

TIMES-CGE-SD model coupling and data exchange mechanism for the LEDS development for Kazakhstan*

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Outline

- Introduction
- Overall approach to iterative model integration
- Deep dive: Automated TIMES-CGE data exchange
- Quick overview of modelling results

Introduction: The context

- Modelling decarbonization pathways to support development of the long-term low-emission development strategy (LEDS) / carbon neutrality by 2060 for Kazakhstan
- Combining “top-down” (macroeconomic), “bottom-up” (energy technology) and system dynamics non-energy sectoral approaches:

computable general equilibrium (CGE) (DIW ECON GmbH)

- Small open economy (KAZ + RoW)
- 34 activities + households + government + capital account
- Calibrated with 2017 National accounts
- Module on industrial process emissions added
- Recursive dynamics: 44 yearly periods, 2017-2060

TIMES (IEF NASU)

- Single-region model
- Full energy system (all energy processes) covered
- Calibrated with 2017 Energy balance
- RSD and COM (TER) demands split by climatic zones
- 24 timeslices
- New technology database compiled considering JRC and Danish Energy Agency technology databases

system dynamics (SD) (KnowlEdge Srl)

- Five sectors: agriculture, buildings, coal, transport, waste
- Calibrated with 2000-2017 data
- Agriculture, buildings and transport split by climatic zones
- Energy technologies aligned with TIMES
- 12 time steps (monthly) per year, to capture seasonality

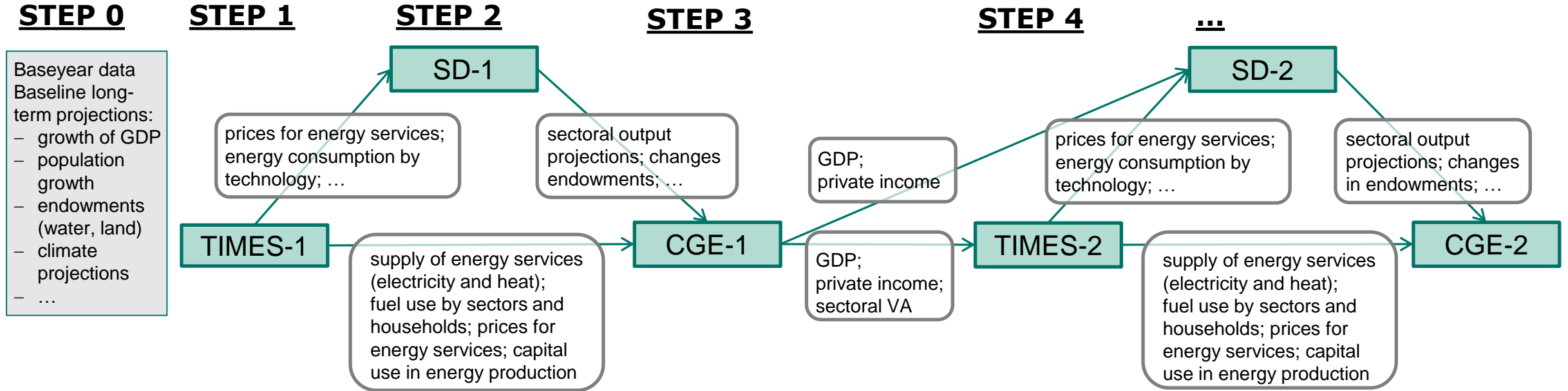
- This model set allows comprehensive analysis of economy-wide & sectoral transformations and of socio-economic effects of decarbonization

Why (soft-)link the three models?

