.77E+04	4.52E+04
TOTAL: Aircraft	1,413	2.15E+06	81.3%	12.5%	1.49E+06	1.21E+06	1.12E+06
Service (Ground) Vehicles	6,235	4.94E+05	18.7%	2.9%	4.94E+05	4.94E+05	4.94E+05
TOTAL: Air Force		2.65E+06	100.0%	15.3%	1.98E+06	1.70E+06	1.61E+06
NAVY							
Frigates	1	4.48E+04	0.7%	0.3%	3.19E+04	3.36E+04	3.36E+04
Corvettes	2	1.79E+04	0.3%	0.1%	1.28E+04	1.34E+04	1.34E+04
Missile Attack Boats	39	1.07E+06	15.7%	6.2%	7.66E+05	8.06E+05	8.06E+05
Patrol and Mine Craft	351	5.05E+06	73.8%	29.2%	3.60E+06	3.79E+06	3.79E+06
Amphibious Craft	324	2.31E+05	3.4%	1.3%	4.53E+05	6.57E+05	5.84E+05
Submarines	84	5.56E+04	0.8%	0.3%	5.56E+04	5.00E+04	4.45E+04
TOTAL: Naval Vessels	801	6.48E+06	94.6%	37.5%	4.92E+06	5.35E+06	5.27E+06
Service (Land) Vehicles	4,077	3.71E+05	5.4%	2.1%	2.81E+05	3.06E+05	3.02E+05
TOTAL: Naval Forces		6.85E+06	100.0%	39.6%	5.20E+06	5.65E+06	5.57E+06
MILITARY MANUFACTURING: Coal Use		8.87E+05	**GJ/yr**	5.1%	6.21E+05	3.99E+05	3.99E+05
MILITARY MANUFACTURING: Electricity Use		4.75E+04	**GJ/yr**	0.3%	3.33E+04	2.14E+04	2.14E+04
TOTAL, ALL MILITARY ENERGY USES ABOVE		**1.73E+07**	**GJ/yr**	**100%**	**1.38E+07**	**1.29E+07**	**1.22E+07**

ESTIMATE OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN DPRK
SUMMARY OF KEY ACTIVITY LEVEL ASSUMPTIONS FOR 1990, AND ESTIMATES FOR 1996, 2000, AND 2005

Detailed Data and Results

Prepared By: David Von Hippel
Date Last Modified: **3/20/2007**

UPDATE 2006

GROUND FORCES		
	Trucks and General Use Vehicles	Tanks, Amph. Veh., Armored Veh., Other Arms
Hours of Maneuvers Per Year, 1990:	1000	100
Hours of Maneuvers Per Year, 1996:	870	80
Hours of Maneuvers Per Year, 2000:	800	70
Hours of Maneuvers Per Year, 2005	750	60

AIRCRAFT				
Mission Hours Per Year:	1990	1996	2000	2005
Fighters/Bombers	24	16	13	12
Transport Aircraft	50	42	34	32
Helicopters	32	24	19	18
Ave. airspeed--Fract. of Maximum	80%	80%	80%	80%

MILITARY SHIPS AND BOATS				
Active Hours Per Year in:	1990	1996	2000	2005
Amphibious	50	50	45	40
Submarines	100	100	90	80
Other Vessels	800	570	600	600
Ave. power use--Fract. of Maximum	50%	50%	50%	50%

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

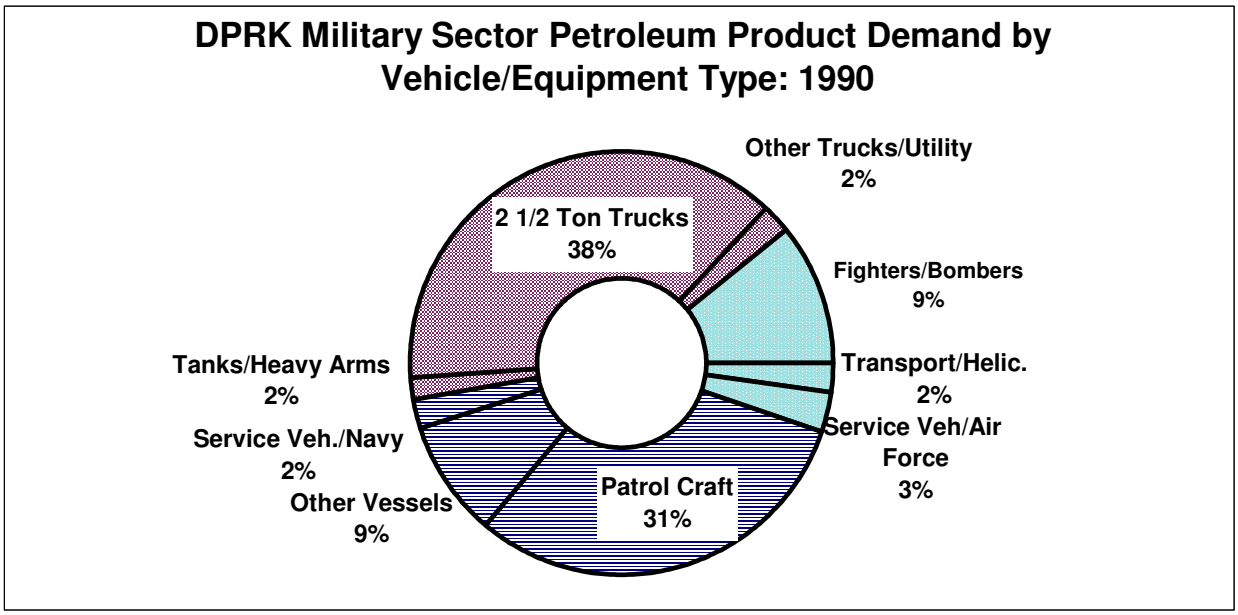
PROJECTION OF ENERGY REQUIRMENTS FOR MILITARY PRODUCT MANUFACTURING	
Ratio of Military Equipment Output in 1996 versus 1990:	0.7
Ratio of Military Equipment Output in 2000 versus 1990:	0.45
Ratio of Military Equipment Output in 2005 versus 1990:	0.45

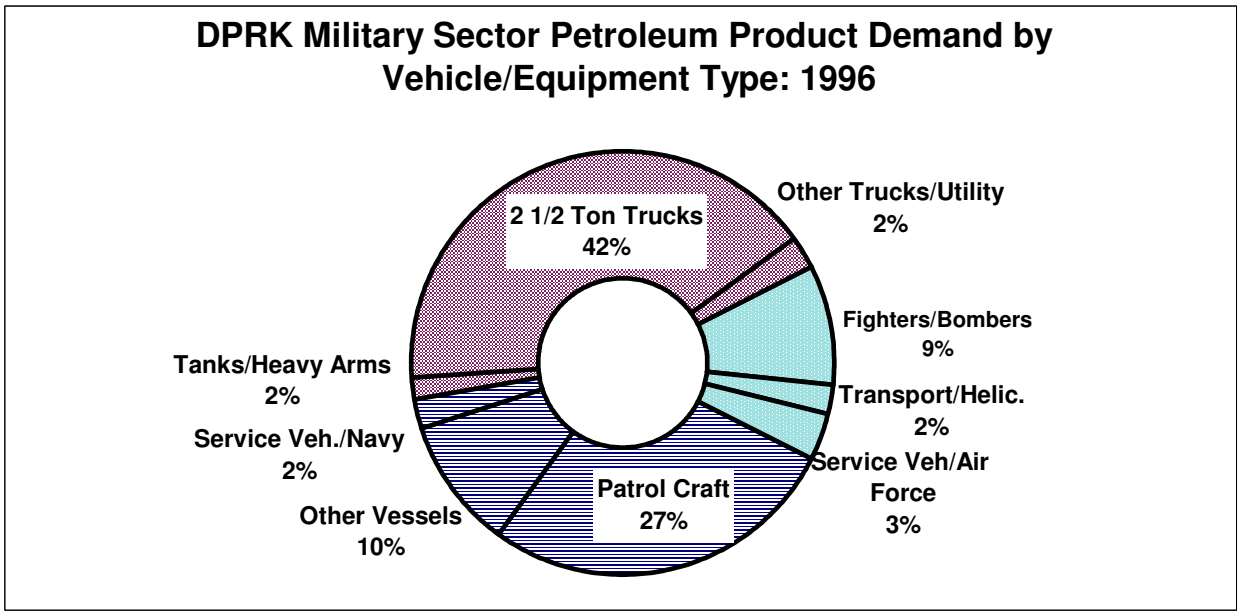
ESTIMATE OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN DPRK
SUMMARY: FUEL USE IN EQUIPMENT, ALL MILITARY BRANCHES--1990, 1996, 2000, AND 2005

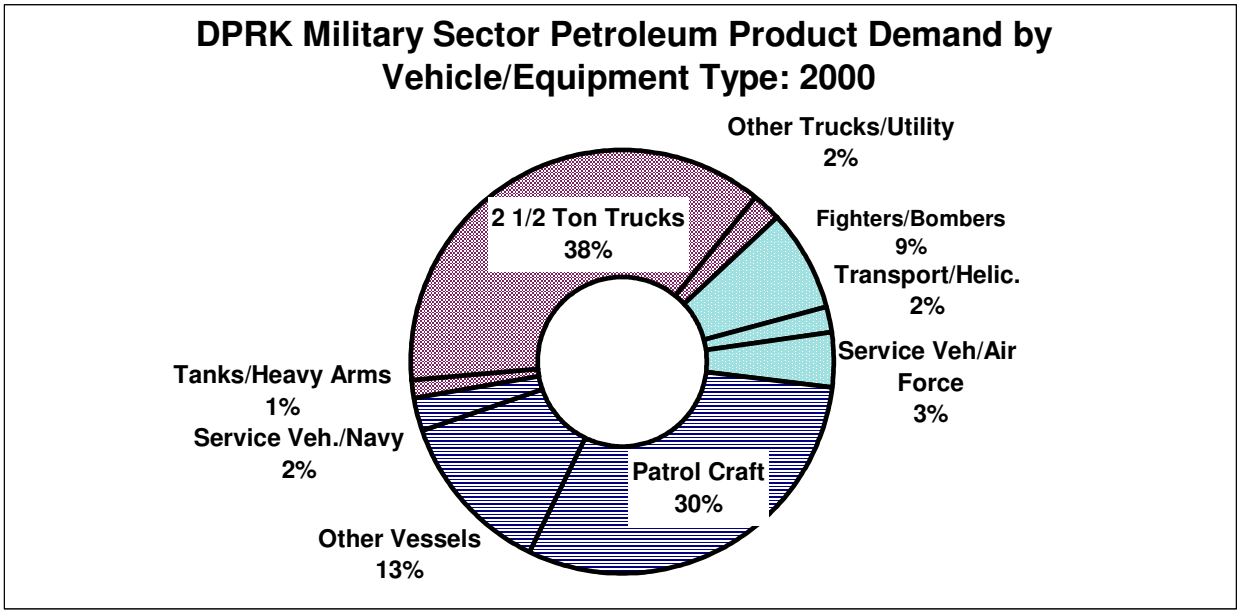
Summary Graphics	
Prepared By:	David Von Hippel
Date Last Modified:	**3/20/2007**

