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PROJECTING LONG-TERM GLOBAL ENERGY PRODUCTION AND CONSUMPTION PATTERNS USING THE GTAP-POWER-AEZ RECURSIVE DYNAMIC MODEL

PRESENTATION AT THE 2023 GTAP
CONFERENCE

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Global Affairs Canada



OVERVIEW

- Russia is one of the most important energy producing countries in the world.
- One of the most important aftermaths of Russia's unprovoked invasion of Ukraine and economic sanctions is the shifts in the global energy trade and production patterns, which have broad implications for the cost structure of production, emission reductions, and carbon footprints in many parts of the world.
- This analysis is to study the shifts in the global energy trade and production patterns, exploring the implications of such shifts for global emission reductions and carbon footprints.



SHIFTS IN THE GLOBAL ENERGY TRADE PATTERNS



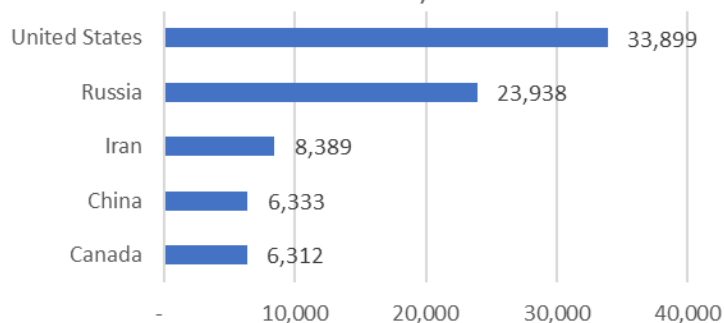
RUSSIA IS A MEDIUM ECONOMIC POWER BUT A SIGNIFICANT ENERGY PRODUCER

GDP	- US\$ 1.69 trillion in 2019 - Global Rank: 11th (equivalent to South Korea, behind Canada and Brazil)
Total Trade	- US\$ 668.8 billion in 2019 - Global Rank: 18th (behind Mexico and UAE)
Exports	- US\$ 424.3 billion in 2019 52.2% of Exports → energy products (HS27)

Data for total trade and exports: Federal Customs Service of Russia
Data for GDP: World Bank
Source: Office of the Chief Economist, Global Affairs Canada

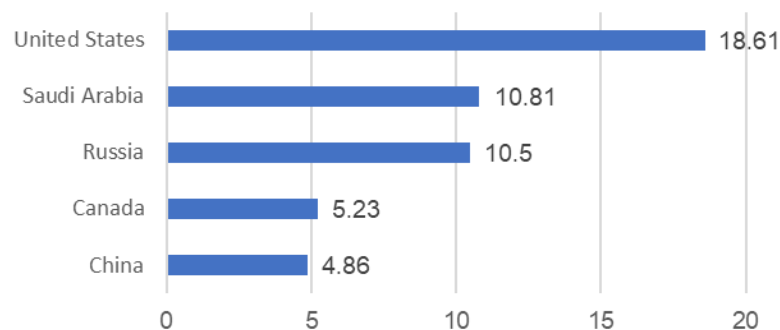


Top Natural Gas Producers in 2019 (billions of cubic feet)



Data: U.S. Energy Information Administration. Source: Office of the Chief Economist, Global Affairs Canada

Top Oil Producers in 2020 (millions of barrels per day)

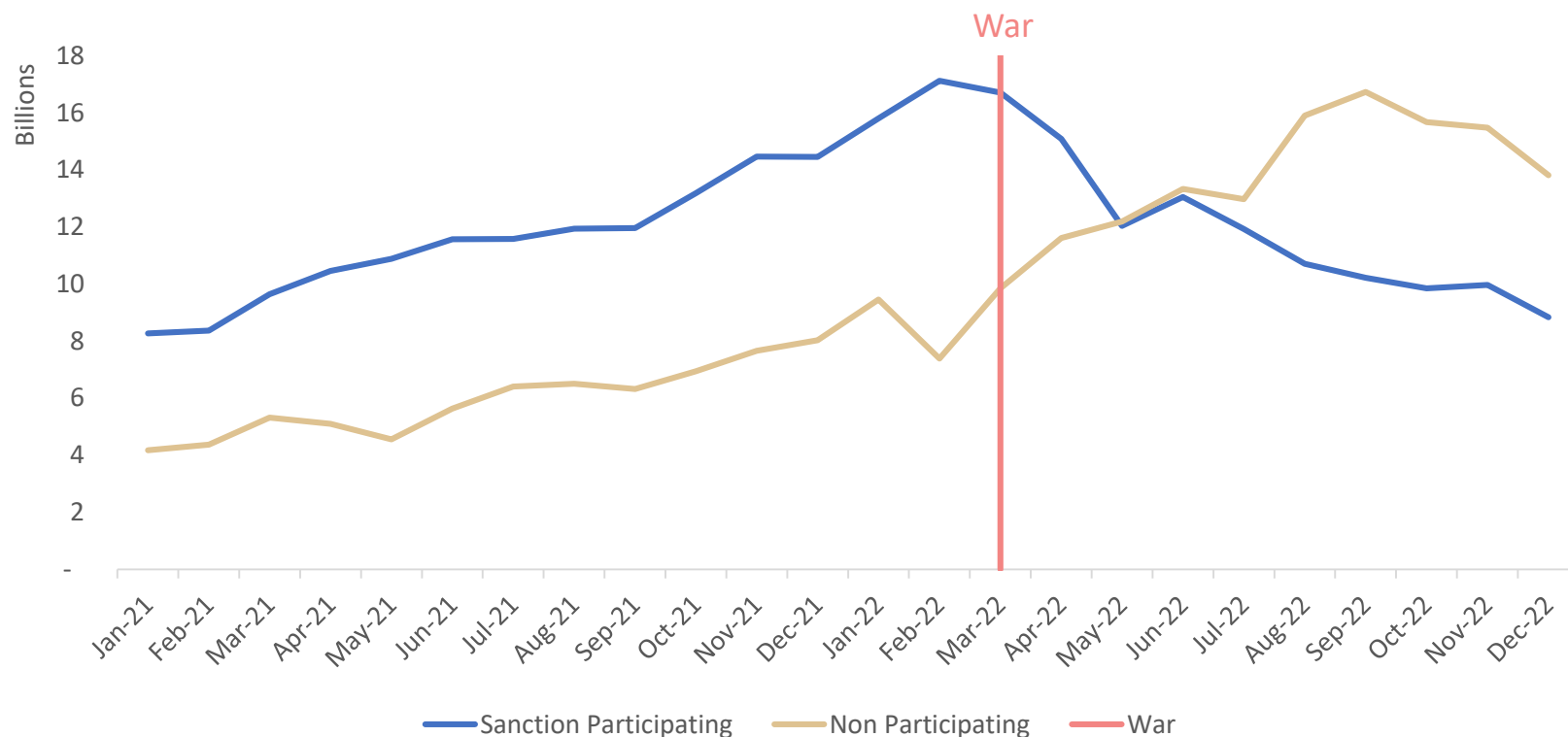


Data: U.S. Energy Information Administration. Source: Office of the Chief Economist, Global Affairs Canada



RUSSIA'S ENERGY EXPORTS TO SANCTION PARTICIPATING COUNTRIES CUT BY HALF, WHILE EXPORTS TO NON-PARTICIPATING COUNTRIES PICKED UP STRONGLY