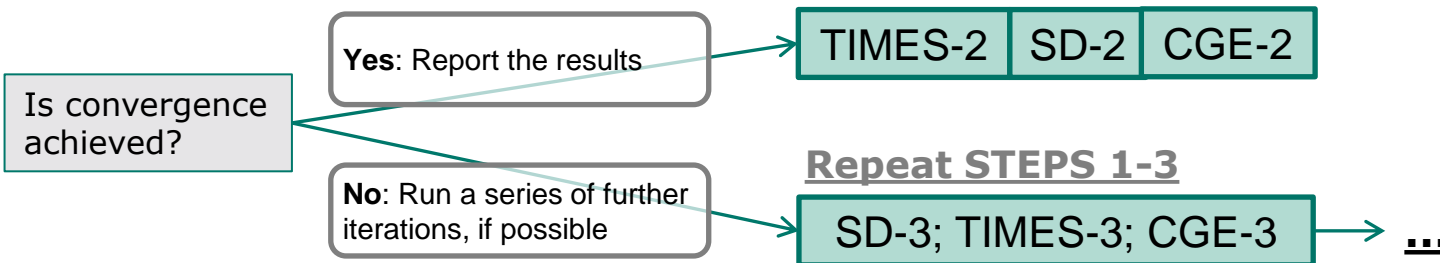
- Why link the models?
 - Each model is focused on its area and makes a number of exogenous assumptions
 - Replacing exogenous assumptions with endogenous results of other models increases breadth and depth of modelling
 - This improves data quality and provides more insightful results

- Why soft-link? – Operability & project sustainability
 - Each of the models remains fully intact and independently operable
 - The linking process is significantly simpler, methodologically less demanding and has higher level of detail
 - Keeping each model separate provides higher transparency and does not require knowledge on all three

Overall integration approach: Iterative data exchange (baseline)



DECISION STEP

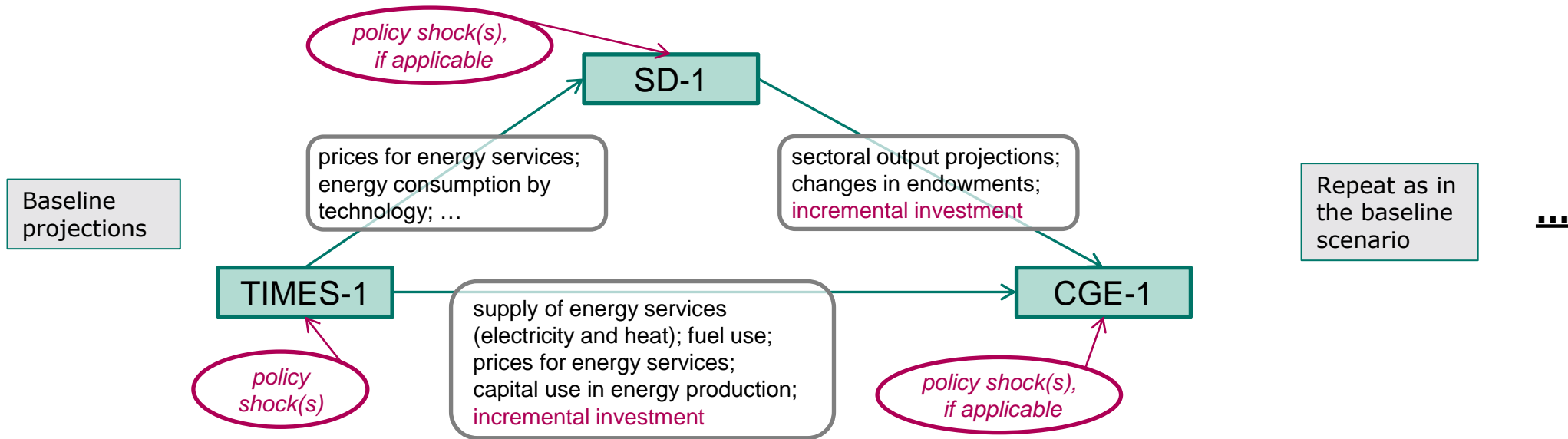


Overall integration approach: Iterative data exchange (policy scenarios)

STEP 0

STEP 1

STEP 2



Data exchange between the models: Challenges & solutions

- Databases and accounting methods
 - Monetary vs. physical data: making use of “real outputs” in CGE, mapping to physical development in SD & TIMES
 - Differences in time dimensions: data interpolation
 - Mapping of sectors and technologies: two-way mapping for each model pair
- Solving methods and behavioral functions
 - Correction of production and consumption functions in CGE
 - Integration switch for SD
 - Adjustment of demand drivers in TIMES
- Asymmetric data exchange & large amount of data exchanged

TIMES-CGE: Exchange automation

- Problem: transform massive, detailed data for selected years from TIMES into annual development indices in CGE

