



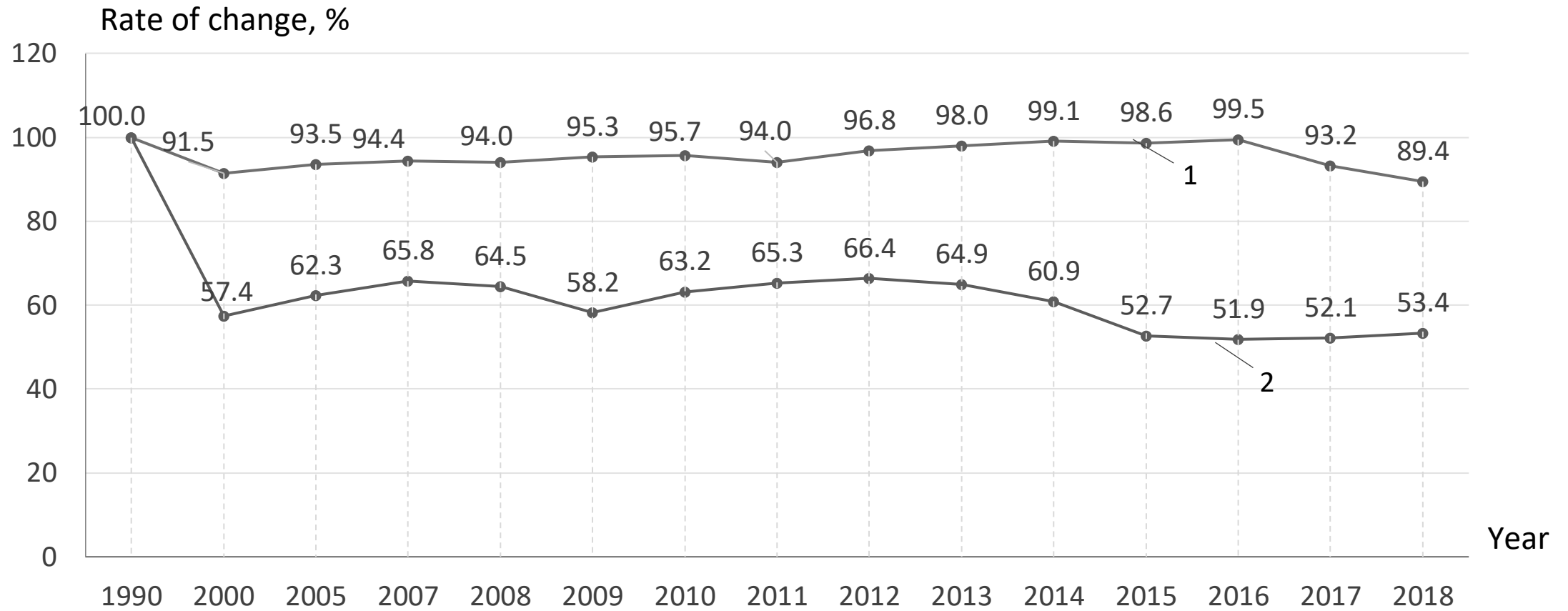
STRUCTURAL CHANGES IN UKRAINE'S ELECTRICITY GENERATION AND THEIR IMPACT ON THE REDUCTION OF CO₂ EMISSIONS

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Behavior of Ukraine CO₂ emissions by economic sector, mln tonnes

Economic sector	Year									
	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Electricity and heat generation	333	191	133	129	123	90	101	83	88	80
Industry	195	98	81	75	61	42	38	31	36	35
Transport	55	33	27	31	34	23	24	25	25	27
Buildings	52	52	41	37	35	23	23	22	22	17
Agriculture	22	5	3	8	4	4	5	4	4	4
Energy	24	13	7	9	7	4	4	3	3	3
Total	689	396	295	291	267	188	198	171	182	170

Trends in Ukraine's electricity generation capacities and electricity generation in 1990-2018



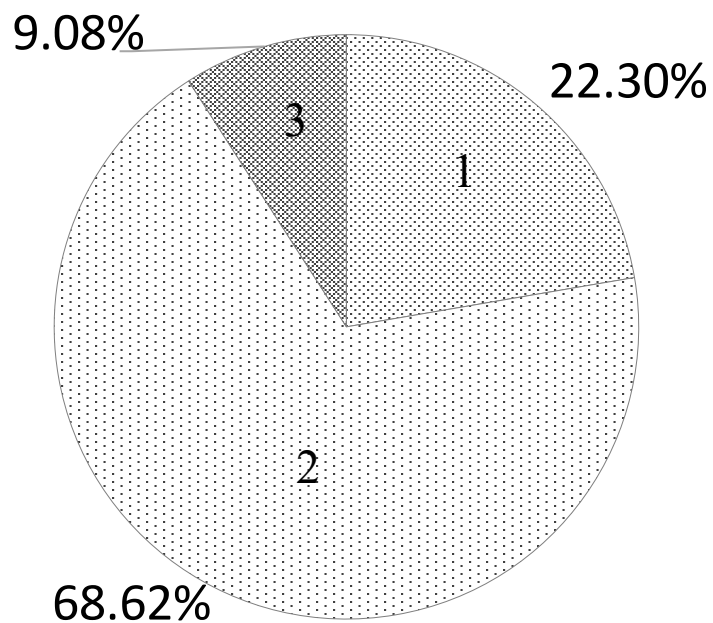
1 – electricity generation capacities; 2 – electricity generation