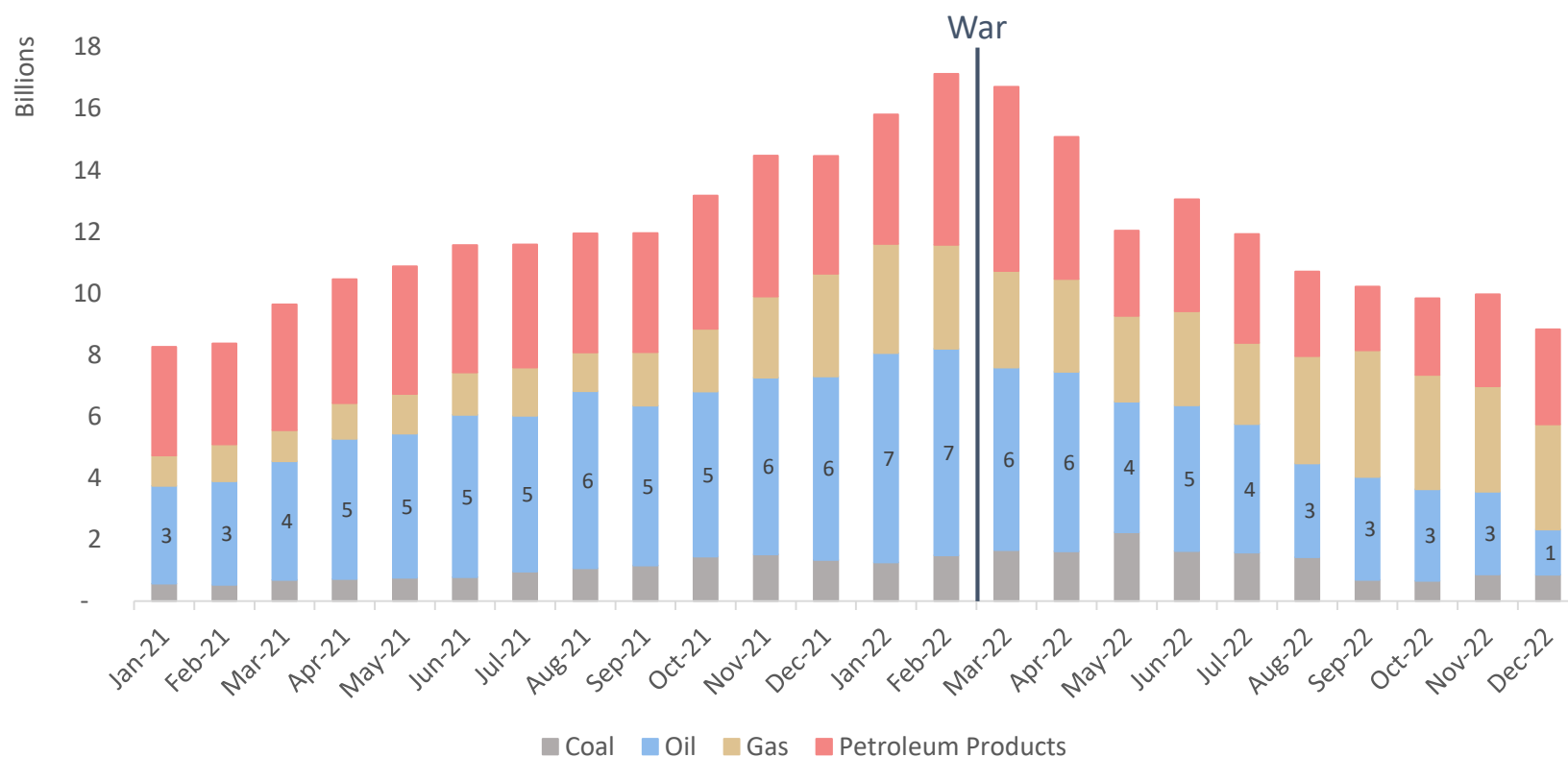
Russia's Energy Exports, US\$





RUSSIA'S ENERGY EXPORTS TO SANCTION-PARTICIPATING COUNTRIES BY TYPE OF ENERGY

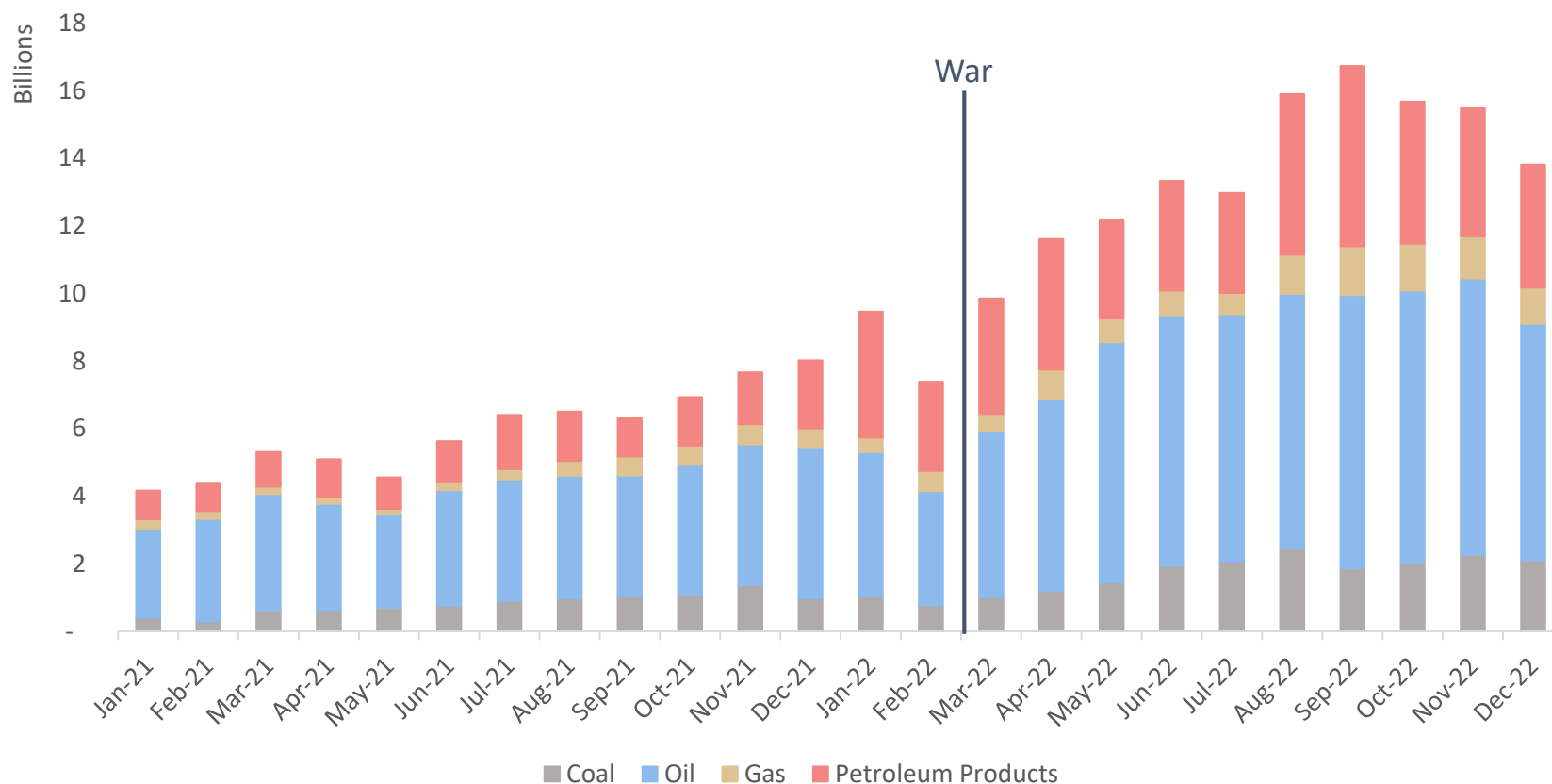
Russia's Energy Exports to Sanction-Participating Countries, US\$ billion