7251	Table Name: __TIMES-CGE_ELCSTG techs_costs							
7252	Active Unit: M USD							
7253	Attribute	UserConstraint	Process\Period	2017	2018	2020	2025	2030
7254	Cap_New	INSTCAP	STGAGRELC					0
7255	Cap_New	INSTCAP	STGBATELC01					1
7256	Cap_New	INSTCAP	STGINDEL			0		0
7257	Cap_New	INSTCAP	STGRSDEL					0
7258	Cap_New	INSTCAP	STGTEREL					1
7259	Cap_New	LUMPINV	STGAGRELC					304
7260	Cap_New	LUMPINV	STGBATELC01					7
7261	Cap_New	LUMPINV	STGINDEL			1		4
7262	Cap_New	LUMPINV	STGRSDEL					0
7263	Cap_New	LUMPINV	STGTEREL					1
7264	Cost_Fom	-	STGAGRELC					0
7265	Cost_Fom	-	STGBATELC01					0
7266	Cost_Fom	-	STGINDEL				0	0
7267	Cost_Fom	-	STGRSDEL					0
7268	Cost_Fom	-	STGTEREL					0
7269	EQ_CombalM	-	-	4307051	1624887	2317977	4721183	3550880
7270								
7271								
7272	Table Name: TIMES-CGE_H2GSTG techs_costs							
7273	Active Unit: M USD							
7274	Attribute	UserConstraint	Process\Period	2017	2018	2020	2025	2030
7275	Cap_New	INSTCAP	STGH2GST					
7276	Cap_New	INSTCAP	STGH2GUG					
7277	Cap_New	LUMPINV	STGH2GST					
7278	Cap_New	LUMPINV	STGH2GUG					
7279	Cost_Fom	-	STGH2GST					
7280	Cost_Fom	-	STGH2GUG					
7281	EQ_CombalM	-	-	4307051	1624887	2317977	4721183	3550880



CGE code	CGE sector	Energy input	Energy code	2017	2018
		Period -->		1	2
5.6	Energy inpl Mining and Quarrying	Coal	36	1	1
	Energy inpl Mining and Quarrying	Crude oil	37	1	1
	Energy inpl Mining and Quarrying	Gas,H2	38	1	0.989815
	Energy inpl Mining and Quarrying	Oil refined products	48	1	1.021912
	Energy inpl Mining and Quarrying	Electricity	53	1	0.98548
	Energy inpl Mining and Quarrying	Heat	55	1	0.989589
	Energy inpl Mining and Quarrying	BIO		1	1
		Period -->		1	2
8	Energy inpl Food industry	Coal	36	0.980864	0.9356
	Energy inpl Food industry	Crude oil	37	1	1
	Energy inpl Food industry	Gas,H2	38	1.017222	1.00778
	Energy inpl Food industry	Oil refined products	48	1	1
	Energy inpl Food industry	Electricity	53	0.922259	0.938283
	Energy inpl Food industry	Heat	55	1.037983	1.04881
	Energy inpl Food industry	BIO		1	1

TIMES-CGE: Exchange automation

- Problem: transform massive, detailed data for selected years from TIMES into annual development indices in CGE
- Solution: use Excel VBA to automate data aggregation and interpolation
- Benefit: high level of flexibility for model extension and analytics