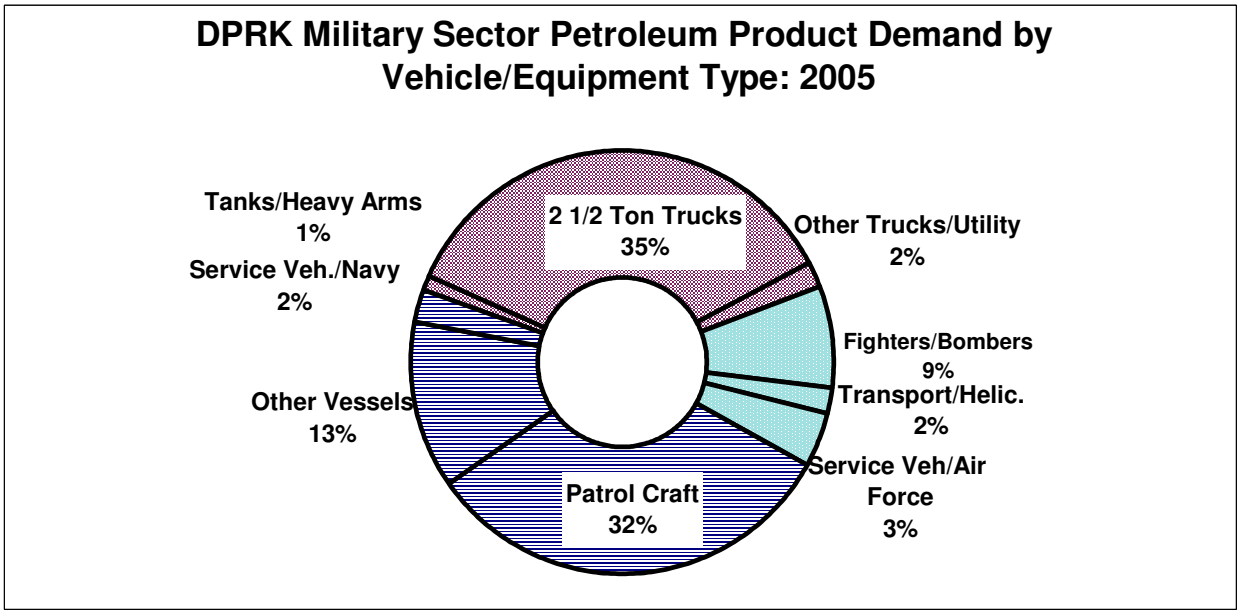
UPDATE 2006

	1990			1996			2000			2005		
MILITARY BRANCH **Equipment**	Fuel Cons GJ	Fraction of Branch	Fraction of Total	Fuel Cons GJ	Fraction of Branch	Fraction of Total	Fuel Cons GJ	Fraction of Branch	Fraction of Total	Fuel Cons GJ	Fraction of Branch	Fraction of Total
GROUND FORCES												
Tanks/Heavy Arms	2.63E+05	3.8%	1.6%	2.11E+05	3.1%	1.6%	1.72E+05	2.5%	1.4%	1.41E+05	2.1%	1.2%
2 1/2 Ton Trucks	6.23E+06	90.9%	38.1%	5.42E+06	79.1%	41.3%	4.65E+06	68.0%	37.4%	4.16E+06	60.8%	35.5%
Oth Trucks/Utility	3.59E+05	5.2%	2.2%	3.17E+05	4.6%	2.4%	2.72E+05	4.0%	2.2%	2.43E+05	3.6%	2.1%
TOTAL: Ground Forces	6.85E+06	100.0%	41.9%	5.94E+06	86.8%	45.3%	5.10E+06	74.4%	40.9%	4.55E+06	66.4%	38.7%
AIR FORCE												
Fighters/Bombers	1.80E+06	67.9%	11.0%	1.20E+06	45.3%	9.1%	9.74E+05	36.8%	7.8%	8.99E+05	33.9%	7.7%
Transport/Helic.	3.56E+05	13.4%	2.2%	2.92E+05	11.0%	2.2%	2.35E+05	8.9%	1.9%	2.22E+05	8.4%	1.9%
Service (Grnd) Veh.	4.94E+05	18.7%	3.0%	4.94E+05	18.7%	3.8%	4.94E+05	18.7%	4.0%	4.94E+05	18.7%	4.2%
TOTAL: Air Force	2.65E+06	100.0%	16.2%	1.98E+06	74.9%	15.1%	1.70E+06	64.3%	13.7%	1.61E+06	61.0%	13.8%
NAVY												
Patrol Craft	5.05E+06	73.8%	30.9%	3.60E+06	52.5%	27.4%	3.79E+06	55.3%	30.4%	3.79E+06	55.3%	32.3%
Other Vessels	1.42E+06	20.8%	8.7%	1.32E+06	19.3%	10.0%	1.56E+06	22.8%	12.5%	1.48E+06	21.6%	12.6%
Service (Land) Veh.	3.71E+05	5.4%	2.3%	2.81E+05	4.1%	2.1%	3.06E+05	4.5%	2.5%	3.02E+05	4.4%	2.6%
TOTAL: Naval Forces	6.85E+06	100.0%	41.9%	5.20E+06	75.9%	39.6%	5.65E+06	82.6%	45.4%	5.57E+06	81.4%	47.5%
TOTAL MILITARY EQUIP ENERGY USE	**1.63E+07**	**GJ/yr**	**100%**	**1.31E+07**	**GJ/yr**	**100%**	**1.25E+07**	**GJ/yr**	**100%**	**1.17E+07**	**GJ/yr**	**100%**


DPRK Military Sector Petroleum Product Demand by Vehicle/Equipment Type: 1990
Other Trucks/Utility 2%
2 1/2 Ton Trucks 38%
Fighters/Bombers 9%
Tanks/Heavy Arms 2%
Transport/Helic. 2%
Service Veh./Navy 2%
Service Veh/Air Force 3%
Other Vessels 9%
Patrol Craft 31%


DPRK Military Sector Petroleum Product Demand by Vehicle/Equipment Type: 1996
Other Trucks/Utility 2%
2 1/2 Ton Trucks 42%
Fighters/Bombers 9%
Tanks/Heavy Arms 2%
Transport/Helic. 2%
Service Veh./Navy 2%
Service Veh/Air Force 3%
Other Vessels 10%
Patrol Craft 27%


DPRK Military Sector Petroleum Product Demand by Vehicle/Equipment Type: 2000
Other Trucks/Utility 2%
2 1/2 Ton Trucks 38%
Fighters/Bombers 9%
Transport/Helic. 2%
Service Veh/Air Force 3%
Tanks/Heavy Arms 1%
Service Veh./Navy 2%
Patrol Craft 30%
Other Vessels 13%


DPRK Military Sector Petroleum Product Demand by Vehicle/Equipment Type: 2005
Tanks/Heavy Arms 1%
2 1/2 Ton Trucks 35%
Other Trucks/Utility 2%
Service Veh./Navy 2%
Fighters/Bombers 9%
Other Vessels 13%
Transport/Helic. 2%
Service Veh/Air Force 3%
Patrol Craft 32%

ESTIMATES AND PROJECTIONS OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK:
MILITARY GROUND VEHICLES AND ARMAMENTS **UPDATE 2006**

Prepared By:	David Von Hippel
Date Last Modified:	**1/4/2007**

Summary Input Data and Results	**Trucks and General Use Vehicles**	**Tanks, Amph. Veh., Armored Veh., Other Arms**
Hours of Ground Maneuvers Per Year, 1990:	**1000**	**100**
Hours of Ground Maneuvers Per Year, 1996:	**870**	**80**
Hours of Ground Maneuvers Per Year, 2000:	**800**	**70**
Hours of Ground Maneuvers Per Year, 2005:	**750**	**60**

						1990				**1996**		
Vehicle Types	Est. Number	Fuel Economy Range (km per Gallon)		Fract. of Time in Use	Ave. Speed when in Use	Annual Hrs Use	Fuel Cons (liters)	Fuel Cons GJ	Fraction of Total	Annual Hrs Use	Fuel Cons (liters)	Fuel Cons GJ
Notes				*1*	*2*							
Tanks	5,832	1.97	2.08	50%	25	50	5.46E+06	2.05E+05	3.0%	40	4.36E+06	1.64E+05
Amphibious Vehicles	900	1.04	26.50	50%	20	50	2.78E+05	1.04E+04	0.2%	40	2.22E+05	8.35E+03
Armored Fighting Vehicles	4,015	6.53	7.50	50%	30	50	1.38E+06	4.50E+04	0.7%	40	1.11E+06	3.60E+04
Truck/Tank-Mounted Guns, Missiles	516	1.97	6.44	25%	20	25	7.06E+04	2.64E+03	0.0%	20	5.65E+04	2.12E+03
Jeeps and Motorcycles	9,045	26.50	50	50%	30	500	6.61E+06	2.15E+05	3.1%	435	5.75E+06	1.87E+05
2 1/2 Ton Trucks	72,403	8.63		50%	30	500	1.91E+08	6.23E+06	90.9%	435	1.67E+08	5.42E+06
Other Trucks and Utility Equipment	1,632	3.85	8.63	50%	25	500	3.97E+06	1.44E+05	2.1%	435	3.45E+06	1.30E+05
TOTALS	94,343						2.09E+08	6.85E+06	100.0%		1.81E+08	5.94E+06
Diesel Consumption							8.69E+06	3.27E+05	4.8%		7.16E+06	2.69E+05
Gasoline Consumption							2.00E+08	6.52E+06	95.2%		1.74E+08	5.68E+06

						2000			2005		
Vehicle Types	Est. Number	Fuel Economy Range (km per Gallon)		Fract. of Time in Use	Ave. Speed when in Use	Annual Hrs Use	Fuel Cons (liters)	Fuel Cons GJ	Annual Hrs Use	Fuel Cons (liters)	Fuel Cons GJ
Notes				*1*	*2*						
Tanks	5,832	1.97	2.08	50%	25	35	3.57E+06	1.34E+05	30	2.92E+06	1.10E+05
Amphibious Vehicles	900	1.04	26.50	50%	20	35	1.82E+05	6.82E+03	30	1.49E+05	5.58E+03
Armored Fighting Vehicles	4,015	6.53	7.50	50%	30	35	9.05E+05	2.95E+04	30	7.40E+05	2.41E+04
Truck/Tank-Mounted Guns, Missiles	516	1.97	6.44	25%	20	17.5	4.62E+04	1.74E+03	15	3.78E+04	1.42E+03
Jeeps and Motorcycles	9,045	26.50	50	50%	30	400	4.94E+06	1.61E+05	375	4.42E+06	1.44E+05
2 1/2 Ton Trucks	72,403	8.63		50%	30	400	1.43E+08	4.65E+06	375	1.28E+08	4.16E+06
Other Trucks and Utility Equipment	1,632	3.85	8.63	50%	25	400	2.97E+06	1.11E+05	375	2.65E+06	9.97E+04
TOTALS	94,343						1.56E+08	5.10E+06		1.39E+08	4.55E+06
Diesel Consumption							5.96E+06	2.24E+05		5.04E+06	1.89E+05
Gasoline Consumption							1.50E+08	4.87E+06		1.34E+08	4.36E+06

Notes:

1 This fraction is assumed to be 25% for vehicles used primarily in engineering operations, 50% for most others.

2 Average speed applies to most, but not necessarily all, vehicles in class.

ESTIMATE OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK
MILITARY GROUND VEHICLES AND ARMAMENTS UPDATE 2006

Detailed Data and Results

Prepared By:	David Von Hippel
Date Last Modified:	**1/4/2007**

COMMON ASSUMPTIONS & PARAMETERS

GROUND FORCES	Trucks and General Use Vehicles	Tanks, Amph. Veh., Armored Veh., Other Arms	
Hours of Maneuvers Per Year, 1990:	**1000**	**100**	***Note 25***
Hours of Maneuvers Per Year, 1996:	**870**	**80**	
Hours of Maneuvers Per Year, 2000:	**800**	**70**	***Note 24***
Hours of Maneuvers Per Year, 2005:	**750**	**60**	***Note 27***
Fraction of Stock Unuseable:	**20%**		***Note 21***

Conversion Factor:	**3.8**	liters/gal
Diesel Energy Content:	**0.037584**	GJ/liter
Gasoline Energy Content:	**0.03253**	GJ/liter

