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

*Lars Handrich, Nadiya Mankovska, Maria Polugodina** (DIW ECON GmbH, Germany)*

Oleksandr Diachuk, Roman Podolets, Andrii Semeniuk (IEF NASU, Ukraine)

Andrea Bassi, Georg Pallaske (KnowlEdge Srl, Italy)

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*** presenter & corresponding author*

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

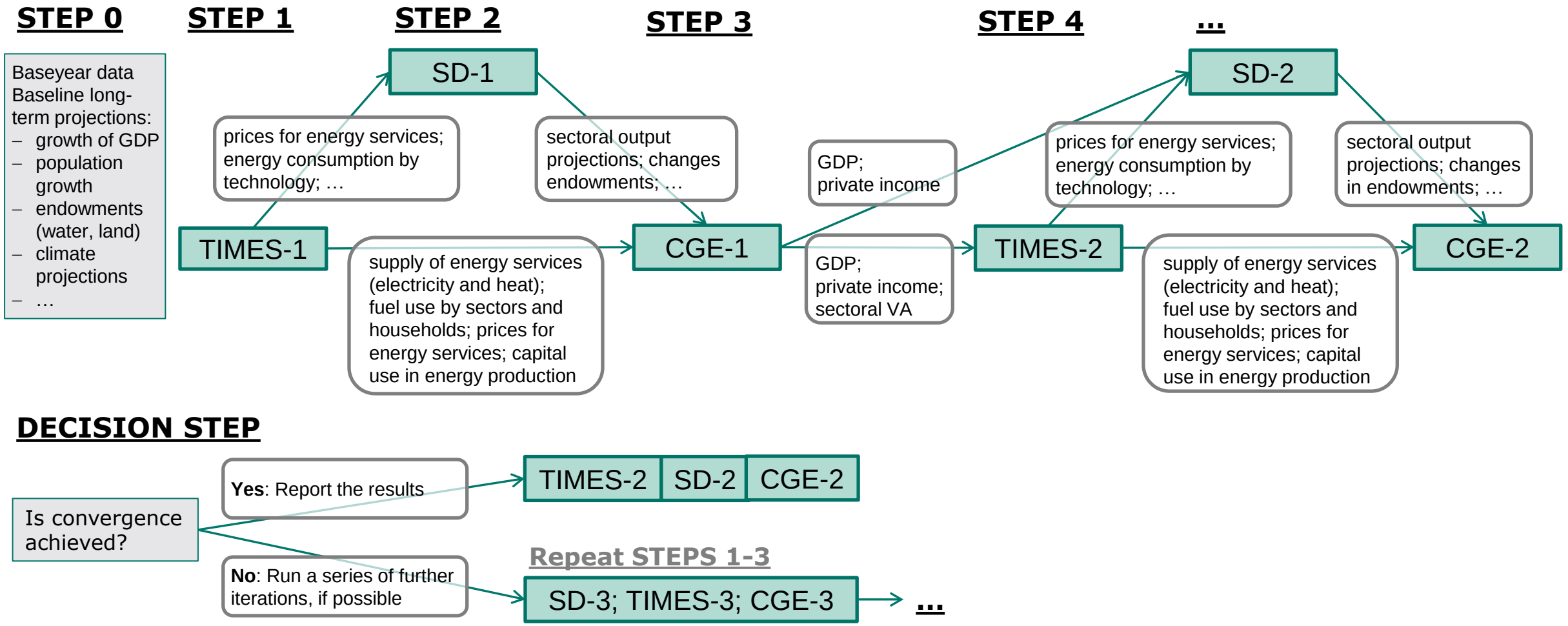
- This model set allows comprehensive analysis of economy-wide & sectoral transformations and of socio-economic effects of decarbonization

Why (soft-)link the three models?