Classification of Ukraine's electricity generation capacities and electricity generation by flexibility

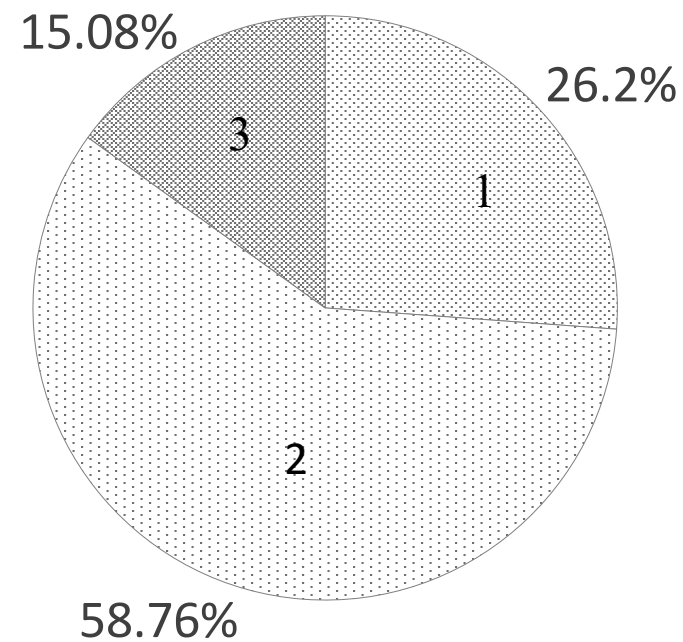
Type of flexibility	Source of electricity generation
Non-flexible	Nuclear power plants
Partially flexible	Thermal power plants and combined heat and power plants
Flexible	Hydroelectric, wind, solar power plants, and other electricity generation facilities

Structure of Ukraine's electricity generation capacities by type of flexibility in 2000 and 2018