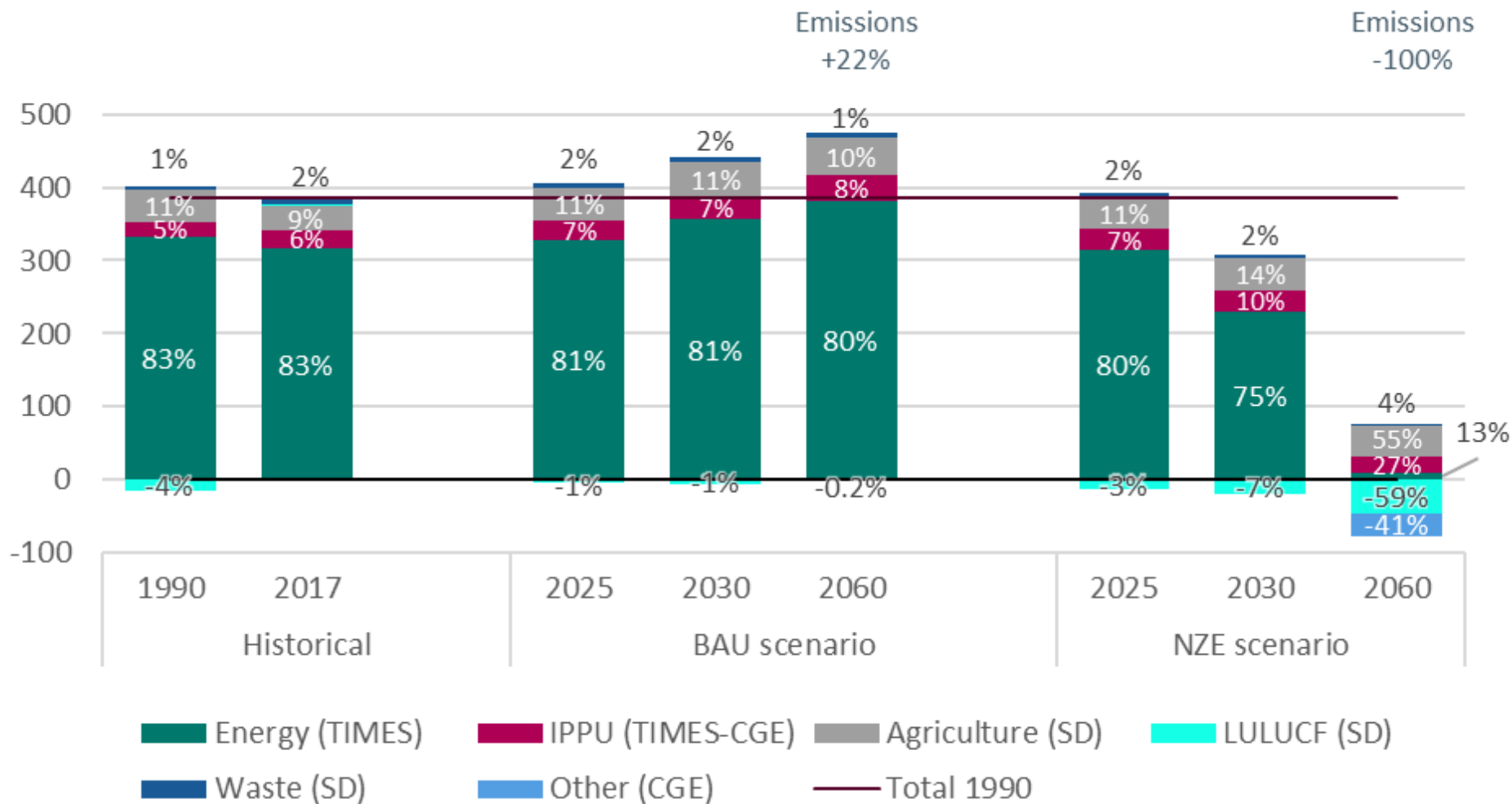
2. Main variables: Final consumption

Sector	Measure	TIMES Table(s)	Attribute	Process
Agriculture	Energy inputs [PJ]	__TIMES-CGE_Agriculture	VAR_FIn	not applicable
Coal	Energy inputs [PJ]	__TIMES-CGE_Coal mining	VAR_FIn	not applicable
Coal	Output (TIMES)	__TIMES-CGE_Coal mining	VAR_FOut	MINCOACOK01,SPR
Crude oil	Energy inputs [PJ]	__TIMES-CGE_Oil and Gas mining	VAR_FIn	SPR_OILCRD_EXTR
Crude oil	Output (TIMES)	__TIMES-CGE_Oil and Gas mining	VAR_FOut	MINOILNGL1,SPR_O
Gas	Energy inputs [PJ]	__TIMES-CGE_Oil and Gas mining	VAR_FIn	SPRGASNAT_EXTR
Gas	Output (TIMES)	__TIMES-CGE_Oil and Gas mining	VAR_FOut	SPRGAS
Mining and Quarrying	Energy inputs [PJ]	__TIMES-CGE_Mining and Quarrying	VAR_FIn	not applicable
Food industry	Energy inputs [PJ]	__TIMES-CGE_Food industry	VAR_FIn	INDFBTH,INDFBTM,
Ferrous metallurgy	Energy inputs [PJ]	__TIMES-CGE_Ferrous metallurgy	VAR_FIn	INDDDEM,INDIS