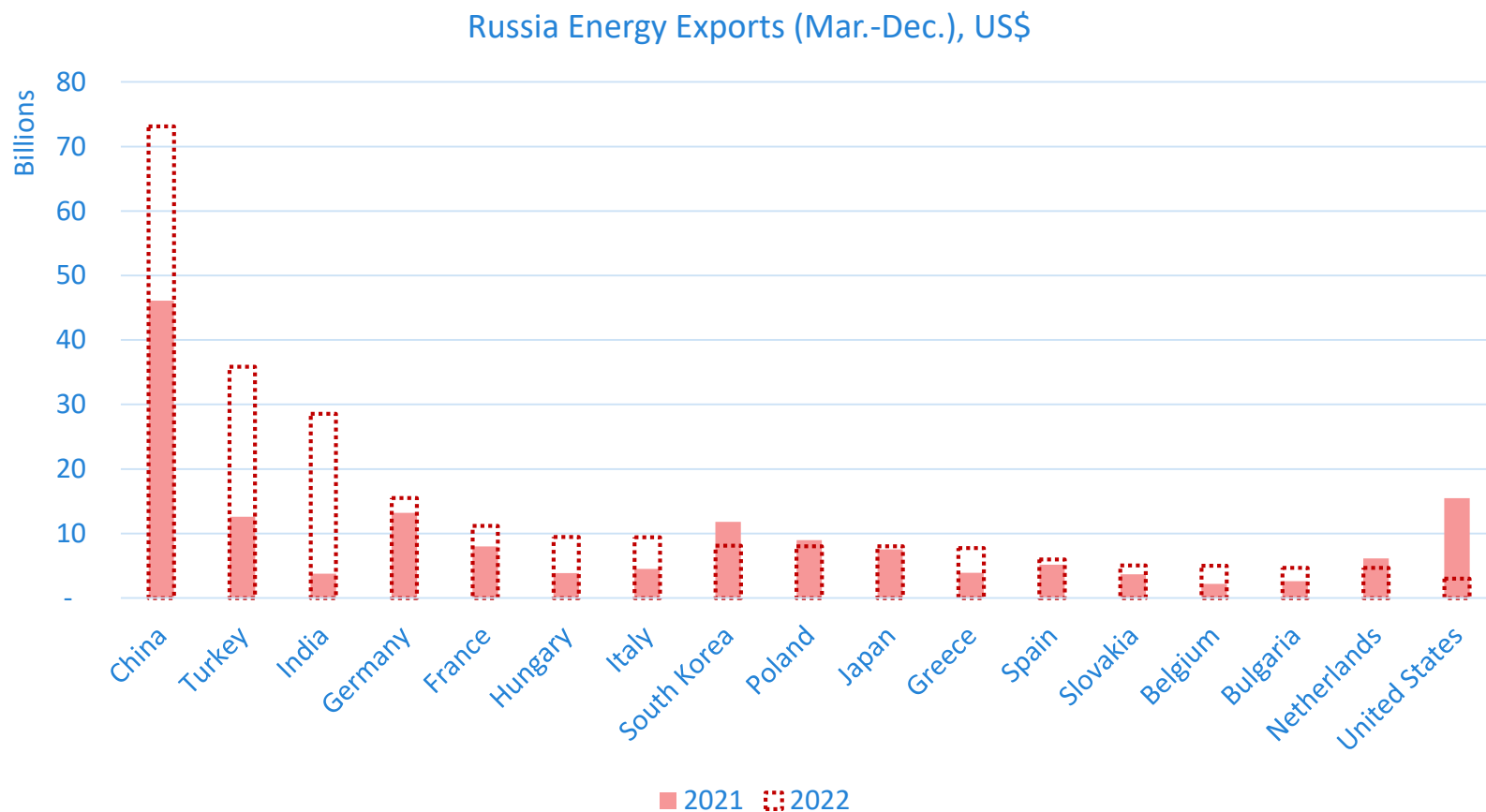
RUSSIA'S ENERGY EXPORTS TO NON-PARTICIPATING COUNTRIES BY TYPE OF ENERGY

Russia's Energy Exports to Non-Participating Countries, US\$ billion





RUSSIA'S ENERGY EXPORTS BY GEOGRAPHIC DISTRIBUTION MAR.-DEC 2021 – MAR.-DEC 2022, US\$ BILLION





MODELLING THE EFFECTS OF SHIFTS IN THE GLOBAL ENERGY TRADE AND PRODUCTION PATTERNS ON EMISSION REDUCTIONS AND CARBON FOOTPRINTS

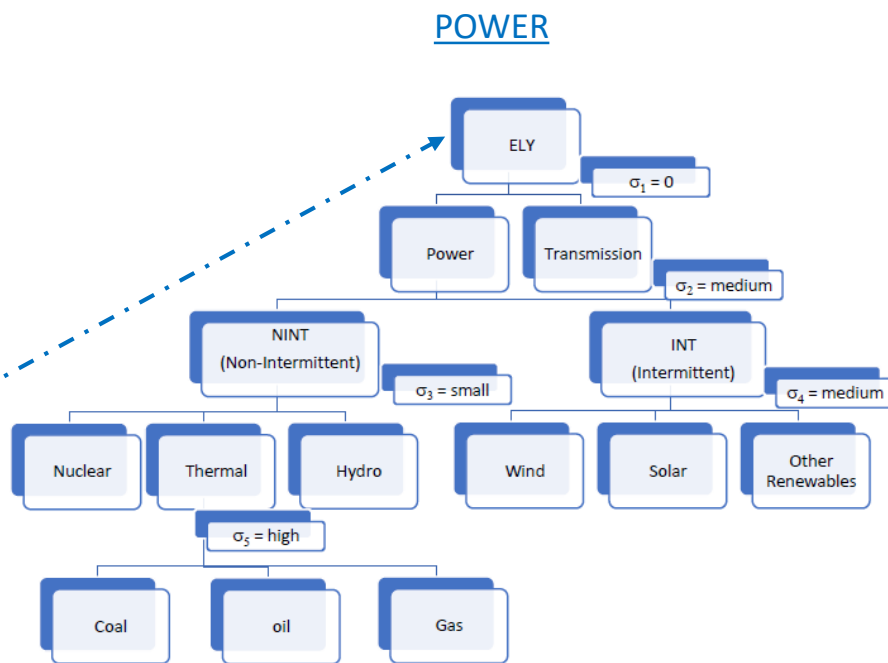
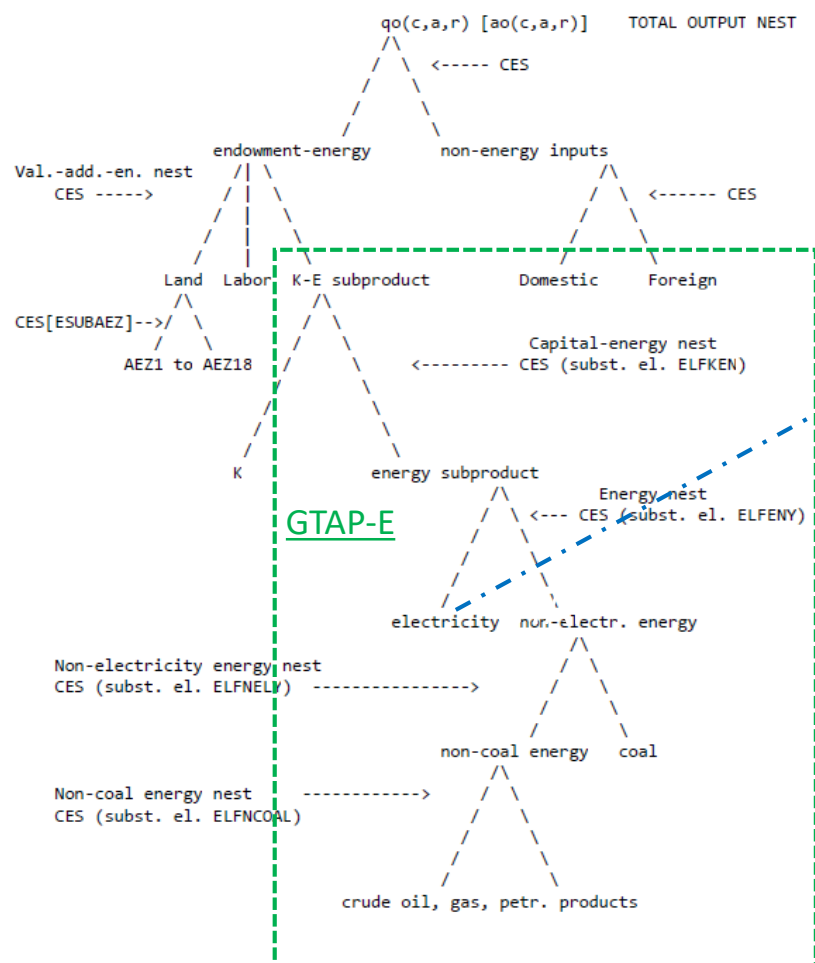


OBJECTIVES AND MODEL

- Objectives: This analysis is to model the effects of shifts in the global energy trade and production patterns as a result of the war on global emission reductions and carbon footprint.
- Model: We use the GTAP-E-Power recursive dynamic model. It builds on the standard GTAP model.



