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Changes in Energy Consumption, Economic Growth and Aspirations for Energy Independence: Sectoral Analysis of Uses of Natural Gas in Ukrainian Economy

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Supplementary Information

Table S1. Indicators of the ratio between real gross domestic product (GDP) and natural gas consumption by country ¹.

Countries	Real GDP (at Constant Prices of 2010), Billion USD			Volume of Consumption of Natural Gas, Billion Cubic Meters			Ratio of Real GDP to the Volume of Natural Gas Consumption, USD per Cubic Meter of Gas		
	2010	2017	Growth Rate, %	2010	2017	Growth Rate, %	2010	2017	Growth Rate, %
USA	14,992.0	17,348.6	15.72	648.2	739.5	14.09	23.13	23.46	1.43
China	6100.6	10,161.0	66.56	108.9	240.4	120.75	56.02	42.27	−24.55
Australia	1144.3	1375.7	20.22	33.8	41.9	23.96	33.86	32.83	−3.02
Austria	391.9	432.8	10.44	9.4	9.0	−4.26	41.69	48.09	15.34
Belgium	483.5	525.5	8.69	19.8	16.4	−17.17	24.42	32.04	31.22
Czech Republic	207.5	241.1	16.19	9.4	8.4	−10.64	22.07	28.70	30.03
Finland	247.8	262.0	5.73	4.1	1.8	−56.10	60.44	145.56	140.83
France	2642.6	2874.7	8.78	49.6	44.7	−9.88	53.28	64.31	20.71
Germany	3417.1	3883.9	13.66	88.1	90.2	2.38	38.79	43.06	11.01
Hungary	130.9	153.6	17.34	11.4	9.9	−13.16	11.48	15.52	35.12
Italy	2125.1	2118.8	−0.30	79.7	72.1	−9.54	26.66	29.39	10.21
Netherlands	846.6	923.7	9.11	45.6	36.1	−20.83	18.57	25.59	37.82
Poland	479.3	600.9	25.37	16.2	19.1	17.90	29.59	31.46	6.34
Romania	166.2	216.3	30.14	12.5	11.9	−4.80	13.30	18.18	36.71
Spain	1431.6	1509.8	5.46	36.2	32.0	−11.60	39.55	47.18	19.30
Turkey	771.9	1206.0	56.24	35.8	51.7	44.41	21.56	23.33	8.19
United Kingdom	2452.9	2818.7	14.91	98.5	78.8	−20.00	24.90	35.77	43.64

¹ Sources of input information: [63,64]

Table S2. Input data and decomposition results of the growth rate of natural gas consumption by Ukrainian industry for 2008–2017 ¹.

Years	Index of Natural gas Consumption (Relative to the Previous Year), times	Index of Physical Volumes of Sales of Products (Relative to the Previous Year), times	Index of Natural Gas Consumption per Unit of Physical Volume of Production (Relative to the Previous Year), times	The Growth Rate of Natural Gas Consumption (Compared to the Previous Year), share of unit			
				Total	Including Due to		
					Changes in Physical Volumes of Products	Changes in the Volume of Natural Gas Consumption per Unit of Physical Output	Joint Influence of Both Factors
2008	0.90	0.95	0.95	0.10	0.05	0.05	0.00
2009	0.58	0.78	0.74	0.42	0.22	0.26	−0.06
2010	1.15	1.12	1.03	−0.15	−0.12	−0.03	0.00
2011	1.02	1.08	0.95	−0.02	−0.08	0.05	0.00
2012	0.80	0.99	0.81	0.20	0.01	0.19	0.00
2013	0.83	0.96	0.86	0.17	0.04	0.14	−0.01
2014	0.76	0.90	0.85	0.24	0.10	0.15	−0.02
2015	0.83	0.87	0.96	0.17	0.13	0.04	−0.01
2016	0.90	1.03	0.87	0.10	−0.03	0.13	0.00
2017	1.06	1.00	1.06	−0.06	0.00	−0.06	0.00

¹ Sources of input information: [65,67]

Table S3. Input data and results of decomposition of changes in volumes of natural gas consumption by industrial sectors of Ukraine in 2017 compared to 2007 ¹.

Industry Sectors	Volume of Natural Gas Consumption, thousand tons of oil equivalent		Index of Physical Volumes of Production (in 2017 compared to 2007), times	Change in Natural Gas Consumption in 2017 compared to 2007, thousand tons of oil equivalent			The Share of Changes in the Volume of Natural Gas Consumption due to Increased Efficiency of its Use in the Total Change in Consumption, %
	2007	2017		Total	As a Result of Changes in Physical Volumes of Products	As a Result of Changes in the Volume of Natural Gas Consumption per unit of Physical Output	
Ferrous metallurgy	6019	1398	0.59	−4621	−1894.6	−2801.9	60.63
Chemical and petrochemical industry	679	141	0.75	−538	−134.5	−389.0	72.31
Color metallurgy	240	144	0.68	−96	−30.7	−11.3	11.76
Production of non-metallic mineral products	2399	338	0.77	−2061	−474.0	−1683.9	81.70
Production of transport equipment	100	21	0.42	−79	−45.8	−39.5	50.00
Machine building	343	122	0.54	−221	−101.7	−75.4	34.13
Mining industry	467	266	0.71	−201	−58.3	−39.7	19.78
Food and tobacco industry	303	151	0.91	−152	−13.7	−68.8	45.24
Pulp and paper and printing industry	31	18	0.76	−13	−3.1	−3.1	23.60
Woodworking industry	55	3	1.02	−52	1.0	−49.2	94.65
Construction	65	9	0.49	−56	−28.6	−40.2	71.74
Textile and leather industry	7	5	0.82	−2	−0.4	−0.3	12.89