Estimate of Number of Vehicles In Military Fleet

Branch or Unit of Ground Forces	Number	Personnel per Unit	TOTAL Personnel	Notes
Reserve Infantry Divisions	26	10,359	269,334	*1*
Reserve-Infantry Brigades	18	8,296	149,328	*2*
Infantry Divisions	30	10,359	310,770	*1*
Truck Mobile Divisions	1	8,194	8,194	*5*
Infantry Brigades	4	8,296	33,184	*2*
Truck Mobile Brigades	20	4,781	95,620	*4*
Armored Brigades	15	2,481	37,215	*3*
Special Operations Brigades	22			*6*
Elite Training Regiments	5	1,490	7,450	
Engineering River Regiments	5	1,660	8,300	
SAM Regiments	5	1,112	5,560	
AAA Regiments	5	529	2,645	
FROG Battalions	10	173	1,730	
Command and Support	1	338	338	
Artillery Regiments	3	735	2,205	
MRL Regiment	1	751	751	
AAA Regiments	2	529	1,058	
Engineering Regiment	1	1,206	1,206	
Signal Battalion	1	299	299	
Decon Battalion	1	315	315	
ATGM Company	1	81	81	
Field Hospital	1	435	435	
TOTAL INDICATED LAND FORCES			936,018	
Reported Ground Personnel	(as of 1990)		1.07E+06	*7, 23, 26*
TRUED-UP LAND FORCES	True-Up Factor, '90/96:		1.14	
Equipment Totals by Category				

MOTORIZED EQUIPMENT, BY TYPE, PER UNIT

	TANKS			AMPHIBIOUS VEH. AND TANK RTVR						ARMORED FTG. VEHICLES		GUNS, MISSILES	
	Medium T-54/55	Med: T62/ 63/PT-76	ASLT	PT-76 Lt Amph	PTS Trk Amph	K-61 Trk Amph	GAZ-46	AMPHI FERRY	Tank Retriever	BTR-60	BRDM	AAG ZSU-57	BM-21 (URAL-375)
Reserve Infantry Divisions	31	2							1				
Reserve-Infantry Brigades													
Infantry Divisions	31	2							1				
Truck Mobile Divisions	93			16					8	330			18
Infantry Brigades													
Truck Mobile Brigades		31		5						99	15		
Armored Brigades	6	133							7	58	3	6	6
Special Operations Brigades													
Elite Training Regiments			95	10					6				
Engineering River Regiments						60	7	12					
SAM Regiments													
AAA Regiments												30	
FROG Battalions													
Command and Support													
Artillery Regiments													
MRL Regiment													30
AAA Regiments													
Engineering Regiment					10	20							
Signal Battalion													
Decon Battalion													
ATGM Company													
Field Hospital													
TOTAL INDICATED LAND FORCES	1,919	2,727	475	166	10	320	35	60	199	3,180	345	240	138
Reported Ground Personnel			5,121						790		3,525		
TRUED-UP LAND FORCES	2,185	3,106	541	189	11	364	40	68	227	3,622	393	273	157
Equipment Totals by Category			5,832						900		4,015		

Estimate of Number of Vehicles In Military Fleet					**MOTORIZED EQUIPMENT, BY TYPE, PER UNIT**													
Branch or Unit of Ground Forces	Number	Personnel per Unit	TOTAL Personnel	Notes	**GUNS, MISSILES (Cont.)**			**LIGHT VEH.**			**TRUCKS AND UTILITY VEHICLES**							
					BM-20,24 (ZIL-151,7)	FROG 3/5 (PT-76)	FROG 7 (ZIL-135)	JEEPS	Motor-Cycles	**2.5 T Truck**	Dump	Zil-135	Zil-151	KRAZ-214	GAZ-63	Zil-157V	Power Boats	Oth Hvy Equip.
Reserve Infantry Divisions	26	10,359	269,334	*1*				57	29	692								
Reserve-Infantry Brigades	18	8,296	149,328	*2*				39	29	503								
Infantry Divisions	30	10,359	310,770	*1*				57	29	692								
Truck Mobile Divisions	1	8,194	8,194	*5*				56		255								
Infantry Brigades	4	8,296	33,184	*2*				39	29	503								
Truck Mobile Brigades	20	4,781	95,620	*4*				28	8	376								
Armored Brigades	15	2,481	37,215	*3*				26		162								
Special Operations Brigades	22			*6*														
Elite Training Regiments	5	1,490	7,450					14	14	133								
Engineering River Regiments	5	1,660	8,300					10		148			96	18	72		24	15
SAM Regiments	5	1,112	5,560					8		60						36		
AAA Regiments	5	529	2,645					14		104								
FROG Battalions	10	173	1,730			3	3			54		3				3		
Command and Support	1	338	338					44	30	68								
Artillery Regiments	3	735	2,205					4		75								
MRL Regiment	1	751	751		15			10		48								
AAA Regiments	2	529	1,058					14		104								
Engineering Regiment	1	1,206	1,206					9		103	23						12	33
Signal Battalion	1	299	299					5	20	37								
Decon Battalion	1	315	315					1		30								
ATGM Company	1	81	81					1		5								
Field Hospital	1	435	435					4		63								
TOTAL INDICATED LAND FORCES			936,018		15	30	30	5,400	2,542	63,575	23	30	480	90	360	210	132	108
Reported Ground Personnel	(as of 1990)		1.07E+06	*7, 23, 26*			453		7,942	63,575								1,433
TRUED-UP LAND FORCES	True-Up Factor, '90/96:		1.14		17	34	34	6,150	2,895	72,403	26	34	547	102	410	239	150	123
Equipment Totals by Category							516		9,045	72,403								1,632

					MOTORIZED EQUIPMENT, BY TYPE, PER UNIT											
					TANKS			AMPHIBIOUS VEH. AND TANK RTVR						ARMORED FTG. VEHICLES		GUNS, MISSILES	
					Medium	Med: T62/		PT-76	PTS	K-61		AMPHI	Tank			AAG	BM-21
Fuel Use Effic. Calculations	Units			Notes	T-54/55	63/PT-76	ASLT	Lt Amph	Trk Amph	Trk Amph	GAZ-46	FERRY	Retriever	BTR-60	BRDM	ZSU-57	(URAL-375)
Reported Range	km				500	500	300	260	500	260	530	500	300	500	750	500	650
Reported Fuel Capacity (*Est*)	gal				254	240	150	67	240	67	*20*	480	148	76.6	100	254	*110*
Reported Horsepower	hp										55						180
Payload	ton								5.5	3.3	0.4	11					4.9
Fuel Used					Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Gas	Diesel	Diesel	Gas??	Gas	Diesel	Diesel??
Fuel Use Efficiency	km/gal				1.97	2.08	2.00	3.88	2.08	3.88	26.50	1.04	2.03	6.53	7.50	1.97	5.91
Notes					*8*	*8, 9*	*8*	*8*	*12*	*13*	*14*	*15*	*8*	*8*	*16*		*11*
Operating Assumptions																	
Fract. Time In-Use During Maneuvers					*50%*	*50%*	*50%*	*50%*	*50%*	*50%*	*50%*	*25%*	*25%*	*50%*	*50%*	*25%*	*25%*
Average Speed During Maneuvers	km/hr				*25*	*25*	*25*	*20*	*20*	*20*	*20*	*15*	*15*	*30*	*30*	*20*	*20*
Hours of Operation, 1990	hrs				50	50	50	50	50	50	50	25	25	50	50	25	25
Hours of Operation, 1996	hrs				40	40	40	40	40	40	40	20	20	40	40	20	20
Hours of Operation, 2000	hrs				35	35	35	35	35	35	35	17.5	17.5	35	35	17.5	17.5
Hours of Operation, 2005	hrs				30	30	30	30	30	30	30	15	15	30	30	15	15
Fuel Consumption Results, 1990																	
TOTAL FUEL USED	gal			*22*	5.55E+05	7.45E+05	1.35E+05	1.95E+04	2.19E+03	3.76E+04	6.02E+02	4.92E+03	8.39E+03	3.3E+05	3.1E+04	1.39E+04	2.66E+03
By Vehicle Category	gal	**All Veh.**	5.50E+07	*22*			1.44E+06						7.31E+04		3.6E+05		
TOTAL FUEL USED	liters				2.11E+06	2.83E+06	5.14E+05	7.41E+04	8.31E+03	1.43E+05	2.29E+03	1.87E+04	3.19E+04	1.3E+06	1.2E+05	5.28E+04	1.01E+04
By Vehicle Category	liters	**All Veh.**	2.09E+08				5.46E+06						2.78E+05		1.4E+06		
TOTAL FUEL USED	GJ				7.93E+04	1.06E+05	1.93E+04	2.78E+03	3.12E+02	5.37E+03	7.44E+01	7.03E+02	1.20E+03	4.1E+04	3.9E+03	1.98E+03	3.80E+02
By Vehicle Category	GJ	**All Veh.**	6.85E+06				2.05E+05						1.04E+04		4.5E+04		
Fuel Consumption Results, 1996																	
TOTAL FUEL USED	gal			*22*	4.44E+05	5.96E+05	1.08E+05	1.56E+04	1.75E+03	3.01E+04	4.81E+02	3.94E+03	6.71E+03	2.7E+05	2.5E+04	1.11E+04	2.13E+03
By Vehicle Category	gal	**All Veh.**	4.78E+07	*22*			1.15E+06						5.85E+04		2.9E+05		
TOTAL FUEL USED	liters				1.69E+06	2.27E+06	4.11E+05	5.92E+04	6.65E+03	1.14E+05	1.83E+03	1.50E+04	2.55E+04	1.0E+06	9.6E+04	4.22E+04	8.09E+03
By Vehicle Category	liters	**All Veh.**	1.81E+08				4.36E+06						2.22E+05		1.1E+06		
TOTAL FUEL USED	GJ				6.34E+04	8.52E+04	1.55E+04	2.23E+03	2.50E+02	4.29E+03	5.95E+01	5.62E+02	9.58E+02	3.3E+04	3.1E+03	1.59E+03	3.04E+02
By Vehicle Category	GJ	**All Veh.**	5.94E+06				1.64E+05						8.35E+03		3.6E+04		
Fuel Consumption Results, 2000																	
TOTAL FUEL USED	gal			*22*	3.63E+05	4.87E+05	8.85E+04	1.27E+04	1.43E+03	2.46E+04	3.94E+02	3.22E+03	5.48E+03	2.2E+05	2.1E+04	9.08E+03	1.74E+03
By Vehicle Category	gal	**All Veh.**	4.10E+07	*22*			9.39E+05						4.78E+04		2.4E+05		
TOTAL FUEL USED	liters				1.38E+06	1.85E+06	3.36E+05	4.84E+04	5.43E+03	9.34E+04	1.50E+03	1.22E+04	2.08E+04	8.3E+05	7.8E+04	3.45E+04	6.61E+03
By Vehicle Category	liters	**All Veh.**	1.56E+08				3.57E+06						1.82E+05		9.1E+05		
TOTAL FUEL USED	GJ				5.19E+04	6.96E+04	1.26E+04	1.82E+03	2.04E+02	3.51E+03	4.86E+01	4.60E+02	7.83E+02	2.7E+04	2.5E+03	1.30E+03	2.48E+02
By Vehicle Category	GJ	**All Veh.**	5.10E+06				1.34E+05						6.82E+03		2.9E+04		
Fuel Consumption Results, 2005																	
TOTAL FUEL USED	gal			*22*	2.97E+05	3.99E+05	7.23E+04	1.04E+04	1.17E+03	2.01E+04	3.22E+02	2.63E+03	4.48E+03	1.8E+05	1.7E+04	7.42E+03	1.42E+03
By Vehicle Category	gal	**All Veh.**	3.65E+07	*22*			7.68E+05						3.91E+04		1.9E+05		
TOTAL FUEL USED	liters				1.13E+06	1.51E+06	2.75E+05	3.96E+04	4.44E+03	7.63E+04	1.22E+03	1.00E+04	1.70E+04	6.8E+05	6.4E+04	2.82E+04	5.40E+03
By Vehicle Category	liters	**All Veh.**	1.39E+08				2.92E+06						1.49E+05		7.4E+05		
TOTAL FUEL USED	GJ				4.24E+04	5.69E+04	1.03E+04	1.49E+03	1.67E+02	2.87E+03	3.98E+01	3.76E+02	6.40E+02	2.2E+04	2.1E+03	1.06E+03	2.03E+02
By Vehicle Category	GJ	**All Veh.**	4.55E+06				1.10E+05						5.58E+03		2.4E+04		