THE PRODUCTION STRUCTURE OF THE GTAP-E-POWER MODEL



Source: Office of Chief Economist, GAC
GTAP center



BASELINE WITHOUT THE WAR



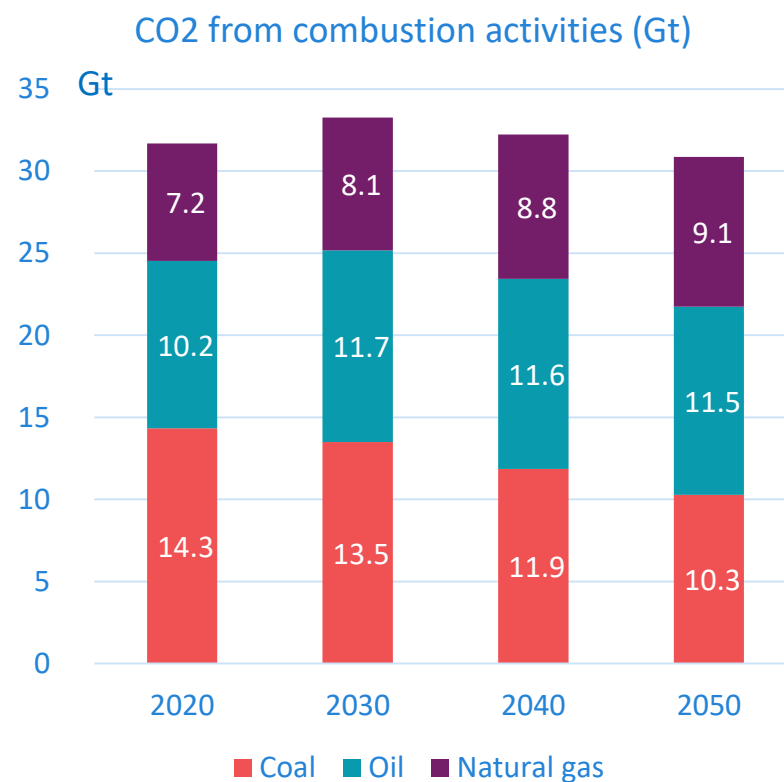
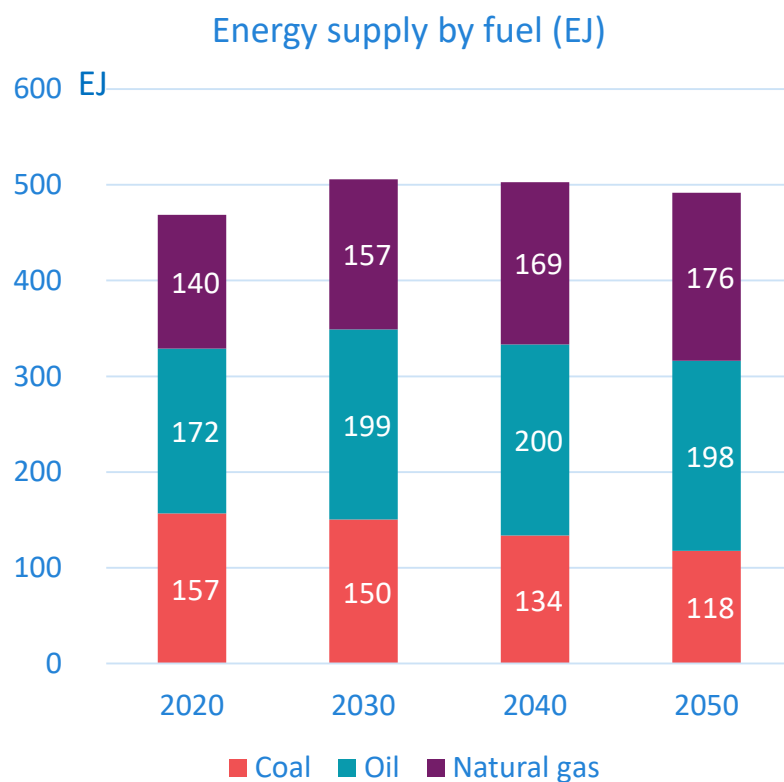
BASELINE

- In this analysis, we include 14 regions and 72 sectors to be consistent with IEA's WEO (2021). Canada and Mexico are separately identified.
- We updated each region's macroeconomic, energy and emission data to 2022 and project them to 2050. The energy supply (including both domestically produced and imports) by fuel, and electricity generation by technology are taken from the Stated Policies Scenario (STEPS*) in IEA's WEO 2021.

*The STEPS shows the emission trajectory implied by today's policies (include Paris Agreement commitments). It represents the conservative emission reduction targets.

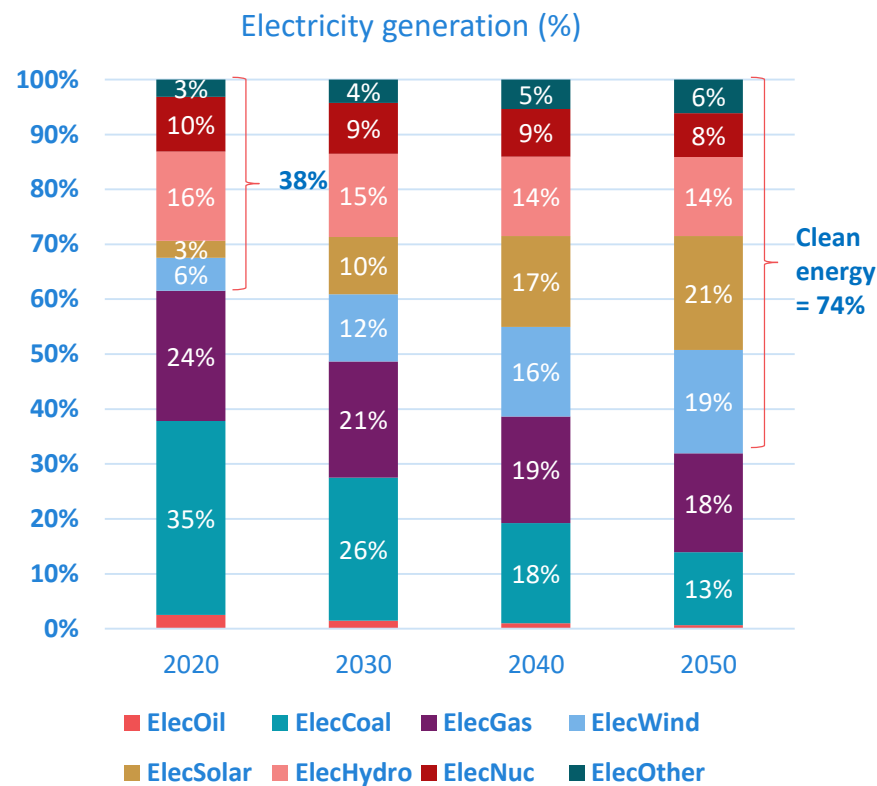
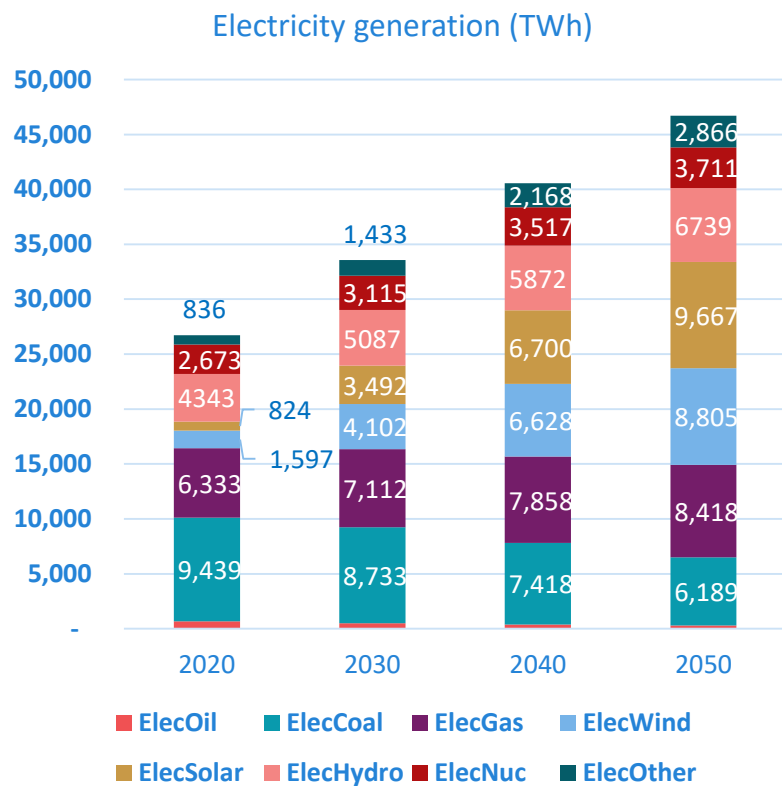