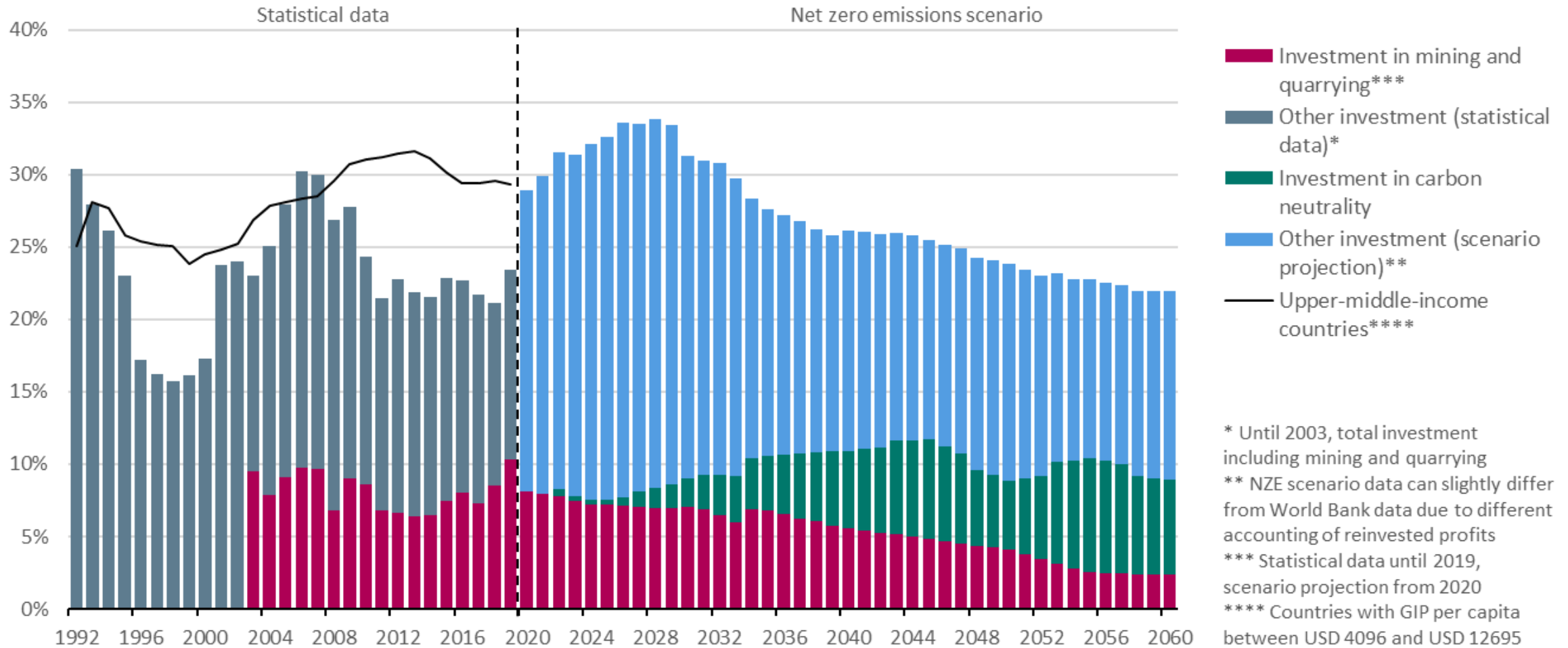
Mining and manufacturing (relevant sectors)					2017	2018	2019	2020
Mining and Quarrying	Energy inputs [PJ]	Coal		0	0	0	0	
Mining and Quarrying	Energy inputs [PJ]	Crude oil						
Mining and Quarrying	Energy inputs [PJ]	Gas,H2	44.8865266	46.0266443	46.9285779	47.8305115	50.6339087	
Mining and Quarrying	Energy inputs [PJ]	Oil refined products	40.4646983	41.4925017	43.6774253	45.862349	50.7261481	
Mining and Quarrying	Energy inputs [PJ]	Electricity	20.5528121	21.0748535	21.3937248	21.7125961	22.1012621	
Mining and Quarrying	Energy inputs [PJ]	Heat	12.5920125	12.9118496	13.1618596	13.4118696	14.1661166	
Mining and Quarrying	Energy inputs [PJ]	BIO	0	0	0	0	0.41477232	
Mining and Quarrying	Energy inputs [PJ]	Total	118.496049	121.505849	125.161588	128.817326	138.042208	
Food industry	Energy inputs [PJ]	Coal	0.51316681	0.49606125	0.47879504	0.46152883	0.44443517	
Food industry	Energy inputs [PJ]	Crude oil						
Food industry	Energy inputs [PJ]	Gas,H2	10.4778855	10.5040553	10.5302905	10.5565256	10.7485104	
Food industry	Energy inputs [PJ]	Oil refined products	0	0	0	0	0	
Food industry	Energy inputs [PJ]	Electricity	4.47298128	4.06553742	4.18534734	4.30515726	4.2702212	
Food industry	Energy inputs [PJ]	Heat	4.66275739	4.7698085	4.8768596	4.98391071	4.99962521	
Food industry	Energy inputs [PJ]	BIO	0	0	0	0	0	
Food industry	Energy inputs [PJ]	Total	20.126791	19.8354625	20.0712925	20.3071225	20.462792	