2000

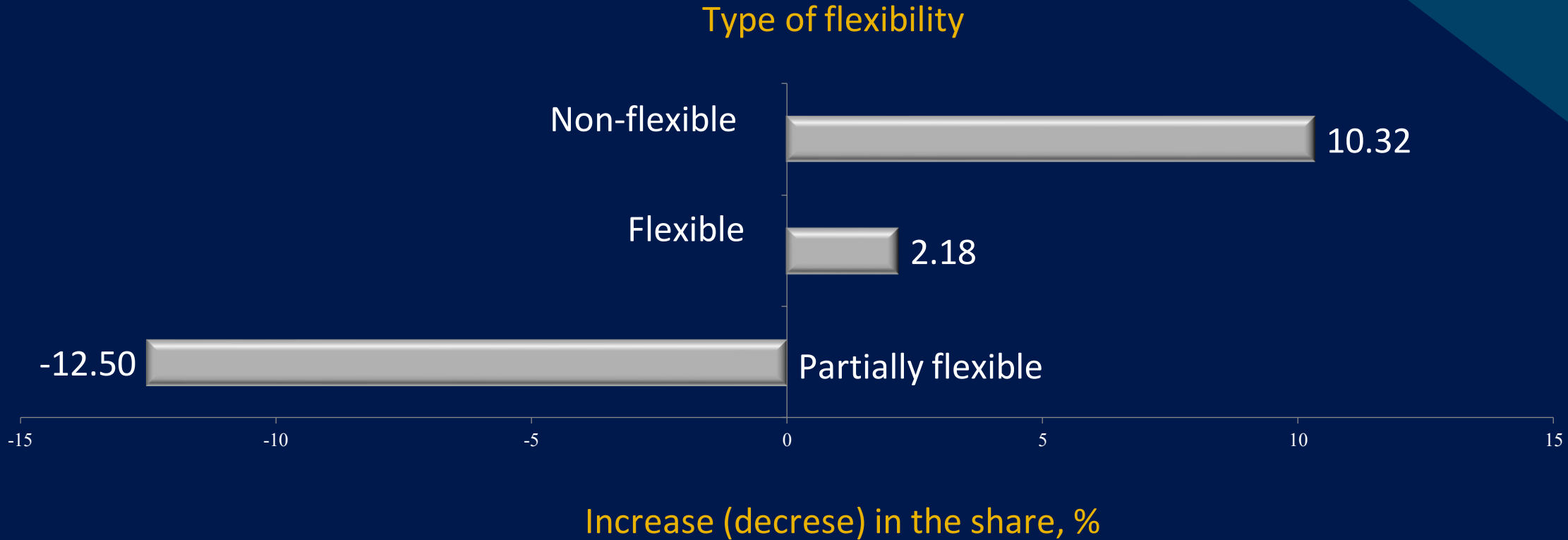


2018



1 – non-flexible; 2 – partially flexible; 3 – flexible

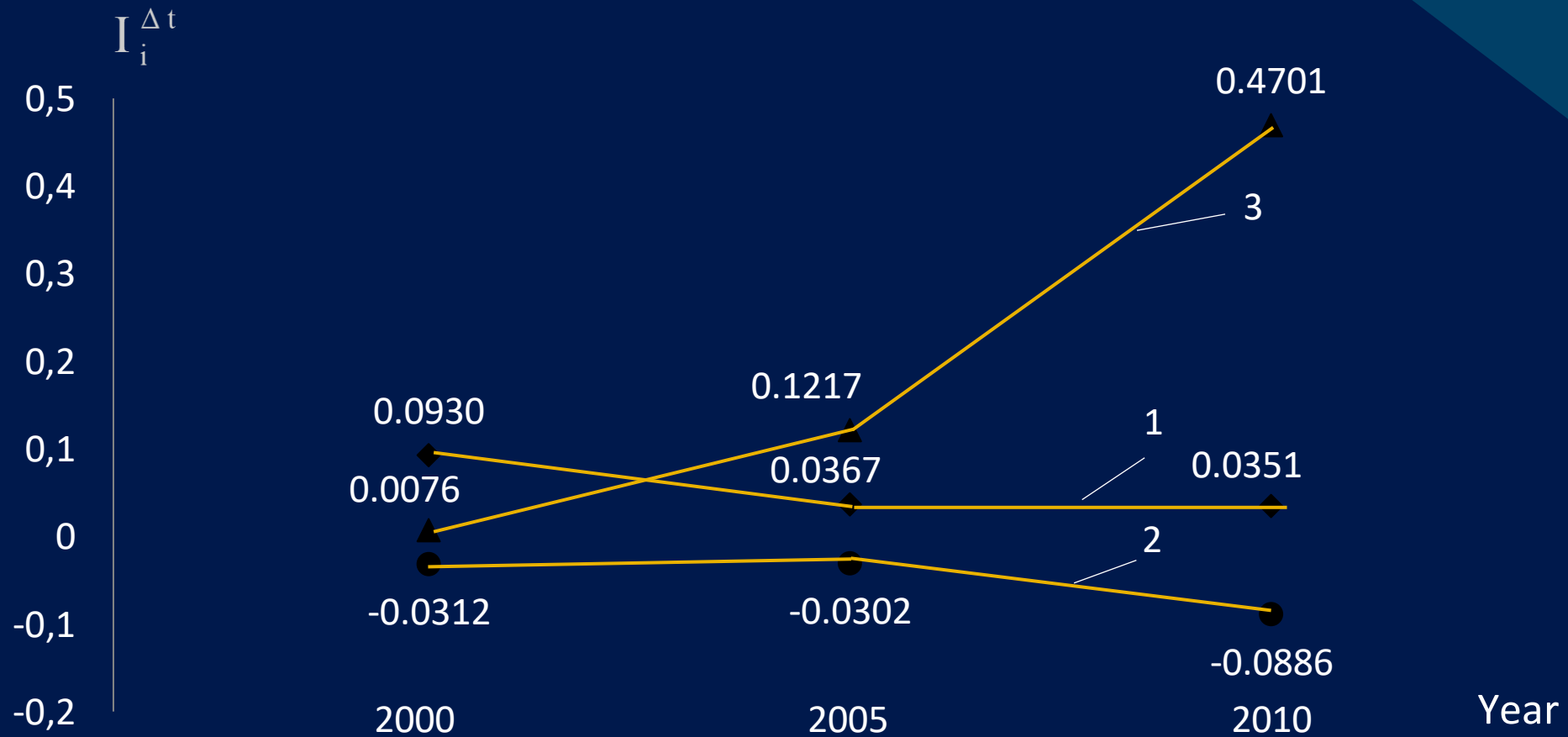
Increase (decrease) in the share of Ukraine's electricity generation by type of flexibility in 2000-2018



Structural changes in Ukraine's electricity generation capacities and electricity generation by type of flexibility