PRIMARY ENERGY SUPPLY AND CO₂ EMISSIONS FROM COMBUSTION ACTIVITIES





ELECTRICITY GENERATION BY TECHNOLOGY



Source: Office of Chief Economist, GAC
WEO 2021, IEA



PROJECTIONS OF MACRO AND PRIMARY FUEL SUPPLY IN THE BASELINE SCENARIO

	GDP	POP	Labour	FossilFuel (PJ)						CO2			
	2021-2050	2021-2050	2021-2050	Coal		Oil		Gas		Petroleum		(Mt)	
	CAGR (%)	CAGR (%)	CAGR (%)	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050
USA	1.7	0.6	0.4	9,329	1,362	29,590	25,053	30,427	27,963	28,461	23,683	4,207	2,827
Canada	2.0	0.8	0.4	536	62	4,575	2,794	3,775	2,437	2,129	1,300	500	442
Mexico	2.8	0.5	0.4	274	313	2,189	3,462	4,015	6,729	3,676	4,179	383	440
CSAmerica	2.7	0.4	0.2	1,295	1,437	9,618	12,105	5,230	6,713	8,581	10,938	1,010	1,221
EU27	1.6	0.1	-0.4	5,976	1,392	17,706	7,883	13,642	10,121	16,173	7,352	2,355	1,074
RofEurope	2.1	0.3	0.0	3,683	3,022	5,993	4,755	6,755	6,885	5,410	4,348	1,078	914
MiddleEast	3.0	1.2	1.1	129	449	12,434	17,990	19,429	29,212	9,360	15,900	1,732	2,488
Russia	2.2	-0.1	-0.5	4,911	4,304	5,873	5,907	16,631	18,382	5,096	5,285	1,536	1,524
China	3.2	-0.3	-0.8	87,501	58,029	27,595	25,489	11,138	17,407	23,092	24,249	10,009	7,195
India	4.9	0.7	0.8	16,323	20,251	9,021	17,857	2,290	7,465	7,907	16,915	2,140	3,336
Japan	0.8	-0.5	-1.0	4,475	2,104	6,021	3,566	3,682	2,209	5,482	3,428	961	479
SEAsia	3.8	0.4	0.2	7,535	11,505	9,268	14,907	5,703	11,633	8,611	14,254	1,544	2,517
Africa	4.7	1.6	1.9	4,560	4,660	7,308	16,166	5,702	11,075	6,349	15,543	1,176	2,040
ROW	2.6	0.8	0.7	10,235	7,910	25,023	40,366	11,358	15,769	23,173	39,726	2,988	4,443
Global	2.7	0.5	0.2	156,762	117,800	172,214	198,300	139,777	175,500	153,500	187,100	31,617	30,940



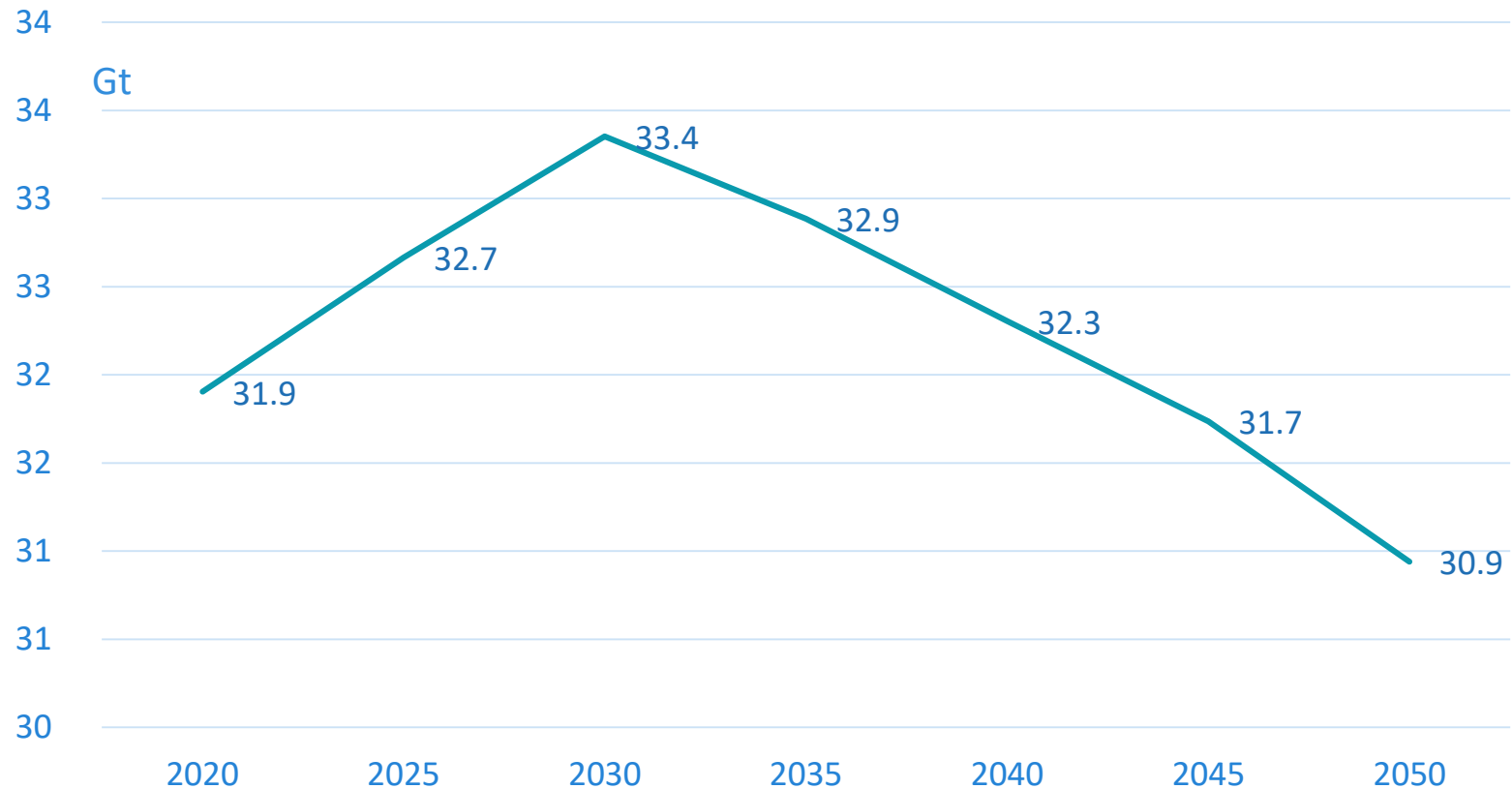
PROJECTIONS OF POWER GENERATION BY TECHNOLOGY IN THE BASELINE SCENARIO

(TWh)	ElecNuc		ElecCoal		ElecGas		ElecWind		ElecHydro		ElecOil		ElecOth		ElecSolar	
	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050
USA	823	517	858	42	1,676	1,555	340	1,179	293	360	38	7	97	215	117	1,300
Canada	83	96	31	1	74	73	35	189	386	446	4	1	8	8	2	62
Mexico	26	29	22	1	205	339	16	31	26	108	35	0	11	37	14	130
CSAmerica	25	67	66	21	242	234	78	393	694	1,162	73	11	77	200	22	346
EU27	681	519	386	15	556	356	398	1,365	347	417	47	5	199	360	142	541
RofEurope	157	191	207	157	291	275	118	580	313	491	4	2	71	148	34	173
MiddleEast	7	96	3	29	844	1,574	2	261	12	44	308	188	0	127	11	445
Russia	216	275	167	127	471	653	1	99	189	215	8	1	3	99	1	19
China	366	1,222	4,958	3,308	230	539	471	2,631	1,335	1,679	11	1	146	667	270	3,140
India	46	292	1,127	947	69	172	68	916	173	386	7	1	55	179	64	2,107
Japan	42	193	316	65	366	139	8	205	85	101	26	2	81	162	79	188
SEAsia	-	24	479	830	360	857	7	201	164	347	17	11	66	224	18	348
Africa	13	44	241	175	329	705	17	271	136	543	69	62	12	213	10	370
ROW	186	148	578	470	621	946	36	483	189	439	17	17	10	228	38	497
Global	2,673	3,711	9,439	6,189	6,333	8,418	1,597	8,805	4,343	6,739	664	308	836	2,866	824	9,667