CGE sector	Energy input	Energy code	2017	2018
	Period -->		1	2
rgy inpl Mining and Quarrying	Coal	36	1	1
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rgy inpl Food industry	BIO		1	1

Modelling results for carbon neutrality in Kazakhstan: Emission reduction



Modelling results for carbon neutrality in Kazakhstan: Investment as a share of GDP



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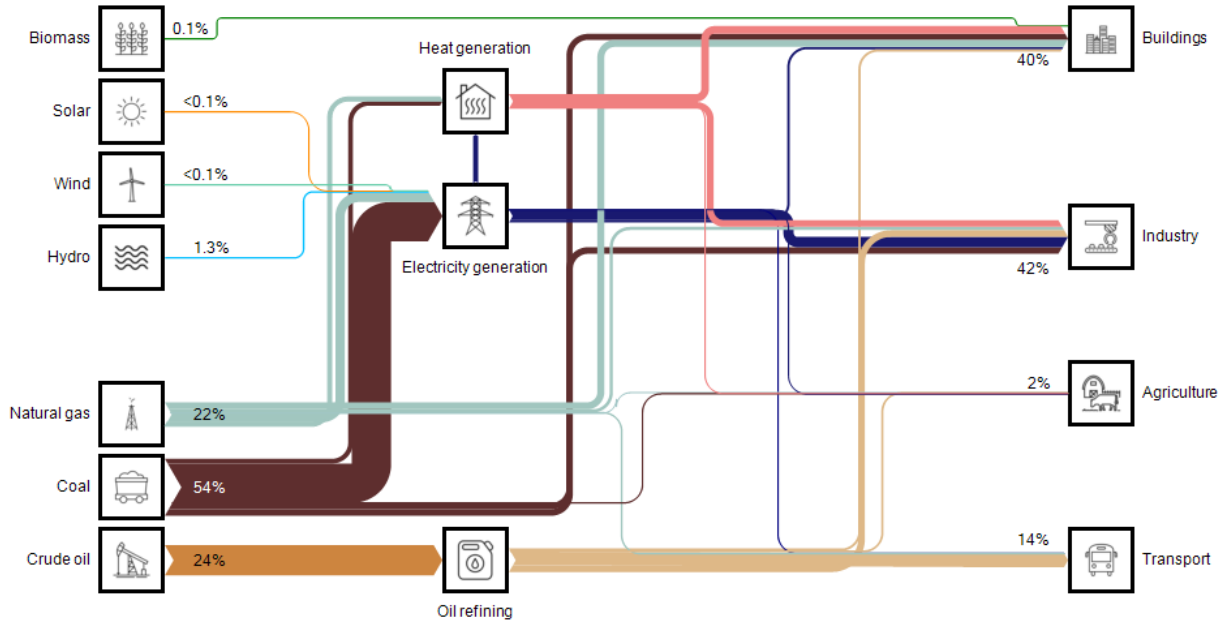
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Thank you for your attention!

Appendix: Modelling results for carbon neutrality of the energy system

2017 reference case



2060 Net zero emissions