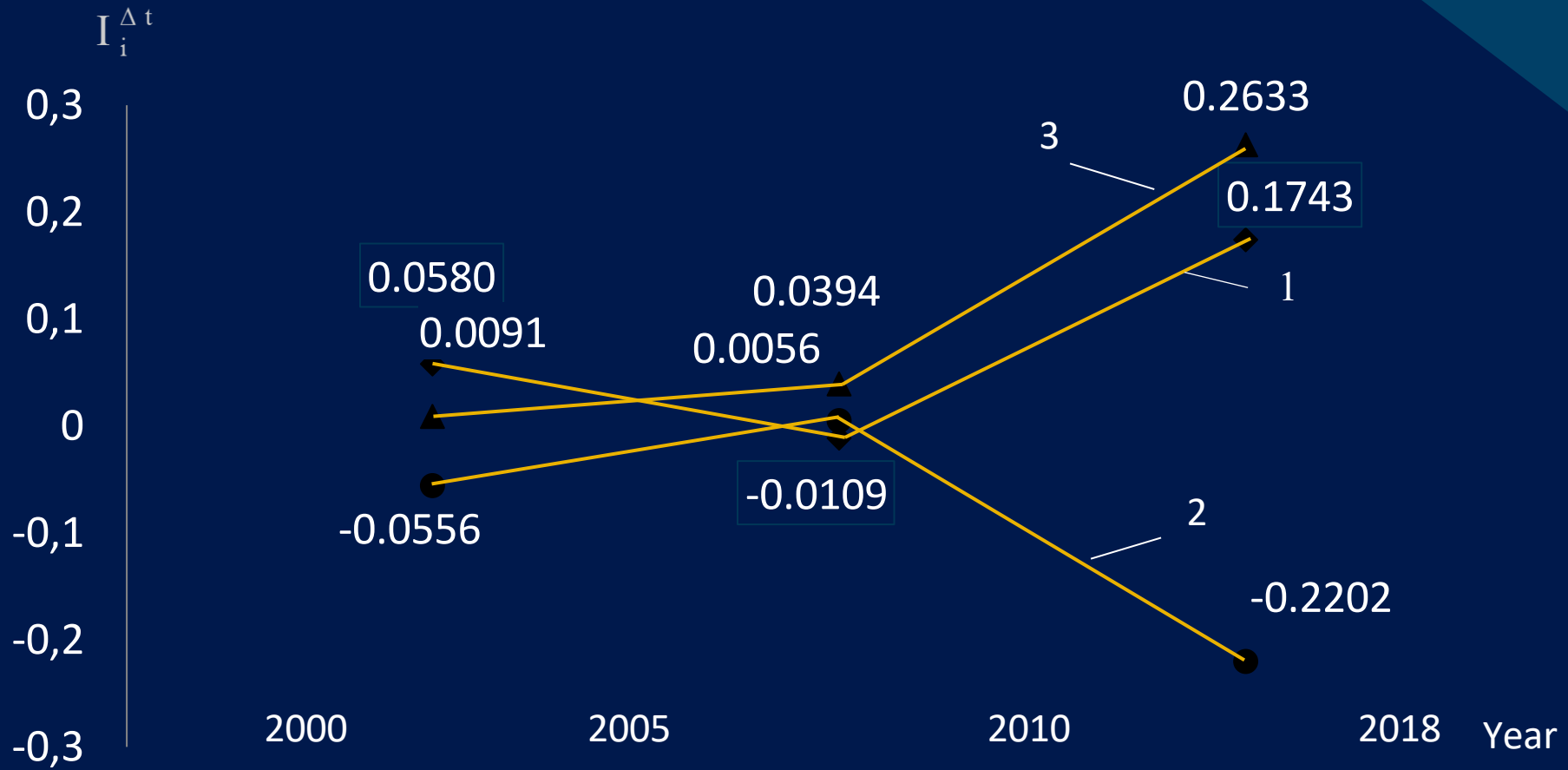
Type of flexibility	Share, %				Difference in the shares, %				Index of structural change ($I_i^{\Delta t}$)			
	d_{2000}	d_{2005}	d_{2010}	d_{2018}	$d_{2005} - d_{2000}$	$d_{2010} - d_{2005}$	$d_{2018} - d_{2010}$	$d_{2018} - d_{2000}$	$I_i^{2000-2005}$	$I_i^{2005-2010}$	$I_i^{2010-2017}$	$I_i^{2000-2018}$
Capacities												
Non-flexible	22.3	24.4	25.3	26.2	2.07	0.89	0.89	3.85	0.0930	0.0367	0.0351	0.1728
Partially flexible	68.6	66.5	64.5	58.8	-2.14	-2.01	-5.71	-9.86	-0.0312	-0.0302	-0.0886	-0.1437
Flexible	9.08	9.15	10.3	15.1	0.07	1.11	4.82	6.01	0.0076	0.1217	0.4701	0.6616
Generation												
Non-flexible	45.1	47.7	47.2	55.4	2.62	-0.52	8.22	10.32	0.0580	-0.0109	0.1743	0.2289
Partially flexible	48.2	45.5	45.8	35.7	-2.68	0.25	-10.08	-12.50	-0.0556	0.0056	-0.2202	-0.2594
Flexible	6.7	6.8	7.0	8.9	0.06	0.27	1.85	2.18	0.0091	0.0394	0.2633	0.3250

Trends in structural changes in Ukraine's electricity generation capacities by type of flexibility



1 – non-flexible; 2 – partially flexible; 3 – flexible

Trends in structural changes in Ukraine's electricity generation by type of flexibility