¹ Sources of input information: [65,66]

Table S4. Indicators of the dynamics of added value and volumes of natural gas consumption in industry in Ukraine for 2008–2017 ¹.

Years	Index of Real Added Value (relative to the previous year)	Index of Natural Gas Consumption (relative to the previous year)	Index of Efficiency of Use of Natural Gas on the Indicator of Real Added Value (relative to the previous year)
2008	1.09	0.90	1.21
2009	0.92	0.58	1.59
2010	1.26	1.15	1.10
2011	1.19	1.02	1.17
2012	1.14	0.80	1.43
2013	0.97	0.83	1.17
2014	0.74	0.76	0.97
2015	0.83	0.83	1.00
2016	1.19	0.90	1.32
2017	1.11	1.06	1.05

¹ Sources of input information: [65,67]

Table S5. Indicators of the dynamics of added value and volumes of natural gas consumption by industries of Ukraine in 2008–2016.

Industries	Real Added Value Index		Index of Natural Gas Consumption		Index of Efficiency of Use of Natural Gas on the Indicator of Real Added Value	
	In 2012, Compared to 2008	In 2016, Compared to 2012	In 2012, Compared to 2008	In 2016, Compared to 2012	In 2012, Compared to 2008	In 2016, Compared to 2012
Ferrous metallurgy	0.935	0.908	0.598	0.379	1.563	2.397
Chemical and petrochemical industry	1.292	0.656	0.702	0.519	1.841	1.264
Color metallurgy	1.113	1.029	0.544	0.949	2.046	1.085
Production of non-metallic mineral products	0.987	1.073	0.236	0.655	4.175	1.638
Production of transport equipment	1.032	0.406	1.713	0.109	0.603	3.705
Machine building	0.937	0.533	0.687	0.461	1.365	1.155
Mining industry	1.069	0.792	0.817	0.857	1.308	0.924
Food and tobacco industry	1.078	0.769	0.893	0.555	1.208	1.386
Pulp and paper and printing industry	0.906	1.167	0.839	0.692	1.081	1.685
Woodworking industry	0.933	1.422	0.432	0.158	2.159	9.009
Construction	0.876	0.597	0.574	0.323	1.526	1.851
Textile and leather industry	1.039	1.040	1.143	0.625	0.909	1.663

Table S6. Input data to determine the impact of the share of costs on purchasing natural gas in the amount of operating costs by industry in Ukraine on the change in the efficiency of consumption of natural gas ¹.

Industry Sectors	The Share of Expenses for the Purchase of Natural Gas in the Total Operating Expenses in 2012, %	Index of Natural Gas Consumption per unit of Physical Output in 2016 Relative to 2012, times	Relative Growth of Operating Expenses as a Result of Increase in Prices for Natural Gas in 2016 Relative to 2012, %
Ferrous metallurgy	12.7	0.533	8.5
Chemical and petrochemical industry	13.9	0.849	8.9
Color metallurgy	10.9	0.538	3.4
Production of non-metallic mineral products	6.7	0.530	2.9
Production of transport equipment	11.2	0.756	4.6
Machine building	11.7	0.764	2.4
Mining industry	12.3	1.152	5.8
Food and tobacco industry	10.2	0.612	4.9
Pulp and paper and printing industry	5.6	0.549	2.7
Woodworking industry	7.5	0.645	3.0
Construction	3.1	0.843	2.6
Textile and leather industry	5.9	0.516	1.7

¹ Sources of input information: [65,67].

Table S7. Division of Ukrainian industrial sectors into sub-sectors.

Industry Sectors	Number of Sub-Sectors	Industry Sub-Sectors
Ferrous metallurgy	5	Production of pig iron; steel production; production of steel and cast iron pipes; coke industry; production of other metallurgical products
Chemical and petrochemical industry	4	Manufacture of basic chemical products, fertilizers, nitrogen compounds, plastics and synthetic rubber; production of other types of chemical products; petrochemical industry
Color metallurgy	5	Production: aluminum; copper; titanium and magnesium; lead and zinc; other metallurgical products
Production of non-metallic mineral products	8	Production: rubber products; plastic products; glass and glassware; refractory products; clay building materials; other porcelain and ceramic products; cement, lime and gypsum mixtures; other non-metallic mineral products
Production of transport equipment	5	Manufacture: motor vehicles; trailers and semi-trailers; assemblies and parts for vehicles; iron locomotives; other vehicles
Machine-building	5	Manufacture: computers, electronic and optical products; electrical equipment; general purpose equipment; metalworking machines; other types of engineering products
Mining industry	3	Mining of coal and lignite; production of oil and natural gas; mining of other minerals
Food and tobacco industry	3	Production: food; drinks; tobacco products
Pulp and paper and printing industry	2	The pulp and paper industry; printing industry
Woodworking industry	3	Production: wood; wood products, except furniture; manufacture of furniture
Construction	3	Housing; industrial construction; other types of construction
Textile and leather industry	4	Textile production; production of clothing; leather production; production of leather goods

Table S8. Some indicators of activity of industrial sub-sectors of Ukraine.