					MOTORIZED EQUIPMENT, BY TYPE, PER UNIT														
					GUNS, MISSILES (Cont.)			LIGHT VEH.			TRUCKS AND UTILITY VEHICLES								
Fuel Use Effic. Calculations	Units			Notes	BM-20,24 (ZIL-151,7)	FROG 3/5 (PT-76)	FROG 7 (ZIL-135)	JEEPS	Motor-Cycles	**2.5 T Truck**	Dump	Zil-135	Zil-151	Kraz-214	GAZ-63	Zil-157V	Power Boats	Oth Hvy Equip.
Reported Range	km				600, 430	260	500	530		345	530	500	600	530	345	430		
Reported Fuel Capacity (*Est*)	gal					67	*130*	*20*		*40*	*130*	*130*	*80*	*130*	*40*	*80*		
Reported Horsepower	hp				92, 109		180	54		70	205	180	92	205	55	109	*28*	
Payload	ton						11			2.2	7.7	11	2.7	7.7	2.2			
Fuel Used					Diesel??	Diesel	Gas	Gas	Gas	Gas	Diesel	Gas	Diesel??	Diesel	Gas	Diesel??	Diesel??	Diesel??
Fuel Use Efficiency	km/gal				6.4375	3.88	3.85	26.50	50	8.63	4.08	3.85	7.50	4.08	8.63	5.38	0.195 l/hp-hr	5.38
Notes					*11*		*17*		*19*	*10*	*17*	*17*	*11*	*11*	*10*	*11*	*20*	*18*
Operating Assumptions																		
Fract. Time In-Use During Maneuvers					*25%*	*25%*	*25%*	*50%*	*50%*	*50%*	*50%*	*50%*	*50%*	*50%*	*50%*	*50%*	*25%*	*25%*
Average Speed During Maneuvers	km/hr				*20*	*20*	*20*	*30*	*30*	*30*	*25*	*25*	*25*	*25*	*25*	*25*		*15*
Hours of Operation, 1990	hrs				25	25	25	500	500	500	500	500	500	500	500	500	250	250
Hours of Operation, 1996	hrs				20	20	20	435	435	435	435	435	435	435	435	435	217.5	217.5
Hours of Operation, 2000	hrs				17.5	17.5	17.5	400	400	400	400	400	400	400	400	400	200	200
Hours of Operation, 2005	hrs				15	15	15	375	375	375	375	375	375	375	375	375	187.5	187.5
Fuel Consumption Results, 1990																		
TOTAL FUEL USED	gal			*22*	2.65E+02	8.80E+02	8.88E+02	1.39E+06	3.47E+05	5.04E+07	3.2E+04	4.4E+04	3.6E+05	1.3E+05	2.4E+05	2.2E+05	0.0E+00	1.7E+04
By Vehicle Category	gal	**All Veh.**	5.50E+07	*22*			1.86E+04		1.74E+06	5.04E+07								1.0E+06
TOTAL FUEL USED	liters				1.01E+03	3.35E+03	3.38E+03	5.29E+06	1.32E+06	1.91E+08	1.2E+05	1.7E+05	1.4E+06	4.8E+05	9.0E+05	8.5E+05	0.0E+00	6.5E+04
By Vehicle Category	liters	**All Veh.**	2.09E+08				7.06E+04		6.61E+06	1.91E+08								4.0E+06
TOTAL FUEL USED	GJ				3.79E+01	1.26E+02	1.10E+02	1.72E+05	4.29E+04	6.23E+06	4.6E+03	5.5E+03	5.2E+04	1.8E+04	2.9E+04	3.2E+04	0.0E+00	2.5E+03
By Vehicle Category	GJ	**All Veh.**	6.85E+06				2.64E+03		2.15E+05	6.23E+06								1.4E+05
Fuel Consumption Results, 1996																		
TOTAL FUEL USED	gal			*22*	2.12E+02	7.04E+02	7.11E+02	1.21E+06	3.02E+05	4.38E+07	2.8E+04	3.9E+04	3.2E+05	1.1E+05	2.1E+05	1.9E+05	0.0E+00	1.5E+04
By Vehicle Category	gal	**All Veh.**	4.78E+07	*22*			1.49E+04		1.51E+06	4.38E+07								9.1E+05
TOTAL FUEL USED	liters				8.07E+02	2.68E+03	2.70E+03	4.60E+06	1.15E+06	1.67E+08	1.1E+05	1.5E+05	1.2E+06	4.2E+05	7.9E+05	7.4E+05	0.0E+00	5.7E+04
By Vehicle Category	liters	**All Veh.**	1.81E+08				5.65E+04		5.75E+06	1.67E+08								3.5E+06
TOTAL FUEL USED	GJ				3.03E+01	1.01E+02	1.01E+02	1.50E+05	3.74E+04	5.42E+06	4.0E+03	5.5E+03	4.5E+04	1.6E+04	3.0E+04	2.8E+04	0.0E+00	2.1E+03
By Vehicle Category	GJ	**All Veh.**	5.94E+06				2.12E+03		1.87E+05	5.42E+06								1.3E+05
Fuel Consumption Results, 2000																		
TOTAL FUEL USED	gal			*22*	1.74E+02	5.76E+02	5.81E+02	1.04E+06	2.60E+05	3.76E+07	2.4E+04	3.3E+04	2.7E+05	9.4E+04	1.8E+05	1.7E+05	0.0E+00	1.3E+04
By Vehicle Category	gal	**All Veh.**	4.10E+07	*22*			1.22E+04		1.30E+06	3.76E+07								7.8E+05
TOTAL FUEL USED	liters				6.60E+02	2.19E+03	2.21E+03	3.96E+06	9.87E+05	1.43E+08	9.1E+04	1.3E+05	1.0E+06	3.6E+05	6.8E+05	6.3E+05	0.0E+00	4.9E+04
By Vehicle Category	liters	**All Veh.**	1.56E+08				4.62E+04		4.94E+06	1.43E+08								3.0E+06
TOTAL FUEL USED	GJ				2.48E+01	8.22E+01	8.30E+01	1.29E+05	3.21E+04	4.65E+06	3.4E+03	4.7E+03	3.9E+04	1.3E+04	2.5E+04	2.4E+04	0.0E+00	1.8E+03
By Vehicle Category	GJ	**All Veh.**	5.10E+06				1.74E+03		1.61E+05	4.65E+06								1.1E+05
Fuel Consumption Results, 2005																		
TOTAL FUEL USED	gal			*22*	1.42E+02	4.71E+02	4.75E+02	9.31E+05	2.32E+05	3.37E+07	2.1E+04	3.0E+04	2.4E+05	8.4E+04	1.6E+05	1.5E+05	0.0E+00	1.1E+04
By Vehicle Category	gal	**All Veh.**	3.65E+07	*22*			9.93E+03		1.16E+06	3.37E+07								7.0E+05
TOTAL FUEL USED	liters				5.39E+02	1.79E+03	1.80E+03	3.54E+06	8.82E+05	1.28E+08	8.2E+04	1.1E+05	9.3E+05	3.2E+05	6.0E+05	5.7E+05	0.0E+00	4.4E+04
By Vehicle Category	liters	**All Veh.**	1.39E+08				3.78E+04		4.42E+06	1.28E+08								2.7E+06
TOTAL FUEL USED	GJ				2.03E+01	6.72E+01	6.78E+01	1.15E+05	2.87E+04	4.16E+06	3.1E+03	4.2E+03	3.5E+04	1.2E+04	2.3E+04	2.1E+04	0.0E+00	1.6E+03
By Vehicle Category	GJ	**All Veh.**	4.55E+06				1.42E+03		1.44E+05	4.16E+06								1.0E+05

NOTES:

1 "Infantry Division" from North Korea Handbook, page 5-5
2 "Basic Corps Independent Infantry Brigade" from Opposing Force Training Module , p. 11-13
3 "Tank Brigade" from North Korea Handbook, page 5-31
4 "Mechanized Infantry Brigade" from North Korea Handbook, page 5-37
5 "Mechanized Infantry Division--Strategic Forces Command" from Opposing Force Training Module, p. 11-3
6 "Special Operations Brigades" are assumed to be those units listed in the Opposing Force Training Module as being under either the Strategic Forces Command or the Basic Army Corps, but which are not obviously included in the force units accounted for separately here.
7 From "Military Balance: North vs. South" Unclassified DOD document, September 27, 1993.
8 From Opposing Force Training Module, pp. 13-16 - 13-22.
9 For T-62. Pt-76 is a lighter, amphibious tank with a range of 260 km and a fuel load of 67 gal, but the ratio of the two types is not known.
10 Engine size and range are as listed for the older but similar Sungni-58, which is reported to be very fuel-inefficient. Fuel tank capacity is a guess. Data from reference 8, page 13-29.
11 Estimates based on measurements of drawings in reference 8.
12 Carriage, size seem similar to T-62 tank.
13 Carriage, size seem similar to PT-76 tank.
14 Built on Jeep chassis--assumed to have similar performance
15 Ferry consists of two tracked vehicles, each of which is assumed to have performance like T-62 tank.
16 Carriage seems similar to GAZ-66 2.2 ton truck. Fuel capacity for latter estimated based on measurement of drawings in reference 8.
17 Assumed similar to KRAZ-214.
18 Assumed similar to Zil-157V on average. Reference 8 lists the lighter Zil-151 as one of the prime movers used for cranes.
19 Rough Estimate
20 Assumes boats will have similar engines to tractors, with similar fuel consumption.
21 Unusable equipment includes equipment rendered unusable by age, rust, or lack of spare parts.
22 Energy use as calculated here excludes fuel that would have been used by equipment considered unusable.
23 Republic of Korea National Intelligence Service, "North Korea Military. The KPA: Troops & Equipment", from http://www.fas.org/irp/world/rok/nis-docs/defense08.htm, visited 5/21/02, lists the total ground forces for the DPRK at a total of 996,000 troops in 20 corps units. Assuming that this estimate holds for the year 2000, a "true-up factor" for the equipment estimates above of 1.06408 is implied.
24 It has not been possible to obtain unclassified information that provides any specific information on recent fuel use by the DPRK military. Analysts contacted regarding the "tempo" of recent DPRK military exercises, and reports in the media (for example, "NK Ground Exercises Up as Navy and Air Force Decline", Yoo Yong-won, www.chosun.com, 2001- 9-10) suggest that the DPRK military exercise tempo for ground forces has increased somewhat in recent years, but not substantially, and that some of the apparent increase in exercises may be an increase in the number of soldiers involved, but not necessarily the number of fuel-using vehicles and armaments. Accordingly, we assume that the average hours of annual use by ground vehicles in 2000 was slightly lower than in 1996 by 2000, and somewhat lower still, in part due to fuel supply restrictions, in 2005.

25 Observers of DPRK and other countries' military activity suggest that the active (mobile) hours for tanks, mobile armaments, armoured vehicles, amphibious vehicles, and similar equipment are typically, under routine (non-wartime) use, likely to be quite limited. Trucks and other utility vehicles that are used both for training/exercise use and also (especially in the DPRK) for other goods and human transport uses, are assumed likely to be used significantly more than tanks and other armaments. See also Note 27.