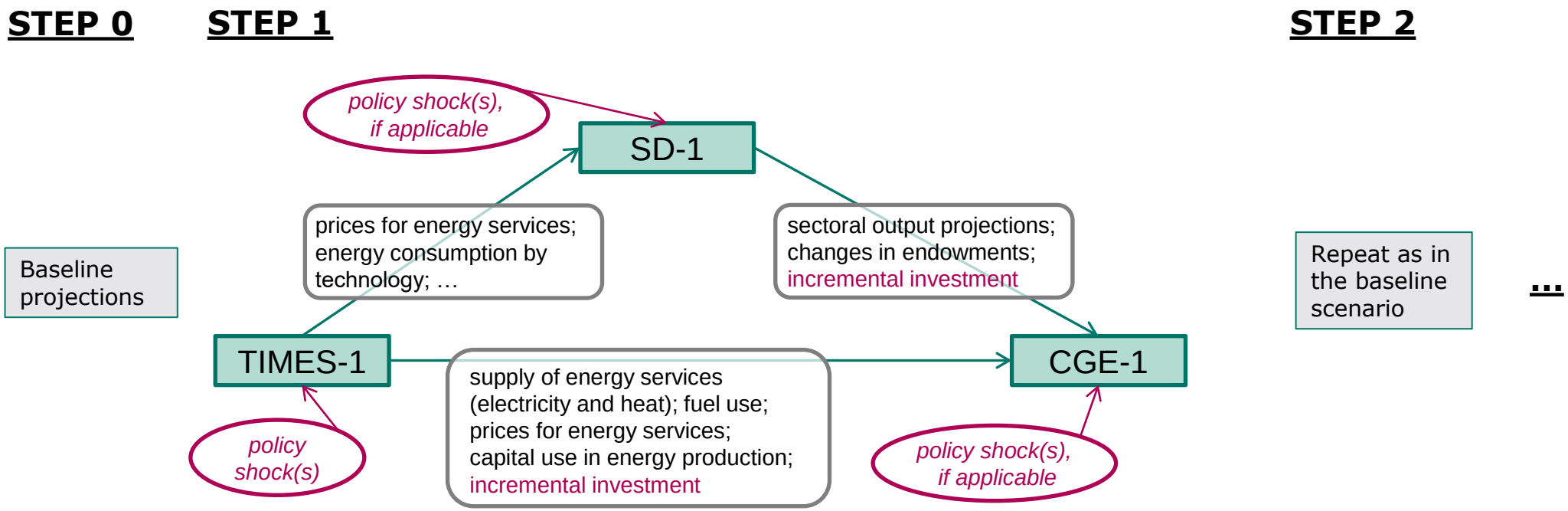
- Why link the models?
  - Each model is focused on its area and makes a number of exogenous assumptions
  - Replacing exogenous assumptions with endogenous results of other models increases breadth and depth of modelling
  - This improves data quality and provides more insightful results

- 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)



Overall integration approach: Iterative data exchange (policy scenarios)



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	STGINDELC				0	0
7257	Cap_New	INSTCAP	STGRSDELC					
7258	Cap_New	INSTCAP	STGTERELC					0
7259	Cap_New	LUMPINV	STGAGRELC					1
7260	Cap_New	LUMPINV	STGBATELC01					304
7261	Cap_New	LUMPINV	STGINDELC				1	7
7262	Cap_New	LUMPINV	STGRSDELC					
7263	Cap_New	LUMPINV	STGTERELC					4
7264	Cost_Fom	-	STGAGRELC					0
7265	Cost_Fom	-	STGBATELC01					1
7266	Cost_Fom	-	STGINDELC				0	0
7267	Cost_Fom	-	STGRSDELC					
7268	Cost_Fom	-	STGTERELC					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 inpu	Mining and Quarrying	Coal	36	1	1
	Energy inpu	Mining and Quarrying	Crude oil	37	1	1
	Energy inpu	Mining and Quarrying	Gas,H2	38	1	0.989815
	Energy inpu	Mining and Quarrying	Oil refined products	48	1	1.021912
	Energy inpu	Mining and Quarrying	Electricity	53	1	0.98548
	Energy inpu	Mining and Quarrying	Heat	55	1	0.989589
	Energy inpu	Mining and Quarrying	BIO		1	1
			Period -->		1	2
8	Energy inpu	Food industry	Coal	36	0.980864	0.9356
	Energy inpu	Food industry	Crude oil	37	1	1
	Energy inpu	Food industry	Gas,H2	38	1.017222	1.00778
	Energy inpu	Food industry	Oil refined products	48	1	1
	Energy inpu	Food industry	Electricity	53	0.922259	0.938283
	Energy inpu	Food industry	Heat	55	1.037983	1.04881
	Energy inpu	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

7251	Table Name: __TIMES-CGE_ELCSTG techs_costs				
7252	Active Unit: M USD				
7253	Attribute	UserConstraint	Process\Period	2017	2018
7254	Cap_New	INSTCAP	STGAGRELC		
7255	Cap_New	INSTCAP	STGBATELC01		
7256	Cap_New	INSTCAP	STGINDELC		
7257	Cap_New	INSTCAP	STGRSDELC		
7258	Cap_New	INSTCAP	STGTERELC		
7259	Cap_New	LUMPINV	STGAGRELC		
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7261	Cap_New	LUMPINV	STGINDELC		
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7264	Cost_Fom	-	STGAGRELC		
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7267	Cost_Fom	-	STGRSDELC		
7268	Cost_Fom	-	STGTERELC		
7269	EQ_CombalM	-	-	4307051	1624887
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7273	Active Unit: M USD				
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7275	Cap_New	INSTCAP	STGH2GST		
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7278	Cap_New	LUMPINV	STGH2GUG		
7279	Cost_Fom	-	STGH2GST		
7280	Cost_Fom	-	STGH2GUG		
7281	EQ_CombalM	-	-	4307051	1624887