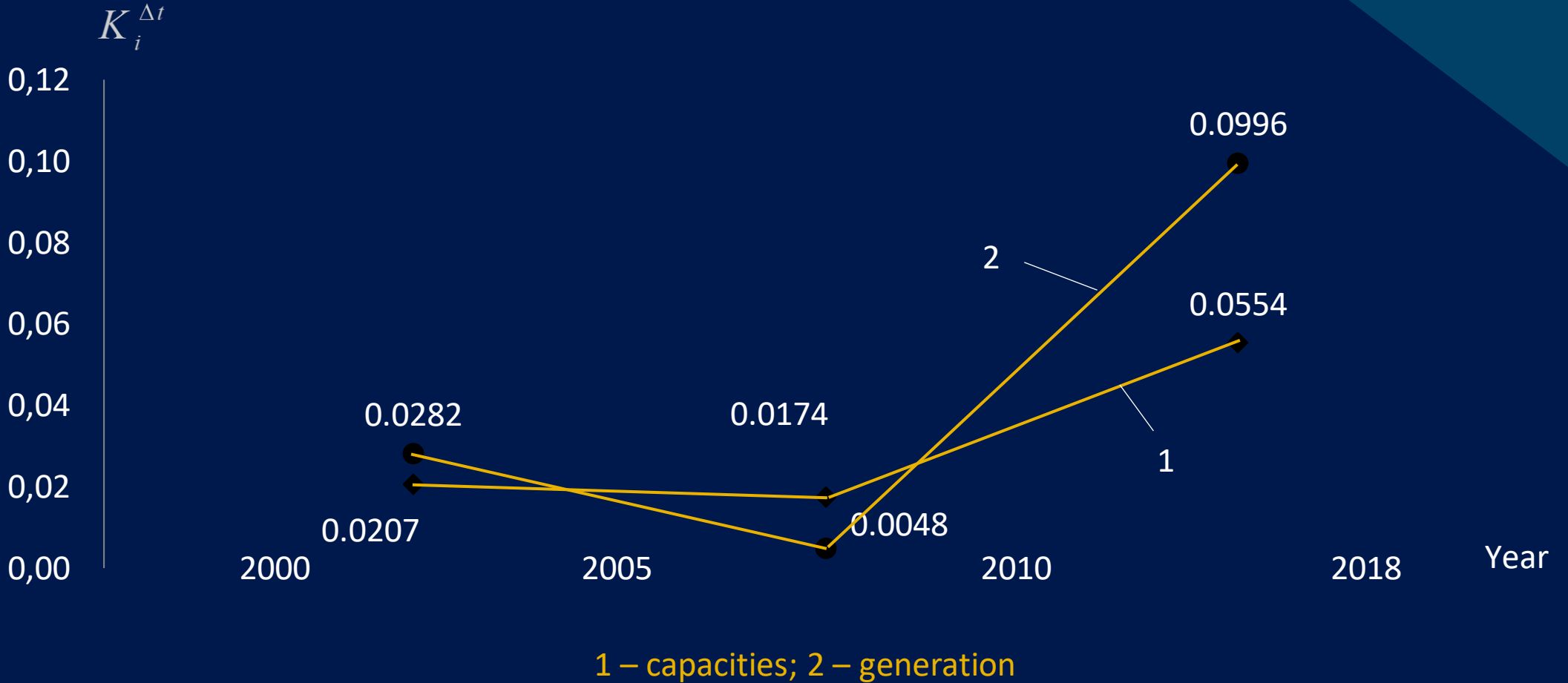


1 – non-flexible; 2 – partially flexible; 3 – flexible

Calculations of the integral coefficients of structural changes in Ukraine's electricity generation capacities and electricity generation by type of flexibility

Type of flexibility	Square of the difference of the shares, %				Square of the sum of the shares, %			
	$(\Delta d_{2005-2000})^2$	$(\Delta d_{2010-2005})^2$	$(\Delta d_{2018-2010})^2$	$(\Delta d_{2018-2000})^2$	$(\Delta d_{2005+2000})^2$	$(\Delta d_{2010+2005})^2$	$(\Delta d_{2018+2010})^2$	$(\Delta d_{2018+2000})^2$
Capacities								
Non-flexible	4.30	0.80	0.78	14.86	2179.6	2465.6	2645.5	2348.9
Partially flexible	4.60	4.03	32.59	97.21	18250.0	17145.7	15184.5	16224.8
Flexible	0.00	1.24	23.26	36.06	332.0	376.5	642.1	583.6
Total	8.9	6.1	56.6	148.1	20761.6	19987.7	18472.1	19157.3
$\frac{(d_i^{t_2} - d_i^{t_1})^2}{(d_i^{t_2} + d_i^{t_1})^2}$					0.0004	0.0003	0.0031	0.0077
$K_i^{\Delta t}$					0.0207	0.0174	0.0554	0.0879
Generation								
Non-flexible	6.76	0.25	17.64	39.69	8614.7	9008.3	10530.1	10104.2
Partially flexible	6.85	0.27	67.65	106.53	8780.5	8332.1	6635.2	7036.0
Flexible	7.17	0.06	101.56	156.30	181.7	190.6	253.7	243.3
Total	0.00	0.07	3.43	4.75	17577.0	17531.1	17419.0	17383.6
$\frac{(d_i^{t_2} - d_i^{t_1})^2}{(d_i^{t_2} + d_i^{t_1})^2}$					0.0008	0.00002	0.0099	0.0154
$K_i^{\Delta t}$					0.0282	0.0048	0.0996	0.1241

Behavior of the integral indicators of structural changes in Ukraine's electricity generation capacities and electricity generation in terms of flexibility