26 There are a range of different estimates for the number of ground troops in the DPRK military in the years since 2000, though the range of estimates is not great. The document The Asian Military Balance: An Analytic Overview--A Comparative Summary of Military Expenditures; Manpower; Land, Air, and Naval, Forces; and Arms Sales, by Anthony H. Cordesman and G. Ryan Faith of the Center for Strategic and International Studies, Washington, D.C., (available as http://www.csis.org/media/csis/pubs/asia_ro_asian_mb_comp%5B1%5D.pdf), published May, 2003, lists the manpower of DPRK ground forces in 2003 at 950,000 troops. *Assuming that this estimate holds for 2005, a "true-up factor" for the equipment estimates above of* 1.01494 *is implied.*

27 The publication Seoul Wolgan Choson published an article by Kim Yon-kwang and Yi Sang-hun, dated 1 October, 2003 (pages 168-181), entitled "Kim Chong-il's Military is Hoarding All Rice Aid as Military Provision", and is based on an interview with a DPRK soldier named Chin Yon-kyu, who had defected to the ROK, but who was (or claimed to be) a driver for a high-ranking officer. This article includes a quote from Chin that suggests typical training for heavy equipment was minimal: "Due to the fuel shortage, the North Korean Army's training exercises for heavily armed vehicles such as tanks is said to involve 'an annual travel distance of 30 kilometers'". This quote would appear to pertain to the time period around 2000, and the interviewee claims to have been based near Wonsan, in the "rear area".

If this information can be taken at face value, it would imply that a true estimate for training use for tanks (and other heavy armaments) might be just a few tens of km, as opposed to the 200 - 700 km/yr we estimate. Although it seems likely that training with heavy armaments is limited, and has been decreasing over the years, we will, until additional information becomes available, stay with our higher estimates of average usage. In so doing, we discount somewhat Chin Yon-kyu's account, in part because A) Chin appears to have been stationed well North of the DMZ, where training (and concentration of operable equipment, as well as fuel supplies) would be expected to be far less than in areas closer to the DMZ, and B) because it is only one, anecdotal account. Additional information on this topic would, however, be very welcome.

In the same interview, the interviewee reported that starting in "…1992, the North Korean Army has begun to gradually use fuel oil (incluidng benzene, gasoline, and diesel) stored for combat emergencies. Fuel oil tanks for use in combat are all empty."

ESTIMATE OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK

MILITARY AIRCRAFT UPDATE 2006

Detailed Data and Results	
Prepared By:	David Von Hippel
Date Last Modified:	**3/20/2007**

COMMON ASSUMPTIONS & PARAMETERS--AIRCRAFT USE *(See Notes 22 and 23)*

Mission Hours Per Year:	**1990**	**1996**	**2000**	**2005**
Fighters/Bombers (*Note 13*)	**24**	**16**	**13**	**12**
Transport Aircraft	**50**	**42**	**34**	**32**
Helicopters	**32**	**24**	**19**	**18**
Ave. airspeed--Fract. of Maximum	**80%**	**80%**	**80%**	**80%**
Kerosene/Jet Fuel Energy Cont. (GJ/ltr)	**0.035**	*Note 15*		
Aviation Gasoline Energy Cont. (GJ/ltr)	**0.0321**	*Note 15*		

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Type of Aircraft	**Class**		Number in Air Force Estimates from Sources 1	2	3	4	17	18	Number in Air Force Assumed	Range km	Fuel Capacity liters	Max. Speed km/hr	Cruise Speed km/hr	Ave. Fuel Consumpt l/hr	**1990** Total Fuel Consumpt liters	**1990** Total Fuel Consumpt GJ	**1996** Total Fuel Consumpt GJ	**2000** Total Fuel Consumpt GJ	**2005** Total Fuel Consumpt GJ
		Notes:							*19*	*14*	*14*	*14*	*14*						
Fixed Wing																			
F-5 (MIG-17) Fresco	Fighter		130			140		120	130	1270	2365	1145		1706	5.32E+06	1.86E+05	1.24E+05	1.01E+05	9.31E+04
F-6 (MIG-19) Farmer	Fighter/Bomber		160	160		110	>100	160	160	1390	2170	1590		1986	7.63E+06	2.67E+05	1.78E+05	1.45E+05	1.33E+05
MIG-21 Fishbed D/F/J	Fighter		160	120		130	120	160	160	971	2340	2230		4299	1.65E+07	5.78E+05	3.85E+05	3.13E+05	2.89E+05
F-7 (Fishbed C)	Fighter		40						40	1203	2340	2230		3470	3.33E+06	1.17E+05	7.77E+04	6.31E+04	5.83E+04
MIG-23 Flogger B/C/E/G/K	Fighter		46				46	45	46	1800	5750	2440		6236	6.88E+06	2.41E+05	1.61E+05	1.30E+05	1.20E+05
MIG-29 Fulcrum A/B	Fighter		10	"2 reg"		13			15	13	2100	4365	2440		4057	1.27E+06	4.43E+04	2.95E+04	2.40E+04	2.21E+04
MIG-15 Fagot	Fighter	*5*					180		190	144	1368	2365	1017		1407	4.86E+06	1.70E+05	1.13E+05	9.21E+04	8.50E+04
SU-7B Fitter A	Fighter		20	20			20	20	20	20	1450	5275	1696	850	4936	2.37E+06	8.29E+04	5.53E+04	4.49E+04	4.15E+04
SU-25 Frogfoot A	Fighter	*9*	35	>20		36		36	35	35	1250	4568	848		2479	2.08E+06	7.29E+04	4.86E+04	3.95E+04	3.64E+04
IL-28 Beagle	Bomber		80	82			85	82	80	82	2180	1740	900		575	1.13E+06	3.96E+04	2.64E+04	2.14E+04	1.98E+04
Y-5 (AN-2 Colt)	Transport	*20*	270	>250			205	270	>300	270	900	1200	220		235	3.17E+06	1.02E+05	8.54E+04	6.91E+04	6.51E+04
AN-24 (Coke)	Transport		6	10				10		6	600	5550	484		3582	1.07E+06	3.45E+04	2.90E+04	2.34E+04	2.21E+04
IL-18 Coot	Transport		2							2	6500	30000	675	625	2885	2.88E+05	9.26E+03	7.78E+03	6.29E+03	5.92E+03
IL-12 Coach (Civil)	Transport	*6,10,11*								10	1500	6500	675	625	2708	1.35E+06	4.35E+04	3.65E+04	2.96E+04	2.78E+04
LI-2 Cab (Civil)	Transport	*6,10,11*								10	1500	6500	675	625	2708	1.35E+06	4.35E+04	3.65E+04	2.96E+04	2.78E+04
IL-14 Crate (Civil)	Transport	*6, 10*								10	1500	6500	675	625	2708	1.35E+06	4.35E+04	3.65E+04	2.96E+04	2.78E+04
Fighters (All)			601	748	748	580				748						5.03E+07	1.76E+06	1.17E+06	9.52E+05	8.79E+05
Bombers (All)			80	82	82	85				82						1.13E+06	3.96E+04	2.64E+04	2.14E+04	1.98E+04
Transport (All)			278	310	310	205				308						8.59E+06	2.76E+05	2.32E+05	1.88E+05	1.76E+05
Helicopters																			
MI-2 Hoplite		*7*		"Most"				188		113	715	846	210		199	7.19E+05	2.31E+04	1.73E+04	1.37E+04	1.30E+04
MI-4 Hound		*8, 12*					75			45	325	846	210	160	416	6.00E+05	1.92E+04	1.44E+04	1.14E+04	1.08E+04
MI-8 Hip		*8*								30	475	1870	250	225	886	8.50E+05	2.73E+04	2.05E+04	1.62E+04	1.53E+04
MI-17 Hip											475	1870	250	240	945					
Hughes 500 D/E				87		>75		87		87	480	240	250	240	120	3.34E+05	1.07E+04	8.04E+03	6.37E+03	6.03E+03
All				275	275					275						2.50E+06	8.03E+04	6.02E+04	4.77E+04	4.52E+04
												Kerosene/Jet Fuel				5.14E+07	1.80E+06	1.20E+06	9.74E+05	8.99E+05
												Aviation Gasoline				1.11E+07	3.56E+05	2.92E+05	2.35E+05	2.22E+05
ALL AIRCRAFT									1413			**TOTAL ALL FUELS**				6.25E+07	2.15E+06	1.49E+06	1.21E+06	1.12E+06
Air Force Personnel		80,000	*3, 21*																	
Service Vehicles		6,235	*16*													1.52E+07	4.94E+05	4.94E+05	4.94E+05	4.94E+05
TOTAL: AIRCRAFT PLUS GROUND SUPPORT VEHICLES												**TOTAL ALL FUELS**				7.76E+07	2.65E+06	1.98E+06	1.70E+06	1.61E+06

Notes:

1 North Korea Handbook, US Department of Defense, 1994. (PC-2600-6421-94). Pages 6-165 - 6-178.
2 North Korea, The Foundations for Military Strength. US Defense Intelligence Agency (1990?). Pp. 47-48.
3 Point Paper, Republic of Korea/North Korea: Military Capabilities (with Military Balance). JICPAC (ONK), Sept. 1993.
4 From Opposing Force Training Module, North Korean Military Forces. Field Manual No. 34-21. Headquarters Department of the Army (US). February, 1982. Chapter 14.
5 Not given in source 1. Number assumed brings total of fighters up to that listed in sources 2 and 3.
6 Not given in source 1. Numbers assumed are guesses to bring total of transports to figures listed in sources 2 and 3.
7 Not given in source 1. Number assumed brings total of helicopters up to that listed in sources 2 and 3.
8 No breakdown between MI-4 and MI-8 available. Breakdown assumed is a guess. MI-8 and MI-17 are similar aircraft.
9 Fuel capacity estimated based on (max weight - empty weight - weapons weight).
10 No information available (1940's vintage aircraft). Range and fuel capacity assumed similar to IL-14.
11 Speed assumed similar to IL-18.
12 Fuel capacity assumed similar to the MI-2.
13 Translates to approximately two 1-hr missions per month per aircraft.
14 Fuel Capacity data are from the following sources: A) Jane's All the World's Aircraft, 1990/91, 1981/82, 1972/73, and 1968/69 editions. Jane's Publishing Co., N.Y., NY; B) Air Forces of the World, C.Chant, Brian Trodd Publishing House, Ltd (1990); C) Military Aircraft of the World, J.W.R. Taylor and G/ Swanborough, Ian Allen Ltd., UK (1979). Range and airspeed data are from a mixture of these sources and sources 1 and 4, above.
15 All jet aircraft are assumed to use Kerosene/Jet Fuel, while all propeller-driven craft and helicopters are assumed to use Aviation Gasoline.
16 Ground support vehicles for Air Force assumed to include light vehicles, 2 1/2 ton trucks, and larger trucks and utility vehicles in the same proportions as are used in the ground forces. The number of these vehicles per person in the Air Force is assumed to be the same as in the DPRK Army.
17 North Korea Country Handbook ,Marine Corps Intelligence Activity, 1997. (MCIA-2630-NK-016-97). File Nkor.pdf, obtained from Federation of American Scientists WWW site, 5/21/02, and dated May, 1997. Data on aircraft are mostly from pages 36 to 38 of this document.
18 North Korea, The Foundations for Military Strength -- Update 1995. US Defense Intelligence Agency (1995). Obtained from Federation of American Scientists WWW site, 5/21/02, and dated December, 1995.
19 As estimates of the numbers of aircraft from newer information sources (17 and 18) are not significantly different from those in earlier documents, we will continue to use the composite estimates of total aircraft shown here for 1996 and 2000 aircraft fuel use estimates.
20 Republic of Korea National Intelligence Service (1999), North Korea Military. The KPA: Troops & Equipment http://www.fas.org/irp/world/rok/nis-docs/defense08.htm, visited 5/21/02. This cource lists the DPRK Air Force as having "a whopping 820 support aircraft and helicopters", but does not indicate of what types are the approximately 200-plus aircraft beyond those listed in other sources (that is, apart from the AN-2 units and helicopters, the totals of which are similar to the listings above).
21 Republic of Korea National Intelligence Service, "North Korea Military. The KPA: Troops & Equipment", from http://www.fas.org/irp/world/rok/nis-docs/defense08.htm, visited 5/21/02, lists the total air force personnel for the DPRK at a total of 103,000, somewhat above the figure used here, but as the personnel totals do not directly affect fuel use estimates for this branch of the service, the figure from source 3 is used.
22 Unclassified informaiton on fuel use in the DPRK military was not available, but the informal opinion or analysts familiar with the DPRK military situation suggests that air force activity in the DPRK is, if anything, declining slowly, perhaps due to lack of fuel, probably due to lack of spare parts, and probably due to a recognition on the part of the DPRK military command that in a real conflict, the DPRK Air Force is unlikely, given the age and condition of its equipment, to play a substantial role. Accordingly, we have assumed that DPRK Air Force training exercises have continued to decrease slowly since 1996, as reflected in the flight-hours estimates shown.