Source: Office of Chief Economist, GAC. WEO 2021, IEA



GLOBAL CO₂ EMISSIONS IN THE BASELINE SCENARIO



Source: Office of Chief Economist, GAC
Data: WEO 2021, IEA



SIMULATION RESULTS UNDER THE WAR SCENARIO

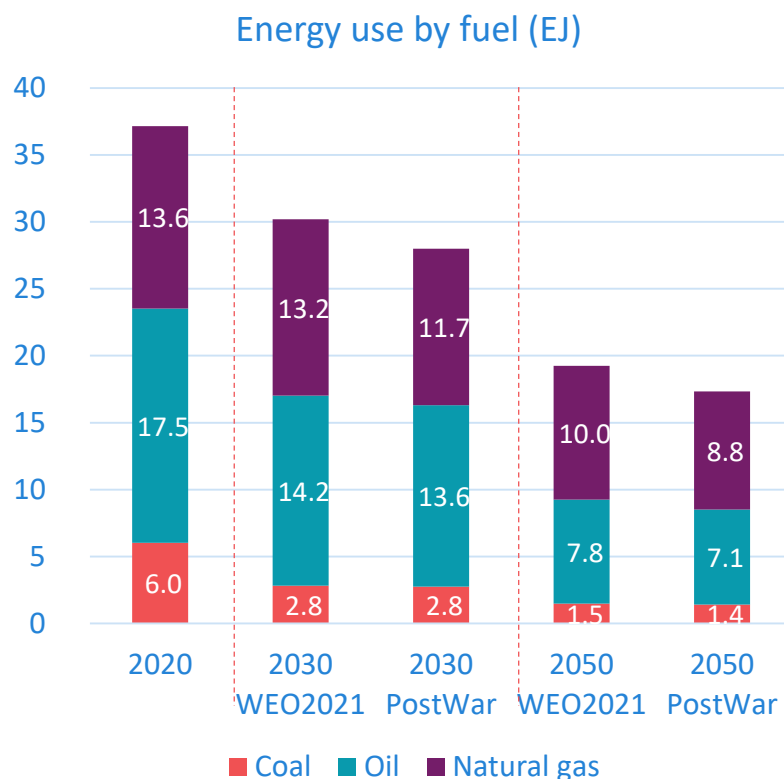


THE DESIGNS OF THE WAR SCENARIO

- We imposed trade shocks to represent the effects of the war and economic sanctions on Russia using the 2022 data.
- We assume that from 2023 onward, Russia's trade with sanction-participating countries would further drop to the 10% of the baseline level.
- We shocked Russia's GDP components in 2022 to represent the effect of economic sanctions and the war on consumption, investment and government expenditures.
- In this scenario, we assume economic sanctions and the war would permanently damaged Russia's economy.
- The results of an alternative scenario assuming that Russia's economy would gradually move back to normal by 2030 is available upon request.



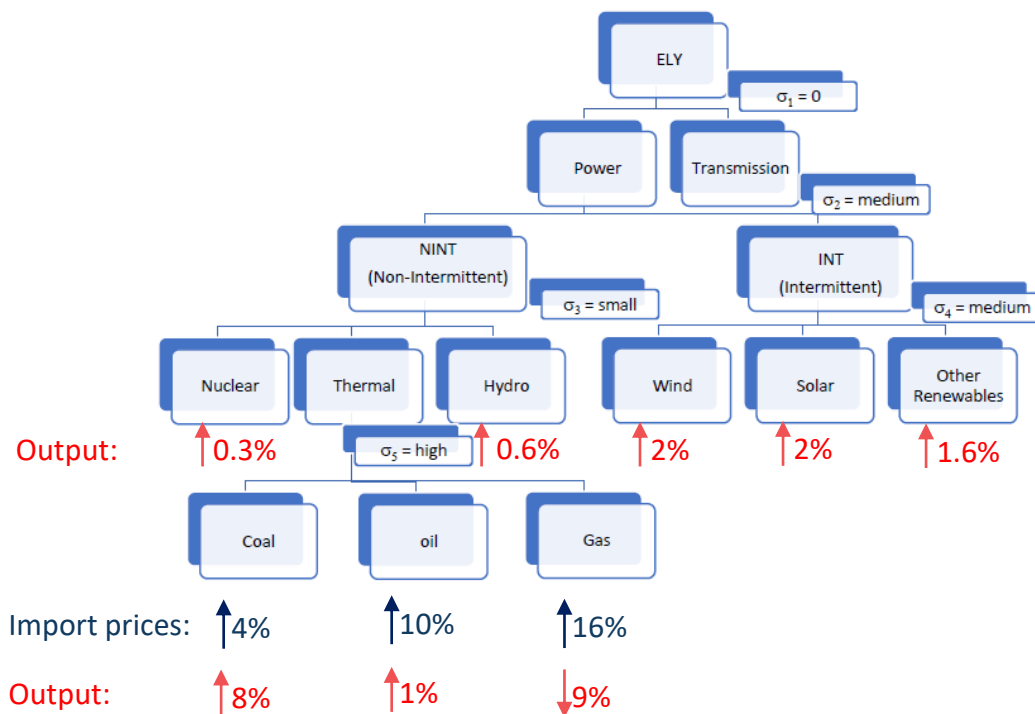
CHANGES IN PRIMARY ENERGY USE IN THE EU UNDER THE WAR SCENARIO



- Allies' import restrictions on Russia's fossil fuels would cause higher fuel prices, which encourages switching to alternative energy, resulting in lower use of coal, oil and gas in the EU.
- Compare to the baseline in 2050 without the war, the use of natural gas and oil in the EU drop by 1.2EJ and 0.7EJ respectively.



ELECTRICITY GENERATION AND ENERGY SUBSTITUTION IN THE EU

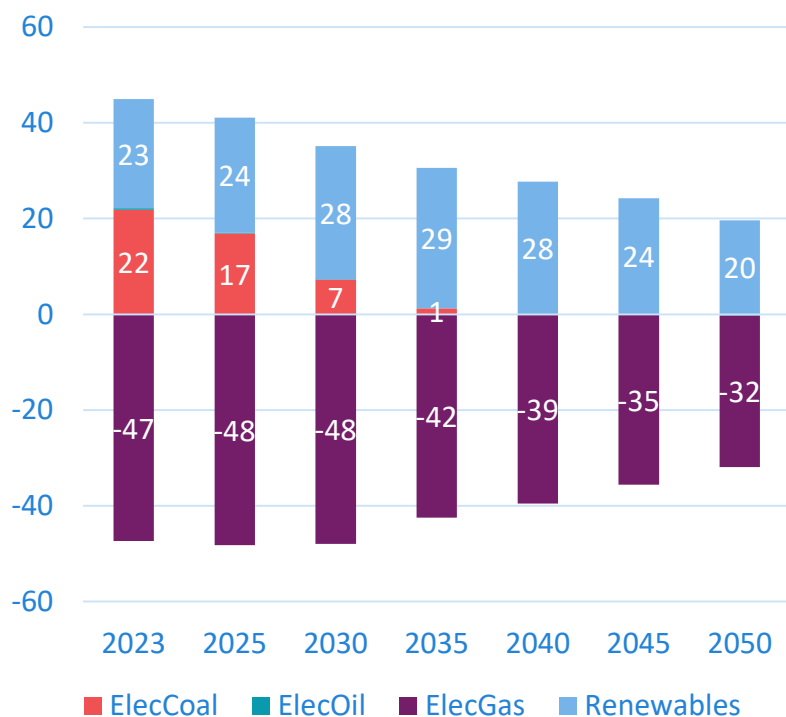


- The relatively weak substitution between pipeline gas and LNG leads to higher gas price than the prices of coal and oil, which would contribute to a decline in the gas-fired power generation.
- The cost of thermal power generation goes up due to higher energy prices. The clean power generation technologies becoming more cost-competitive. So the output from these clean power plants increase.