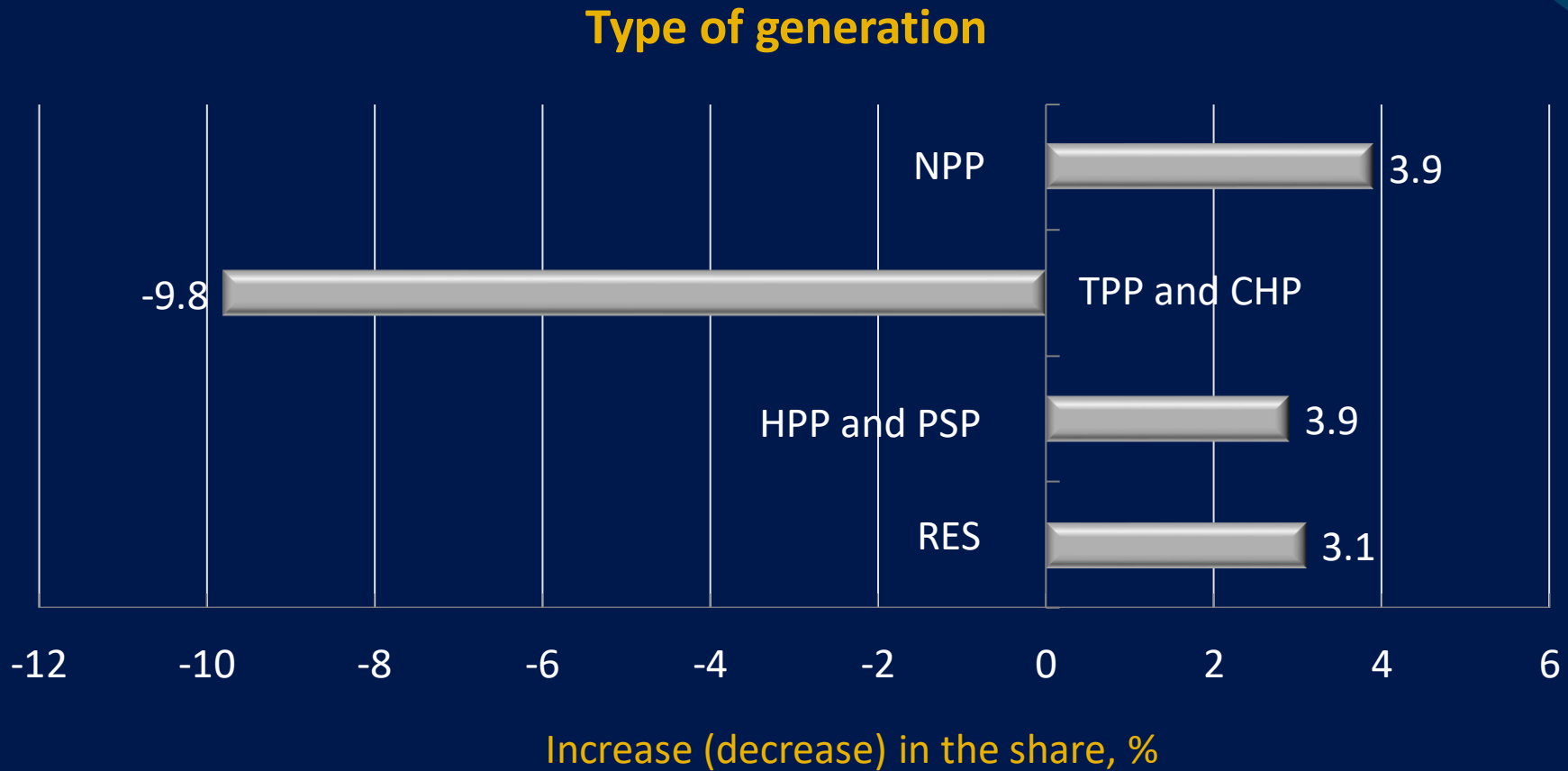
General characteristics of structural changes in Ukraine's electricity generation capacities and electricity generation by type of flexibility

Type of flexibility	Share, %				Rate of changes, %				Structural changes, 2018 in relation to 2000		
	d ₂₀₀₀	Rank	d ₂₀₁₈	Rank	Absolute	Rank	2018 in relation to 2000	Rank	Index of structural change	Rank	Degree of significance
Capacities											
Non-flexible	22.31	2	26.16	2	3.85	2	117.28	2	0.1728	2	significant
Partially flexible	68.62	1	58.76	1	-9.86	3	85.63	3	-0.1437	3	inconsiderable
Flexible	9.08	3	15.08	3	6.01	1	166.16	1	0.6616	1	significant
Generation											
Non-flexible	45.10	2	55.42	1	10.32	1	122.89	2	0.2289	2	significant
Partially flexible	48.19	1	35.69	2	-12.50	3	74.06	3	-0.2594	3	significant
Flexible	6.71	3	8.89	3	2.18	2	132.50	1	0.3250	1	significant