23 The article "Korean People's Army Air Force" (http://www.globalsecurity.org/military/world/dprk/airforce.htm) on the Global Security website includes the following passage on the topic of training time for DPRK flight crews:

> "Pilot proficiency is difficult to evaluate because it is crudely proportionate to hours and quality of flight time. Although the Republic of Korea Ministry of National Defense's Defense White Paper, 1990 states that flight training levels are 60 percent of South Korea's, other sources believe the figure is closer to 20 to 30 percent. Lower flight times are attributed to fuel shortages, a more conservative training philosophy, and perhaps a concern for older airframe life expectancies or maintenance infrastructure capacity. The training of pilots on the NKAF's most modern aircraft is much more significant than "seven flying hours per year" sometimes claimed in the West. But air crew are being trained in accordance with outdated procedures and, with lack of fuel, have very little experience."

Although this article does not provide definitive information on aircraft use in training, it would seem to be consistent with the assumptions of limited, and slowly decreasing, training levels made in this analysis.
The same article also inicates that "Kazakhstan had transferred lethal military equipment, specifically about 40 MiG-21 fighter aircraft, to North Korea" in the late 1990s. We assume that this transfer has had little impact on overall usable stocks of that aircraft, or on training levels (and thus energy use).

ESTIMATE OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK
MILITARY SHIPS AND BOATS UPDATE 2006

Detailed Data and Results

Prepared By: David Von Hippel
Date Last Modified: 3/20/2007

True-Up Factors (*see Note 14*)	
Missile Attack Boats:	1.50
Amphibious:	1.46
Other Sm. Surface Vessels:	1.04

COMMON ASSUMPTIONS & PARAMETERS--NAVAL ENERGY USE

(Note 30)

Active Hours Per Year in:	**1990**	**1996**	**2000**	**2005**
Amphibious	**50**	**50**	**45**	**40**
Submarines	**100**	**100**	**90**	**80**
Other Vessels	**800**	**570**	**600**	**600**
Ave. power use--Fract. of Max.	**50%**	**50%**	**50%**	**50%**

THIS SECTION OF THIS WORKSHEET NOT USED FOR THIS ANALYSIS

Marine Diesel Fuel Cons. (*15*)	0.38	lb/hp-hr	
Sub Diesel Fuel Cons. (*16*)	0.5	lb/hp-hr	
Diesel Energy Content:	0.04	GJ/liter	Liters per gallon 3.78
Conversion Factor	2.2	lb/kg	
Diesel Fuel Density	0.87	kg/liter	

Type of Vessel	**Class**		Number in DPRK Navy Estimates from Sources *1*	*2*	*3*	*4*	*5*	*22*	*23*	*24*	Number in Navy Assumed	Displcmt Tons	Range n.miles	Speed knots	Engine Power (b/s/hp)
		Notes:												*6*	*5*
Nanjin Class	Frigate	*21*				4	2		2	2	1	1800	4000	14	15000
T (Tral) Class	Lg Patrol					2					2	475		18	3000
Sariwon Class	Lg Patrol					3	4			4	4	450		21	3000
SO 1 Class	Lg Patrol					15	15			18	16	250	1100	13	7500
Artillerist Class	Lg Patrol	*17*				2					2	240		25	7500
Hainan Class	Lg Patrol					4	6			6	6	400	1000	10	8800
Taechong Class	Lg Patrol					2	7			13	7	*400*			7500
OSA 1 Class	Missile Att.					8	16	12		26	24	200	800	25	12000
Komar Class	Missile Att.					10	8		39?	6	15	80	400	30	4800
Shanghi Class--Gun	Fast Att.					8	12			14	13	155	800	17	4800
Swatow Class--Gun	Fast Att.					8	8				8	80	500	28	3000
Chodo Class--Gun	Fast Att.					4	4				4	130	2000	10	6000
K-48 Class--Gun	Fast Att.					4	4				4	100		24	5000
MO IV Class--Gun	Fast Att.	*13*				20					21	56		25	3000
Chongjin Class--Gun	Fast Att.	*7*				30	45	31		51	47	*80*		*40*	4800
P 6--Torpedo	Fast Att.	*26*				62				30	65	75	450	30	4800
P 4--Torpedo	Fast Att.					12	60				13	25		50	4800
Iwon--Torpedo	Fast Att.	*10*				15	15				16	40			3600
An Ju--Torpedo	Fast Att.					6	6				6	35	1300	20	4800
Chaho Class--Torpedo	Fast Att.			>60		60	66	62		52	69	80		40	4800
Sin Hung/Kosong--Torp.	Fast Att.	*8*				60	72			98	75	35			2400
Shersen Class--Torpedo	Fast Att.					4	3				4	160		41	12000
KM 4--Torpedo	Fast Att.					10	10				10	10			146
Torpedo Boats	Patrol			150		229		200	320						
Light Patrol	Patrol	*19*				20					21	*2*			146
Hantae	Landing	*12, 18*		8			8	8		10	12	*150*			5000
Nampo	Landing			>100		70	100	100	130	95	146	82	375	40	4800
Hanchon	Landing	*9, 18*				5	25			7	36	*150*		10	5000
Kong Bang (Hovercraft)	Landing	*24,27*						125	130	135	130			52	8000
Whiskey	Submarine			4		4	15			4	4	1030	13,000	8	4000
Romeo, Chinese	Submarine			4							4	1100	16,000	10	4000
Romeo, NK	Submarine			16		11			26	22	16	1100	16,000	10	4000
YUGO mini-sub	Submarine	*25*							48+	40+	48	25		4	160
Sang-O coastal infiltration	Submarine	*29*							3	22	12	277		8.8	*800*
Frigates				1	1					1	1				
Corvettes				2	2					2	2				
Missile Attack Boats				39	39	18					39				
Coastal Patrol Craft				388	388										
Mine Warfare Craft		*11*		23	23	42				23	56				
Amphibious Craft				194	194	75					324				
Submarines				24	24	15					84				
Trawlers						105									
TOTAL, ALL VESSELS				671	671	568					801	89,216			
Those Using Heavy Fuel Oil											1	1,800			
Naval Personnel	60,000	*3, 28*													
Service Vehicles	4,077	*20*													
TOTAL: VESSELS PLUS SERVICE VEHICLES															

FUEL CONSUMPTION RESULTS: MILITARY VESSELS

		1990			1996			2000			2005		
Type of Vessel	**Class**	Per Vessel Fuel Cons. liters/year	Per Class Fuel Cons. liters/year	Per Class Fuel Cons. GJ/year	Per Vessel Fuel Cons. liters/year	Per Class Fuel Cons. liters/year	Per Class Fuel Cons. GJ/year	Per Vessel Fuel Cons. liters/year	Per Class Fuel Cons. liters/year	Per Class Fuel Cons. GJ/year	Per Vessel Fuel Cons. liters/year	Per Class Fuel Cons. liters/year	Per Class Fuel Cons. GJ/year
Nanjin Class	Frigate	1,191,223	1.19E+06	4.48E+04	848,746	8.49E+05	3.19E+04	893,417	8.93E+05	3.36E+04	893,417	8.93E+05	33,578
T (Tral) Class	Lg Patrol	238,245	4.76E+05	1.79E+04	169,749	3.39E+05	1.28E+04	178,683	3.57E+05	1.34E+04	178,683	357,367	13,431
Sariwon Class	Lg Patrol	238,245	9.53E+05	3.58E+04	169,749	6.79E+05	2.55E+04	178,683	7.15E+05	2.69E+04	178,683	7.15E+05	2.69E+04
SO 1 Class	Lg Patrol	595,611	9.53E+06	3.58E+05	424,373	6.79E+06	2.55E+05	446,708	7.15E+06	2.69E+05	446,708	7.15E+06	2.69E+05
Artillerist Class	Lg Patrol	595,611	1.19E+06	4.48E+04	424,373	8.49E+05	3.19E+04	446,708	8.93E+05	3.36E+04	446,708	8.93E+05	3.36E+04
Hainan Class	Lg Patrol	698,851	4.19E+06	1.58E+05	497,931	2.99E+06	1.12E+05	524,138	3.14E+06	1.18E+05	524,138	3.14E+06	1.18E+05
Taechong Class	Lg Patrol	595,611	4.17E+06	1.57E+05	424,373	2.97E+06	1.12E+05	446,708	3.13E+06	1.18E+05	446,708	3.13E+06	1.18E+05
OSA 1 Class	Missile Att.	952,978	2.29E+07	8.60E+05	678,997	1.63E+07	6.12E+05	714,734	1.72E+07	6.45E+05	714,734	1.72E+07	644,701
Komar Class	Missile Att.	381,191	5.72E+06	2.15E+05	271,599	4.07E+06	1.53E+05	285,893	4.29E+06	1.61E+05	285,893	4.29E+06	161,175
Shanghi Class--Gun	Fast Att.	381,191	4.96E+06	1.86E+05	271,599	3.53E+06	1.33E+05	285,893	3.72E+06	1.40E+05	285,893	3.72E+06	1.40E+05
Swatow Class--Gun	Fast Att.	238,245	1.91E+06	7.16E+04	169,749	1.36E+06	5.10E+04	178,683	1.43E+06	5.37E+04	178,683	1.43E+06	5.37E+04
Chodo Class--Gun	Fast Att.	476,489	1.91E+06	7.16E+04	339,498	1.36E+06	5.10E+04	357,367	1.43E+06	5.37E+04	357,367	1.43E+06	5.37E+04
K-48 Class--Gun	Fast Att.	397,074	1.59E+06	5.97E+04	282,915	1.13E+06	4.25E+04	297,806	1.19E+06	4.48E+04	297,806	1.19E+06	4.48E+04
MO IV Class--Gun	Fast Att.	238,245	5.00E+06	1.88E+05	169,749	3.56E+06	1.34E+05	178,683	3.75E+06	1.41E+05	178,683	3.75E+06	1.41E+05
Chongjin Class--Gun	Fast Att.	381,191	1.79E+07	6.73E+05	271,599	1.28E+07	4.80E+05	285,893	1.34E+07	5.05E+05	285,893	1.34E+07	5.05E+05
P 6--Torpedo	Fast Att.	381,191	2.48E+07	9.31E+05	271,599	1.77E+07	6.64E+05	285,893	1.86E+07	6.98E+05	285,893	1.86E+07	6.98E+05
P 4--Torpedo	Fast Att.	381,191	4.96E+06	1.86E+05	271,599	3.53E+06	1.33E+05	285,893	3.72E+06	1.40E+05	285,893	3.72E+06	1.40E+05
Iwon--Torpedo	Fast Att.	285,893	4.57E+06	1.72E+05	203,699	3.26E+06	1.22E+05	214,420	3.43E+06	1.29E+05	214,420	3.43E+06	1.29E+05
An Ju--Torpedo	Fast Att.	381,191	2.29E+06	8.60E+04	271,599	1.63E+06	6.12E+04	285,893	1.72E+06	6.45E+04	285,893	1.72E+06	6.45E+04
Chaho Class--Torpedo	Fast Att.	381,191	2.63E+07	9.89E+05	271,599	1.87E+07	7.04E+05	285,893	1.97E+07	7.41E+05	285,893	1.97E+07	7.41E+05
Sin Hung/Kosong--Torp.	Fast Att.	190,596	1.43E+07	5.37E+05	135,799	1.02E+07	3.83E+05	142,947	1.07E+07	4.03E+05	142,947	1.07E+07	4.03E+05
Shersen Class--Torpedo	Fast Att.	952,978	3.81E+06	1.43E+05	678,997	2.72E+06	1.02E+05	714,734	2.86E+06	1.07E+05	714,734	2.86E+06	1.07E+05
KM 4--Torpedo	Fast Att.	11,595	1.16E+05	4.36E+03	8,261	8.26E+04	3.10E+03	8,696	8.70E+04	3.27E+03	8,696	8.70E+04	3.27E+03
Torpedo Boats	Patrol												
Light Patrol	Patrol	11,595	2.43E+05	9.15E+03	8,261	1.73E+05	6.52E+03	8,696	1.83E+05	6.86E+03	8,696	1.83E+05	6.86E+03
Hantae	Landing	24,817	2.98E+05	1.12E+04	24,817	2.98E+05	1.12E+04	22,335	2.68E+05	1.01E+04	19,854	2.38E+05	8.95E+03
Nampo	Landing	23,824	3.48E+06	1.31E+05	23,824	3.48E+06	1.31E+05	21,442	3.13E+06	1.18E+05	19,060	2.78E+06	1.05E+05
Hanchon	Landing	24,817	8.93E+05	3.36E+04	24,817	8.93E+05	3.36E+04	22,335	8.04E+05	3.02E+04	19,854	7.15E+05	2.69E+04
		113,400	1.47E+06	5.54E+04	113,400	7.37E+06	2.77E+05	102,060	1.33E+07	4.99E+05	90,720	1.18E+07	4.43E+05
Whiskey	Submarine	52,247	2.09E+05	7.85E+03	52,247	2.09E+05	7.85E+03	47,022	1.88E+05	7.07E+03	41,797	1.67E+05	6.28E+03
Romeo, Chinese	Submarine	52,247	2.09E+05	7.85E+03	52,247	2.09E+05	7.85E+03	47,022	1.88E+05	7.07E+03	41,797	1.67E+05	6.28E+03
Romeo, NK	Submarine	52,247	8.36E+05	3.14E+04	52,247	8.36E+05	3.14E+04	47,022	7.52E+05	2.83E+04	41,797	6.69E+05	2.51E+04
		2,090	1.00E+05	3.77E+03	2,090	1.00E+05	3.77E+03	1,881	9.03E+04	3.39E+03	1,672	8.03E+04	3.02E+03
		10,449	1.25E+05	4.71E+03	10,449	1.25E+05	4.71E+03	9,404	1.13E+05	4.24E+03	8,359	1.00E+05	3.77E+03
Frigates			1.19E+06	4.48E+04		8.49E+05	3.19E+04		8.93E+05	3.36E+04		8.93E+05	3.36E+04
Corvettes			4.76E+05	1.79E+04		3.39E+05	1.28E+04		3.57E+05	1.34E+04		3.57E+05	1.34E+04
Missile Attack Boats			2.86E+07	1.07E+06		2.04E+07	7.66E+05		2.14E+07	8.06E+05		2.14E+07	8.06E+05
Coastal Patrol Craft													
Mine Warfare Craft													
Amphibious Craft			6.14E+06	2.31E+05		1.20E+07	4.53E+05		1.75E+07	6.57E+05		1.55E+07	5.84E+05
Submarines			1.48E+06	5.56E+04		1.48E+06	5.56E+04		1.33E+06	5.00E+04		1.18E+06	4.45E+04
Trawlers													
TOTAL, VESSELS			1.72E+08	6.48E+06		1.31E+08	4.92E+06		1.42E+08	5.35E+06		1.40E+08	5.27E+06
Those Using Heavy Fuel Oil			1.19E+06	4.48E+04		8.49E+05	3.19E+04		8.93E+05	3.36E+04		8.93E+05	3.36E+04
Service Vehicles			1.14E+07	3.71E+05		8.63E+06	2.81E+05		9.39E+06	3.06E+05		9.25E+06	3.02E+05
TOTAL: VESSELS PLUS SERVICE VEHICLES			1.84E+08	6.85E+06		1.39E+08	5.20E+06		1.52E+08	5.65E+06		1.49E+08	5.57E+06