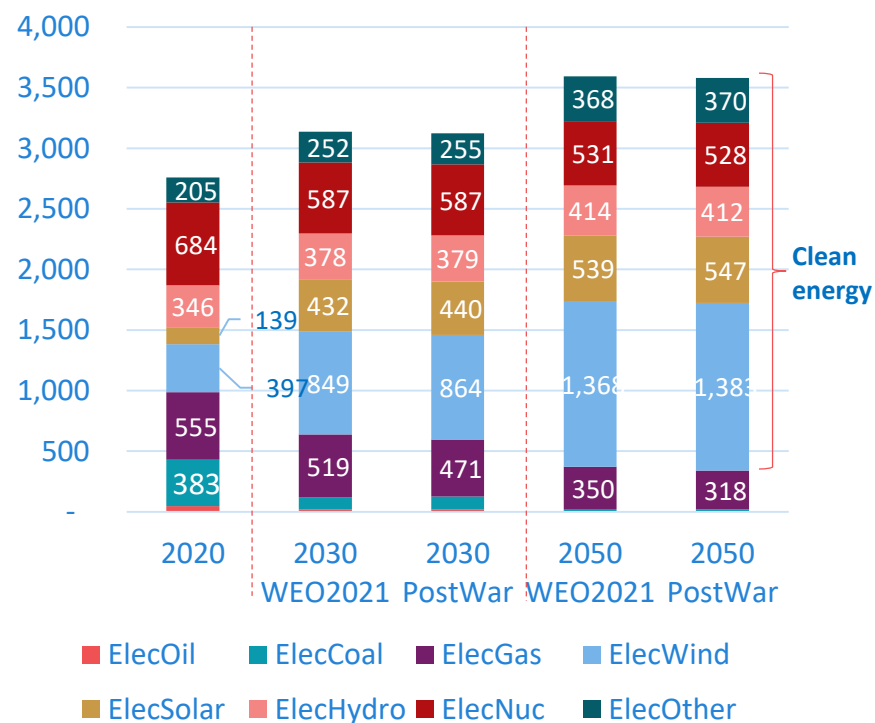


SHORT-TERM PAIN AND LONG-TERM GAIN

Changes in electricity generation (TWh)

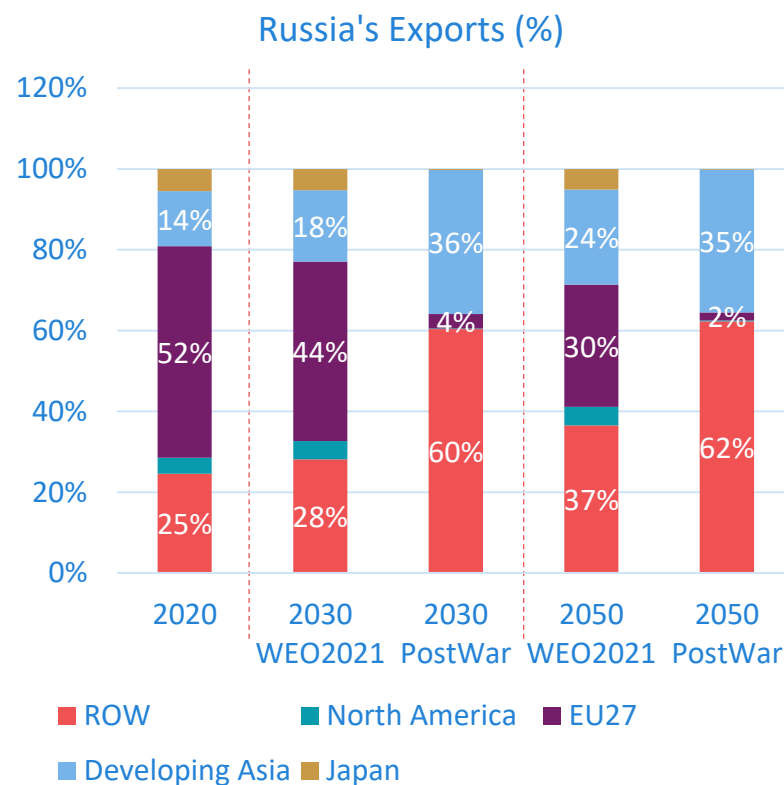
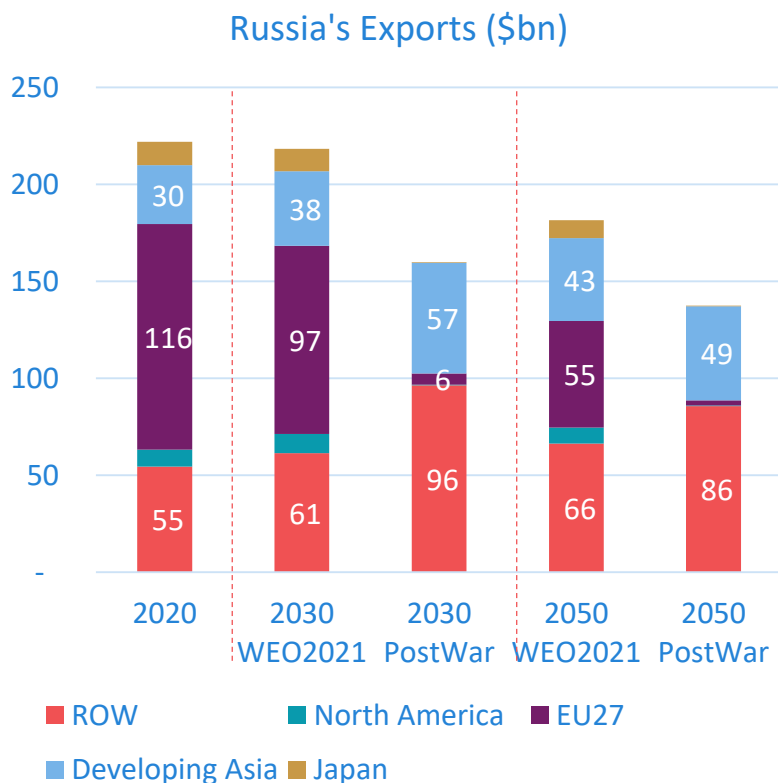


Electricity generation (TWh)





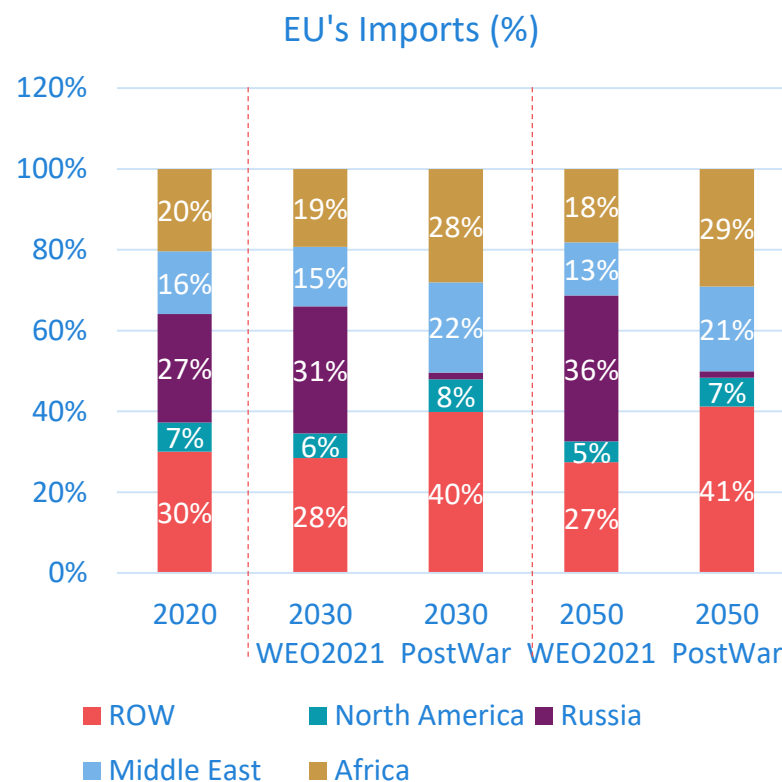
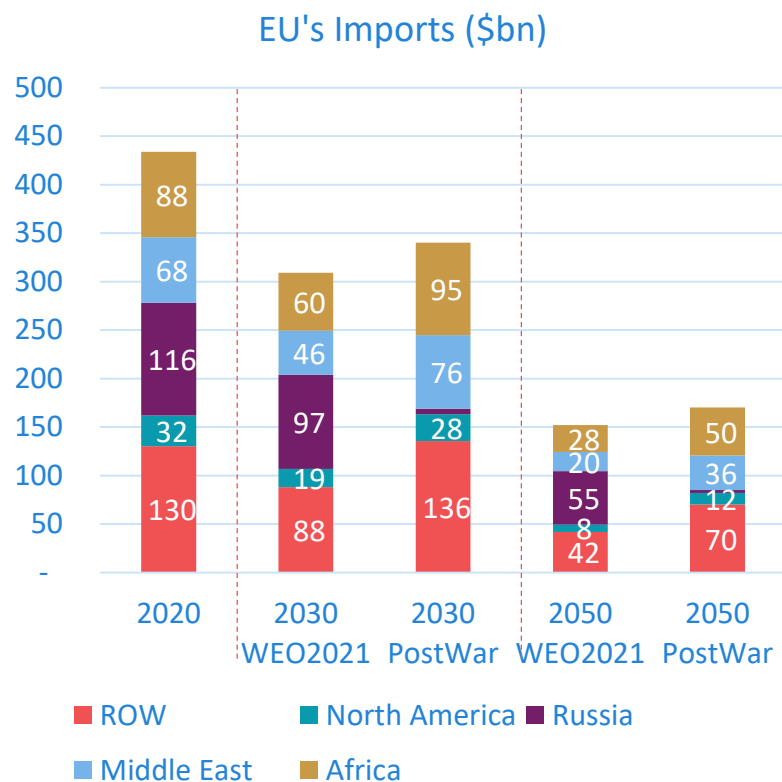
RUSSIA'S ENERGY EXPORTS BY REGION IN 2020, 2030 AND 2050