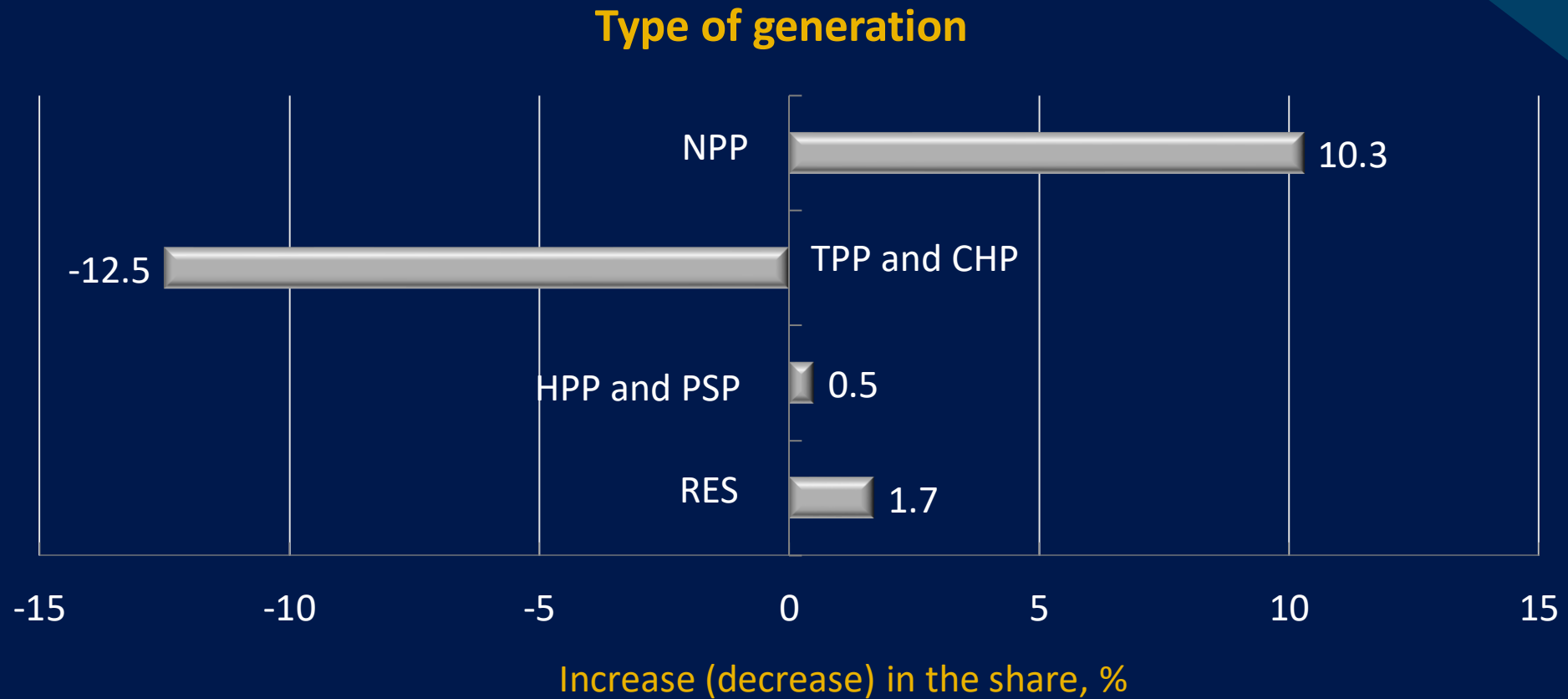
Classification of Ukraine's electricity generation capacities and electricity generation by generation type

Type of generation	Source of electricity generation
Nuclear (NPP)	Nuclear power plants
Thermal (TPP)	Thermal power plants and combined heat and power plants
Hydro (HPP)	Hydroelectric power plants
Renewable energy sources (RES)	Wind and solar power plants, and other electricity generation facilities

Increase (decrease) in the share of Ukraine's electricity generation capacities by type of generation in 2000-2018



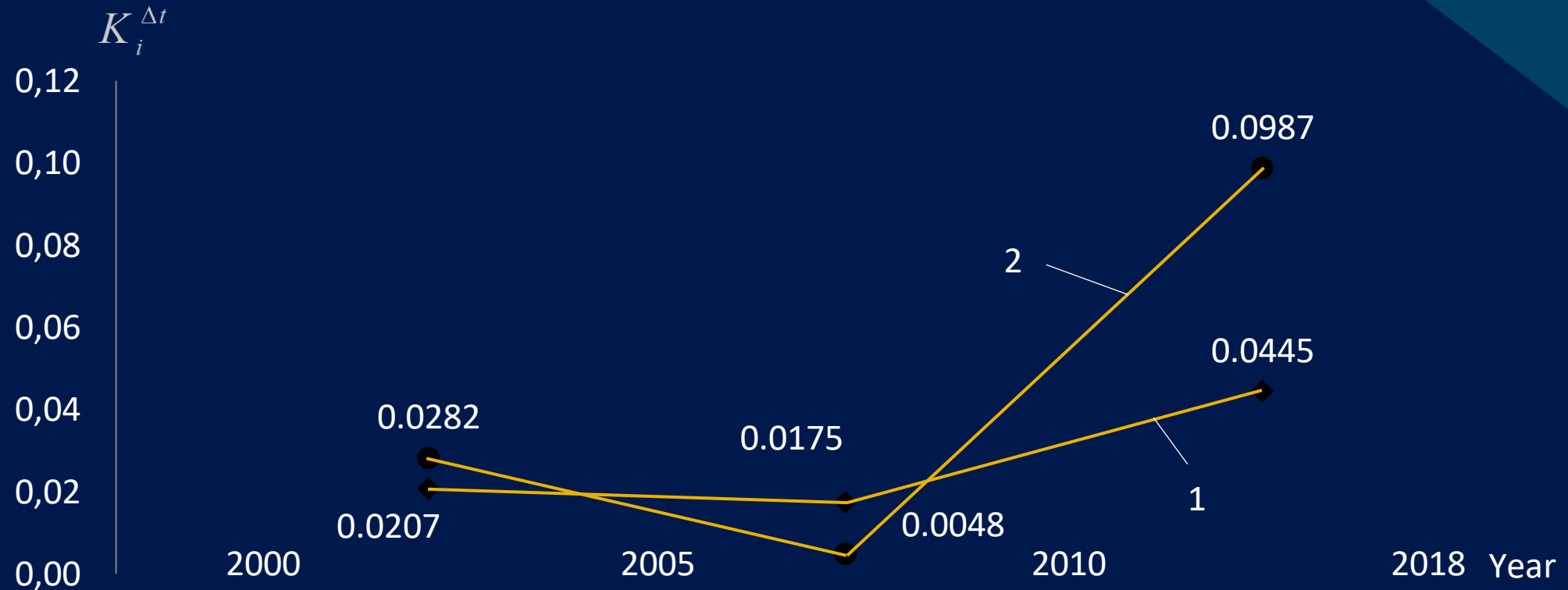
Increase (decrease) in the share of Ukraine's electricity generation by type of generation