Notes:

1 North Korea Handbook , US Department of Defense, 1994. (PC-2600-6421-94). Pages 6-165 - 6-178.
2 North Korea, The Foundations for Military Strength . US Defense Intelligence Agency (1990?). Pp. 44-46.
3 Point Paper, Republic of Korea/North Korea: Military Capabilities (with Military Balance). JICPAC (ONK), Sept. 1993.
4 From Opposing Force Training Module, North Korean Military Forces. Field Manual No. 34-21 . Headquarters Department of the Army (US). February, 1982. Chapter 15.
5 Jane's Fighting Ships, 1987-88 . Edited by J. Moore, Jane's Publishing Co., NY, NY. P. 329-222.
6 Speed shown is that given with the range of the vessel, if specified.
7 Assumed similar to Chaho Class based on information in source 4.
8 Similar to Soviet "D3" class.
9 Source 4 shows this vessel as approximately twice as long and 10% wider than the Nampo.
10 Similar to Soviet "P 2" class.
11 Total shown for source 4 are vessels listed in source 1 as mine-capable.
12 Source 1 shows this vessel to be about 30% longer, 10% narrower than the Hanchon
13 Assumed similar to Swatow class (engine size)
14 "True-up" factors are used to inflate numbers of vessels by individual class (from 4 and 5) to the aggregate values presented in sources 2 and 3. True-up factors are not applied to Kong Bang hovercraft or mini-subs.
15 Generic value for fuel consumption by marine diesel engines from The Marine Power Plant, L.B.Chapman McGraw-Hill, 1942. This figure may (or may not) be slightly high for the DPRK Navy. Figure judged to be reasonable by a representative of a US distributor of marine diesel engines, who gave a range of 0.32 lb/hp-hr for best modern diesels, to 0.40+ for older diesels, with 20 hp-hr/gallon (0.364 lb/hp-hr) as a modern rule of thumb. Same representative also indicated that a range of 0.4 to 0.6 of maximum power use was a reasonable range for a ship cruising at sea.
16 Generic value for fuel consumption by submarine diesel engines from Submarine Design and Development , N.Freedman, Naval Institute Press, Annapolis, MD, 1984. P. 131.
17 Assumed similar to SO 1 class (engine size)
18 Assumed similar to K-48 class (engine size)
19 Assumed similar to KM-4 torpedo class (engine size)
20 Service vehicles for Navy assumed to include light vehicles, 2 1/2 ton trucks, and larger trucks and utility vehicles in the same proportions as are used in the ground forces. The number of these vehicles per person in the Navy is assumed to be the same as in the DPRK Army.
21 Frigate is assumed to be fueled with heavy oil. All other vessels are assumed to be diesel-fueled.
22 North Korea Country Handbook ,Marine Corps Intelligence Activity, 1997. (MCIA-2630-NK-016-97). File Nkor.pdf, obtained from Federation of American Scientists WWW site, 5/21/02, and dated May, 1997. Data on naval vessels are mostly from pages 39 and 40 of this document.

23 North Korea, The Foundations for Military Strength -- Update 1995. US Defense Intelligence Agency (1995). Obtained from Federation of American Scientists WWW site, 5/21/02, and dated December, 1995.

24 World Navies Today: North Korea, from www.hazegray.org/worldnav/ (visited 5/22/02) suggests that the DPRK has "135 Kongbang class assault hovercraft, carrying 35-55 troops". Source 22 lists three types of these craft, with sizes ranging from 23 x 60.7 feet to 29.5 x 75.5 feet. Source 22 lists the speed of these vessels as 52 knots. No specific information on the propulsion systems used in these craft was included in either of these sources, but a somewhat larger troop landing hovercraft (47 x 88 feet) used by the US Navy, and with a slightly lower speed, is listed as having 16,000 hp (total?) in four turbine engines. http://www.fas.org/man/dod-101/sys/ship/lcac.htm (visited 5/22/02) lists the US "LCAC" as having 12,280 bhp, and "Fuel capacity is 5000 gallons. The LCAC uses an average of 1000 gallons per hour." Assume that the somewhat smaller DPRK vessels would have lower fuel consumption and power ratings perhaps 600 gallons per hour. According to source 23, production of the Kong Bang type II and III craft began in 1988, suggesting that the major portion of the Kong Bang fleet was produced after 1990. Assume that 10% of the fleet shown was in service by 1990, and 50% was in service by 1996.

25 Source 23 suggests that there are "over 48" YUGO submarines and 3 SANGO coastal submarines in the DPRK fleet.

26 Source 24 lists 18 "Sinpo class" small patrol boats, with 66.5 tons full load displacement, and 4800 hp diesels, and "up to 12" P-6 class small torpedo boats.

27 Estimate of 8000 bhp shown here for the Kong Bang hovercraft is a rough figure based on the specifications for the larger US vessel described in note 24. Fuel consumption, however, is based on the estimate given in note 24, not on the horsepower estimate. See also notes 31 and 32.

28 Republic of Korea National Intelligence Service, "North Korea Military. The KPA: Troops & Equipment", from http://www.fas.org/irp/world/rok/nis-docs/defense08.htm, visited 5/21/02, lists the total naval force personnel for the DPRK at a total of 48,000, somewhat above the figure used here, but as the personnel totals do not directly affect fuel use estimates for this branch of the service, the figure from source 3 is used.

29 Engine size for the Sang-O submarines is a rough estimate based on reported engine size for other DPRK subs and the relative size of the different submarine models.

30 There does not appear to be any available definitive intormation of an unclassified nature that could be used to even quailitatively estimate the level of activity in the DPRK naval forces as of 2000 or 2005. Analysts contacted in researching this update, however, indicate that the DPRK Navy did not, as of about 2002 seem to be operating under any particular fuel restrictions, and that the level of incursions (from DPRK vessels) experienced in ROK waters seems to be fairly consistent with prior years. As a result, we have assumed that DPRK naval activity was about the same (in terms of activity per vessel) as in 1996 for vessels other than submarines and amphibious craft. We have assumed that submarine and amphibious craft activity in the DPRK navy declined slightly in the period after 1996, in part, in the case of amphibious craft, in keeping with our assumption of reduced training levels for ground forces, as well as taking into account reported restrictions on fuel availability in the general economy.

31 http://www.globalsecurity.org/military/world/dprk/navy.htm states "[t]he North Korean navy has built over 140 hovercraft capable of carrying platoon-size units ashore…" which is on the same order as the estimates of the number of these craft provided in other sources, but slightly higher.

32 Two recent ROK media reports--"North Korea Deploys Air Cushion Warships", Seoul, The Korea Times (Internet Version-WWW) in English, by Cho'ng Su'ng-ki, dated April 1, 2007 (and quoting the 2006 ROK Defense White Paper); and "N.Korea Develops High-Speed Military Hovercraft", Seoul. Chosun Ilbo WWW-Text in English, dated April 2, 2007--report the development of DPRK hovercraft, but these appear to be the same as the Kong Bang hovercraft developed deployed during the 1990s, with no apparent change in the number of such vessels (both of the 2007 articles give a number of 130 hovercraft) since about 2000.