Source: Office of Chief Economist, GAC
WEO 2022, IEA



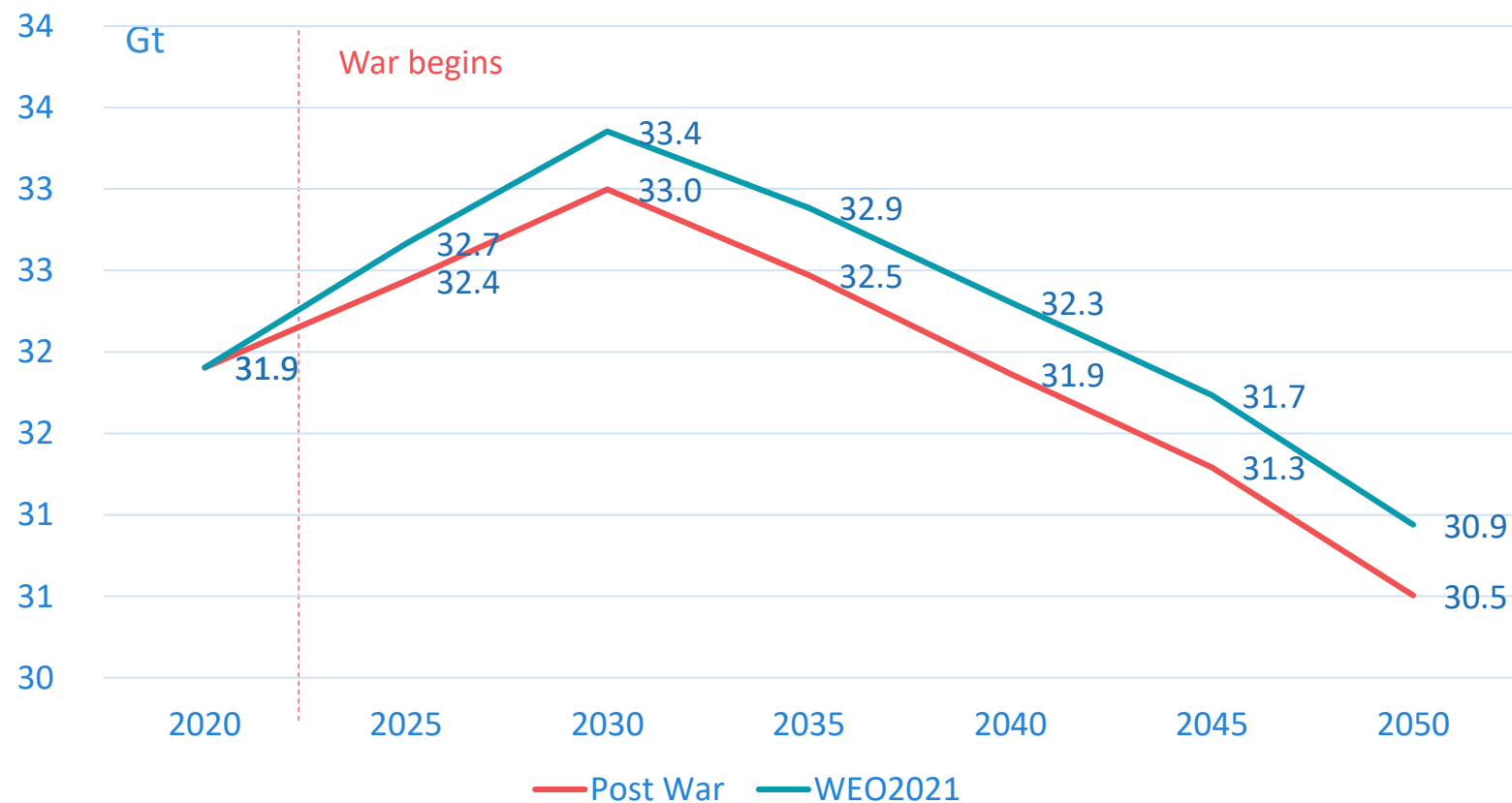
EU ENERGY IMPORTS BY REGION IN 2020, 2030 AND 2050



Source: Office of Chief Economist, GAC
WEO 2022, IEA



GLOBAL CO₂ EMISSIONS: THE BASELINE AND WAR SCENARIOS



Source: Office of Chief Economist, GAC
WEO 2022, IEA



CO₂ EMISSIONS, GDP AND CARBON INTENSITY (CI)

	2020			2050 WEO2021			2050 Post War			Deviation in 2050		
	CO2 (Mt)	GDP (\$Bn)	CI (kg/\$)	CO2 (Mt)	GDP (\$Bn)	CI (kg/\$)	CO2 (Mt)	GDP (\$Bn)	CI (kg/\$)	CO2 (Mt)	GDP (%)	CI (%)
EU27	2,371	17,359	0.137	1,089	26,443	0.041	984	26,010	0.038	-104	-1.6%	-8.1%
Canada	527	1,791	0.294	468	2,931	0.160	471	2,953	0.159	3	0.7%	-0.2%
USA	4,379	19,128	0.229	2,934	28,017	0.105	2,922	28,060	0.104	-12	0.2%	-0.6%
Russia	1,444	1,941	0.744	1,416	2,922	0.484	1,097	2,295	0.478	-318	-21.4%	-1.3%
China	8,741	15,117	0.578	6,179	26,565	0.233	6,155	26,541	0.232	-24	-0.1%	-0.3%
Middle East	1,778	2,745	0.648	2,525	5,796	0.436	2,545	5,898	0.432	20	1.7%	-0.9%
Developing Asia	3,702	5,826	0.635	5,675	16,228	0.350	5,693	16,288	0.350	18	0.4%	-0.1%
Africa	1,138	2,624	0.434	1,973	9,000	0.219	1,982	9,112	0.217	9	1.2%	-0.8%
ROW	7,825	22,497	0.348	8,682	40,419	0.215	8,657	40,697	0.213	-25	0.7%	-1.0%
Global	31,904	89,028	0.358	30,940	158,321	0.195	30,506	157,854	0.193	-433	-0.3%	-1.1%



CONCLUSIONS

- The global energy crisis sparked by Russia's invasion of Ukraine is having far-reaching implications. This is a global crisis, but Europe is the main theatre in which it is playing out, and natural gas is centre stage.
- The crisis provides a short-term boost to demand for oil and coal. But the lasting gains from the crisis accrue to low-emissions sources, mainly renewables.
- The CO₂ emissions from combustion activities drop noticeably in EU and Russia. EU mainly due to its speeding up transition to clean energy, while Russia mainly due to the shrink of its economy.
- Global CO₂ emissions drop by 443mt by 2050, and the carbon intensity of GDP drop by 1.1%.