Sub-Sectors Numbering	s_0 , %	I_e , times	ΔC_{opr} , %	I_{va} , times	I_{E_r} , times
1	11.9	0.564	9.3	0.875	0.402
2	13.0	0.676	8.6	0.816	0.387
3	9.4	0.512	5.8	1.058	0.326
4	12.3	0.558	9.0	0.919	0.376
5	12.9	0.625	8.8	0.890	0.381
6	13.6	0.819	9.3	0.707	0.568
7	14.2	0.924	8.8	0.621	0.612
8	12.5	0.851	9.6	0.664	0.459
9	14.0	0.889	9.1	0.634	0.537
10	9.2	0.586	2.8	1.013	0.912
11	11.5	0.617	4.2	1.008	1.012
12	9.6	0.530	3.5	1.047	0.879
13	11.8	0.608	5.1	1.005	1.087
14	9.4	0.511	3.0	1.043	0.972
15	4.5	0.635	2.6	0.967	0.834
16	7.8	0.479	3.4	1.113	0.560
17	6.3	0.508	3.6	1.098	0.498
18	3.9	0.679	2.7	1.076	0.713
19	4.2	0.647	2.2	0.945	0.785
20	8.4	0.535	3.1	1.156	0.613
21	3.5	0.629	2.8	0.987	0.679
22	2.7	0.708	2.2	1.067	0.652
23	9.1	0.562	3.8	0.753	0.213
24	11.9	0.830	5.6	0.345	0.112
25	13.0	0.812	5.2	0.401	0.102
26	11.4	0.785	5.7	0.326	0.208
27	9.5	0.526	3.4	0.288	0.095
28	10.1	0.665	3.7	0.312	0.079
29	12.0	0.822	4.1	0.589	0.398
30	11.5	0.765	4.3	0.603	0.536
31	10.3	0.674	1.6	0.457	0.424
32	11.9	0.851	2.2	0.523	0.483
33	11.6	1.098	5.5	0.834	0.765
34	13.2	1.179	6.1	0.765	1.038
35	12.2	1.156	5.3	0.722	0.809
36	9.6	0.527	4.1	1.025	0.578
37	8.5	0.543	4.4	1.037	0.488
38	11.7	0.678	5.7	0.719	0.673
39	10.9	0.632	6.3	0.675	0.514
40	4.1	0.608	2.5	0.914	0.667
41	7.2	0.509	3.1	1.326	0.714
42	8.3	0.528	3.9	1.521	0.214
43	4.9	0.564	2.6	0.998	0.135
44	7.7	0.473	3.0	1.608	0.157
45	2.6	0.876	1.9	0.612	0.316
46	3.5	0.816	2.4	0.724	0.376
47	2.8	0.852	2.2	0.507	0.276
48	4.7	0.658	1.5	0.987	0.734
49	6.8	0.468	2.6	1.113	0.567
50	4.2	0.539	1.2	0.956	0.617

¹ Designation of indicators: s_0 —share cost of purchasing natural gas in total operating expenses in 2012,%; I_e —index of natural gas consumption per unit of physical output in 2016 relative to 2012, times; ΔC_{op} —relative growth of operating expenses as a result of increase in prices for natural gas in

2016 relative to 2012,%; I_{Va} —sectoral (industry) value added index in 2016 relative to 2012, times;
 I_E —sectoral index of volumes of consumption of natural gas, times.

Table S9. Dynamics of natural gas consumption and production in Ukraine and indicators of dependence on its import for 2007–2017 ¹.

Years	Total Consumption of Natural Gas, billion m ³	Own Production of Natural Gas, billion m ³	Level of Dependence on Imports of Natural Gas	
			Absolute Value, billion m ³	Relative to Total Consumption, %
2007	69.8	20.0	49.8	71.35
2008	66.3	20.3	46.0	69.38
2009	51.9	20.3	31.6	60.89
2010	57.6	19.4	38.2	66.32
2011	59.3	19.5	39.8	67.12
2012	54.8	19.4	35.4	64.60
2013	50.4	20.2	30.2	59.92
2014	42.6	20.2	22.4	52.58
2015	33.8	18.8	15.0	44.38
2016	32.0	19.0	13.0	40.63
2017	31.5	19.4	12.1	38.41

¹ Sources of input information: [63,65].



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