ESTIMATE OF ANNUAL FUEL USE BY THE MILITARY SECTOR IN THE DPRK
ENERGY USE IN MANUFACTURING MILITARY EQUIPMENT UPDATE 2006

Detailed Data and Results	
Prepared By:	David Von Hippel
Date Last Modified:	**1/5/2007**

COMMON ASSUMPTIONS & PARAMETERS, MILITARY MANUFACTURING	
Lifetime of Ground Forces Equipment (yrs):	20
Lifetime of Small Armaments (yrs):	10
Lifetime of Naval Vessels (yrs):	30
Fract. of Weight of Equipment as Iron & Steel	90%

GROUND FORCES: VEHICLES		Estimated Number in Service	Average Weight Each (t)	Made in DPRK?	Equip. Lifetime (years)	Total Weight (t)	Estimated Iron&Steel Needed (t)
	Notes:		*1*				
Tanks							
T-54/55		2,185	36	Yes?	20	7.87E+04	3.54E+03
T62/63/PT-76		3,106	36.4	Yes?	20	1.13E+05	5.09E+03
Assault		541	30	Yes?	20	1.62E+04	7.30E+02
Amphibious Vehicles +							
PT-76		189	14	Yes?	20	2.65E+03	1.19E+02
PTS		11	*20*	Yes?	20	2.28E+02	1.02E+01
K-61		364	*15*	Yes?	20	5.47E+03	2.46E+02
GAZ-46		40	*2*	Yes	20	7.97E+01	3.59E+00
Amphibious Ferry		68	50	Yes?	20	3.42E+03	1.54E+02
Tank Retriever		227	29	Yes?	20	6.57E+03	2.96E+02
Armored Fighting Vehicles							
BTR-60		3,622	10	Yes?	20	3.62E+04	1.63E+03
BRDM		393	*5*	Yes?	20	1.96E+03	8.84E+01
Truck/Tank Mtd Guns & Missiles							
AAG		273	31	Yes?	20	8.47E+03	3.81E+02
BM-21	*2*	157	13	Yes?	20	2.04E+03	9.19E+01
BM-20,24		17	9	Yes?	20	1.54E+02	6.92E+00
FROG 3/5		34	16	Yes?	20	5.47E+02	2.46E+01
FROG 7		34	20	Yes?	20	6.83E+02	3.07E+01
Light Vehicles							
Jeeps		6,150	1.5	Yes	20	9.22E+03	4.15E+02
Motorcycles		2,895	0.2	Yes	20	5.79E+02	2.61E+01
2 1/2 T Trucks		72,403	2.9	Yes	20	2.10E+05	9.45E+03
Trucks and Utility Vehicles					20		
Dump		26	13.5	Yes	20	3.54E+02	1.59E+01
Zil-135		34	12.4	No	20	4.24E+02	0.00E+00
Zil-151		547	6.1	No	20	3.33E+03	0.00E+00
KRAZ-214		102	13.5	Yes	20	1.38E+03	6.23E+01
GAZ-63		410	2.9	Yes	20	1.19E+03	5.35E+01
Zil-157V		239	6.6	No	20	1.58E+03	0.00E+00
Power Boats		150	*1*	Yes	20	1.50E+02	6.76E+00
Other Heavy Equipment		123	6.6	Yes	20	8.12E+02	3.65E+01
TOTAL--GROUND FORCES VEHICLES		94,343				5.05E+05	2.25E+04

		Estimated Number in Service	Average Weight Each (t)	Made in DPRK?	Equip. Lifetime (years)	Total Weight (t)	Estimated Iron&Steel Needed (t)
	Notes:		*1*				
GROUND FORCES: OTHER ARMAMENTS							
Towed Guns and Missile Launchers	*3*	10,000	6	Yes?	20	6.00E+04	2.70E+03
Light Arms, Various	*4*			Yes?	10	*42,640*	3.84E+03
TOTAL--GROUND FORCES OTHER						1.03E+05	6.54E+03

NAVAL FORCES						
Total Tonnage of Naval Vessels	*5*		Yes	30	8.92E+04	2.68E+03
Service Vehicles	7	4,077	(varies)	20	1.29E+04	5.66E+02
TOTAL--NAVAL FORCES					1.02E+05	3.24E+03
AIR FORCES						
AIRCRAFT	*6*		No			0
Service Vehicles	*7*	6,235	(varies)	20	1.72E+04	7.55E+02
TOTAL--AIR FORCES					1.72E+04	7.55E+02
TOTAL IRON&STEEL REQUIRED/YR FOR MILITARY EQUIPMENT						3.30E+04

CALCULATION OF ENERGY REQUIRMENTS FOR MILITARY PRODUCT MANUFACTURING, 1990				
Energy Required to melt iron for steel	**250**	kgce/te crude steel	*Note 8*	
Average number of melts to produce military products		**2**	*Note 9*	
DPRK Steelmaking processes assumed to be	**10%**	more energy intensive than in China		
Conversion Factor:		29.3	GJ/tce	
ESTIMATED COAL TO MANUFACTURE IRON AND STEEL MILITARY EQUIPMENT			5.32E+05	GJ
Fract. Energy Use in Production of Military Equipment Represented by Iron and Steel			**60%**	*Note 9*
ESTIMATED TOTAL COAL USED IN MILITARY EQUIPMENT MANUFACTURE			**8.87E+05**	GJ
Ratio of Electricity Use to Coal Use in DPRK (Non-Military) Iron and Steel Industry			0.054	*Note 10*
ESTIMATED TOTAL ELECTRICITY USED IN MILITARY EQUIPMENT MANUFACTURE			**4.75E+04**	GJ

PROJECTION OF ENERGY REQUIRMENTS FOR MILITARY PRODUCT MANUFACTURING

Ratio of Military Equipment Output in 1996 versus 1990:	**0.7**	
Ratio of Military Equipment Output in 2000 versus 1990:	**0.45**	***(See Notes 11 - 13)***
Ratio of Military Equipment Output in 2005 versus 1990:	**0.45**	***(See Notes 11 - 13)***

	1996	**2000**	**2005**
Projection of Coal Use in Military Manufacturing (GJ)	**6.21E+05**	**3.99E+05**	**3.99E+05**
Projection of Electricity Use in Military Manufacturing (GJ)	**3.33E+04**	**2.14E+04**	**2.14E+04**

Notes:

1 *From Opposing Force Training Module, North Korean Military Forces. Field Manual No. 34-21. Figures in* ***italics*** *are guesses--no data available.*

2 *Weight of launcher only--prime mover assumed to be imported..*

3 *Point Paper, Republic of Korea/North Korea: Military Capabilities (with Military Balance). JICPAC (ONK), Sept. 1993. This source reports roughly 10,800 artillery pieces and rocket launchers. Figure shown nets out roughly guns and missiles included in the accounting of ground forces vehicles. Weight per unit is a rough estimate, and is probably more likely to be high than low.*

4 *Assumes an average of 40 kg of light arms per person in the Army.*

5 *Sum of displacement of Naval vessels. Actual weight of vessels may be different.*

6 *All aircraft assumed to be imported.*

7 *Based on service/ground support vehicle totals calculated in the Aircraft and Navy sheets, and the vehicle tonnages shown in the Ground Forces section of this sheet.*

8 *"The Energy Efficiency of the Steel Industry of China", M.Ross and L.Feng. Energy, Volume 16, no. 5 (1991), pp. 833-848.*

9 *Peter Zimmerman, personal communication.*

10 *Assumes that the ratio of electricity to coal use in military manufacturing will be similar to that in the iron and steel subsector of the DPRK's (assumed) non-military industries. Ratio calculated from figures in estimated energy balance for DPRK.*

11 *There has been little direct or quantitative information available on the intensity of military manufacturing in the DPRK in recent years. There have been some reports of missile exports from the DPRK. The Seoul T'ongil Kyongje article referenced below (13) suggests that exports of SCUD-C missles in the "early 1990s" were on the order of 100-150 per year. The same article also suggests that "weapons exports at the 15 to 20 percent [presumably of total national exports] in the Cold War…dropped to less than 5 percent after the mid 1990s". It seems unlikely that such exports of relatively high-value armaments would have a substantial effect on overall military sector manufacturing. We assume that the level of military manufacturing is approximately the same as in 1996, though even that level may be difficult for the DPRK to sustain given the reported difficulties in the DPRK coal sector.*

12 A description of SCUD missles ("Weapons of Mass Destruction (WMD): R-11 / SS-1B SCUD-A R-300 9K72 Elbrus / SS-1C SCUD-B") from http://www.globalsecurity.org/wmd/world/russia/r-11.htm suggests that the typical weight of a SCUD missile is about 6.5 tonnes, of which "3,500 kilograms (7,700 pounds) of IRFNA [inhibited red fuming nitric acid, a fuel oxidant] and about 1,000 kilograms (2,200 pounds) of fuel".
An article in Janes.com, "SS-1 `Scud' (R-11/8K11, R-11FM (SS-N-1B) and R-17/8K14)", dated April 26, 2001, lists the SCUD-C as having a launch weight of 6.4 tonnes and a warhead weight of 600 kg (http://www.janes.com/security/international_security/news/misc/sws_scud010426.shtml).
these figures together suggest that the weight of the missile hardware itself is about 1.3 tonnes. Assuming that most or all of this mass is steel, exports of SCUD-C missiles in the early-1990s imply a use of iron/steel of about 130-200 tonnes--which amounts to on the order of half of 1 percent of the iron/steel needed for routine replacement of DPRK equipment (as of 1990), as calculated above. Thus, exports of these missiles, at least, would seem to have little impact on overall DPRK Military manufacturing energy use.

13 The journal Seoul T'ongil Kyongje, dated July 2002, contains an article (pages 28-36) by So Chu-sok entitled "North Korean Industries (Part X): Munitions Industry". Among the information in this article is the following: "…North Korean military power has not changed greatly since….the mid 1990s", apart from some missile development and "expanded forward deployment of long-range artillery". The article estimates the size of the military at 1.7 million people, consuming much more than 5% of food in the country, and more than 15 percent of fuel oil used in the DPRK. Military stockpiles of food and fuel are "100 to 120 days worth", but it is not stated whether. this refers to days under typical non-combat or combat conditions. The article states that there are about 180 munitions factories in the DPRK, including about 40 gun factories, 10 armored vehicle factories, 50 ammunitions factories, and 10 naval shipyards, producing a total of 25 percent of GNP. Exports of SCUD-C missiles in the early 1990s are estimated at 100 to 150 per year. Factories, largely based on Soviet/East Bloc technology, have become "technologically obsolete and their facilities are run down", resulting in "extremely low" efficiency and high rates of consumption of energy and materials that, coupled with fuel and materials shortages, have "caused production setbacks" in some factories. This general description, together with the information in notes 11 and 12, leads us to believe that military manufacturing has fallen fairly substantially since 1996, in part due to further loss of exports since then, but also due to fuels, material, and parts shortages. We assume that military manufacturing activity was 45 percent of (estimated) 1990 levels in 2005. This would mean that miltary-sector manufacturing, while substantially less than in 1990, has not fallen by as much as average industrial sector output in the DPRK.

ESTIMATES OIL FUEL USE IN A CONFLICT BY THE MILITARY SECTOR IN THE DPRK

Prepared by: D. Von Hippel, 6/3/04 **(Updated 6/23/06)**

Based on our estimates of 1990 Fuel Use (from MIL_NK8.XLS), total use of fuel per hour of exercise-level activity are as follows:

Conversions from GJ to tonnes assume	43	GJ/tonne fuel

Service	GJ/hr	Tonnes/hr	Notes
Ground Forces	7,638	178	Per hour overall ground forces activity*
Air Forces	110,342	2,566	Per hour fighter/bomber activity
Naval Forces	8,559	199	Per hour "other vessels" activity

*Assumes armaments (including tanks) move 4 times as much as during routine exercises.

Assuming a 30-day conflict in which:
50% of ground forces are destroyed/rendered inoperable by the end of the period,
and ground forces are moving about 50% of the time,
100% of air forces are destroyed/rendered inoperable or placed in deep storage within
24 hours of the start of the conflict, and
90% of naval forces are destroyed/rendered inoperable/placed in deep storage within
120 hours of the start of the conflict.

Total fuel use during a 30-day conflict would be: 129,387 tonnes

Based on our estimates of year 2000 diesel plus gasoline production plus imports in the DPRK,
it would take on the order of 3.0 months to replenish the stocks consumed in the
conflict, even if A) all domestic production and imports were diverted to the war effort, and B) all supply
lines remained intact.
Running the two operating refineries at full capacity (only possible if sufficient imported crude oil
supplies are available) would increase the total output of gasoline plus diesel by about
43,355 tonnes per month, meaning that the stocks consumed could be replenished in
about 1.5 months

The rate of fuel use by the forces remaining after a 30-day war as above would be 108.71 tonnes/hr
This is about 180% of the total average year 2000 rate of diesel plus gasoline production and imports, or
about 90% of the total rate of diesel plus gasoline production and imports with refineries running to full capacity.