Calculations of the indices and directions of structural changes in Ukraine's electricity generation capacities and electricity generation by types of generation

Type of generation	Share, %				Difference in the shares, %				Index of structural change, $I_i^{\Delta t}$			
	d ₂₀₀₀	d ₂₀₀₅	d ₂₀₁₀	d ₂₀₁₈	d ₂₀₀₅ – d ₂₀₀₀	d ₂₀₁₀ – d ₂₀₀₅	d ₂₀₁₇ – d ₂₀₁₀	d ₂₀₁₈ – d ₂₀₀₀	$I_i^{2000-2005}$	$I_i^{2005-2010}$	$I_i^{2010-2017}$	$I_i^{2000-2018}$
Capacities												
NPP	22.3	24.4	25.3	26.2	2.07	0.89	0.89	3.85	0.0930	0.0367	0.0351	0.1728
TPP	68.6	66.5	64.5	58.8	-2.14	-2.01	-5.71	-9.86	-0.0312	-0.0302	-0.0886	-0.1437
HPP	8.9	9.0	10.1	11.7	0.07	1.12	1.67	2.86	0.0076	0.1252	0.1663	0.3223
RES	0.192	0.193	0.186	3.334	0.001	-0.007	3.15	3.14	0.0076	-0.0385	16.9379	16.3794
Generation												
NPP	45.1	47.7	47.2	55.4	2.62	-0.52	8.22	10.32	0.0580	-0.0109	0.1743	0.2289
TPP	48.2	45.5	45.8	35.7	-2.68	0.25	-10.08	-12.50	-0.0556	0.0056	-0.2202	-0.2594
HPP	6.7	6.7	7.0	7.2	0.01	0.27	0.17	0.45	0.0011	0.0398	0.0248	0.0668
RES	0.0	0.054	0.053	1.732	0.054	-0.001	1.68	1.73	+∞	-0.0153	31.7430	+∞

Behavior of the integral indicators of structural changes in Ukraine's electricity generation capacities and electricity generation due to the changes in generation types



1 – capacities; 2 – generation

General characteristics of the structural changes in Ukraine's electricity generation capacities and electricity generation by generation type

Type of generation	Share, %				Rate of changes, %				Structural changes, 2018 in relation to 2000		
	d ₂₀₀₀	Rank	d ₂₀₁₈	Rank	Absolute	Rank	2018 in relation to 2000	Rank	Index of structural change	Rank	Degree of significance
Capacities											
NPP	22.3	2	26.2	2	3.9	2	117.3	3	0.1728	3	significant
TPP	68.6	1	58.8	1	9.9	1	85.6	4	-0.1437	4	inconsiderable
HPP	8.9	3	11.7	3	2.9	4	132.2	2	0.3223	2	significant
RES	0.192	4	3.3	4	3.1	3	1737.9	1	16.3794	1	considerable
Generation											
NPP	45.1	2	55.4	1	10.3	2	122.9	2	0.2289	2	significant
TPP	48.2	1	35.7	2	12.5	1	74.1	4	-0.2594	4	significant
HPP	6.7	3	7.2	3	0.4	4	106.7	3	0.0668	3	inconsiderable
RES	0.0	4	1.7	4	1.7	3	+∞	1	+∞	1	considerable

General characteristics of the structural changes in Ukraine's electricity generation capacities and electricity generation by flexibility and generation type

Electricity generation	Rate of changes, %				Characteristics			
	Absolute	Rank	2018 in relation to 2000	Rank	Type of flexibility	Degree of significance	Type of generation	Degree of significance
Capacities								
NPP	3.9	2	117.3	3	NF	SSC	NPP	SSC
TPP	9.9	1	85.6	4	PF	-ISC	TPP	-ISC
HPP	2.9	4	132.2	2	F	SSC	HPP	SSC
RES	3.1	3	1737.9	1			RES	CSC
Generation								
NPP	10.3	2	122.9	2	NF	SSC	NPP	SSC
TPP	12.5	1	74.1	4	PF	-SSC	TPP	-SSC
HPP	0.4	4	106.7	3	F	SSC	HPP	ISC
RES	1.7	3	+∞	1			RES	CSC

Conclusions

- The decrease in Ukraine's electricity generation was more significant than the decrease in its generation capacity. This is especially true for thermal generation. As a result, the decrease in electricity generation has led to a reduction in carbon dioxide emissions in the country.
- Over the analyzed period, in the structure of Ukraine's electricity generation capacities, the most significant decrease occurred in the share of partially flexible capacities (thermal generation). As concerns the volume of electricity generation, there was a decrease in partially flexible capacities (thermal generation) and an increase in non-flexible capacities (nuclear generation).
- The structural changes in the electric power industry of Ukraine were not adequate to the structural changes in the country's economy, which has led to a shortage of flexible capacities but also resulted in the reduction of carbon dioxide emissions due to a decline in electricity generation.
- The state of Ukraine's energy generation capacities requires urgent modernization to ensure their safe and uninterrupted operation.



Thank you for your
attention!