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-[illegible]Ferrous metallurgy	VAR_FIn	INDDEM,INDIS

ining 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
gy inpu	Mining and Quarrying	Coal	36	1	1
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inpu	Mining and Quarrying	Gas,H2	38	1	0.989815
pu	Mining and Quarrying	Oil refined products	48	1	1.021912
	Mining and Quarrying	Electricity	53	1	0.98548
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inpu	Mining and Quarrying	BIO		1	1
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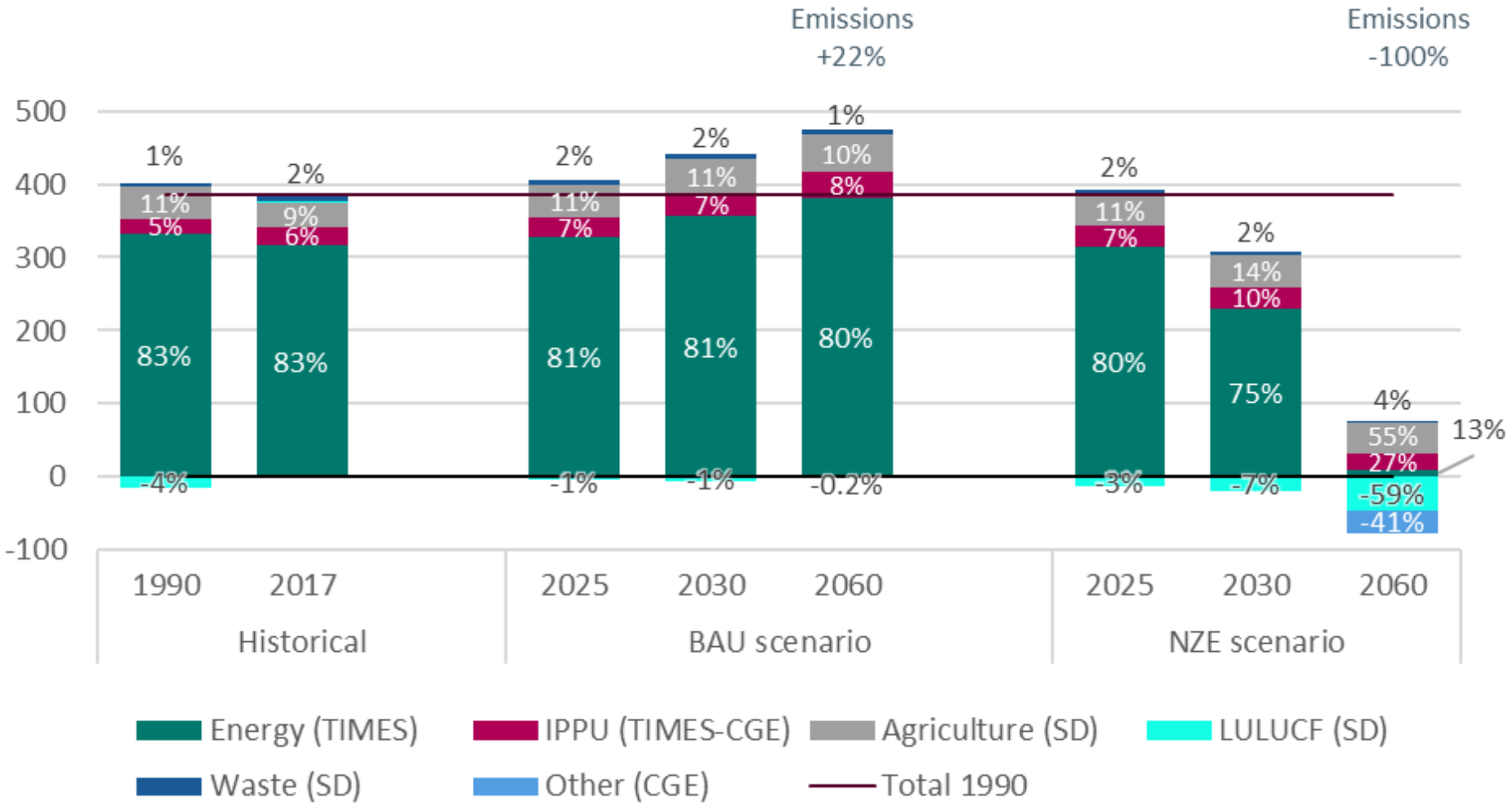
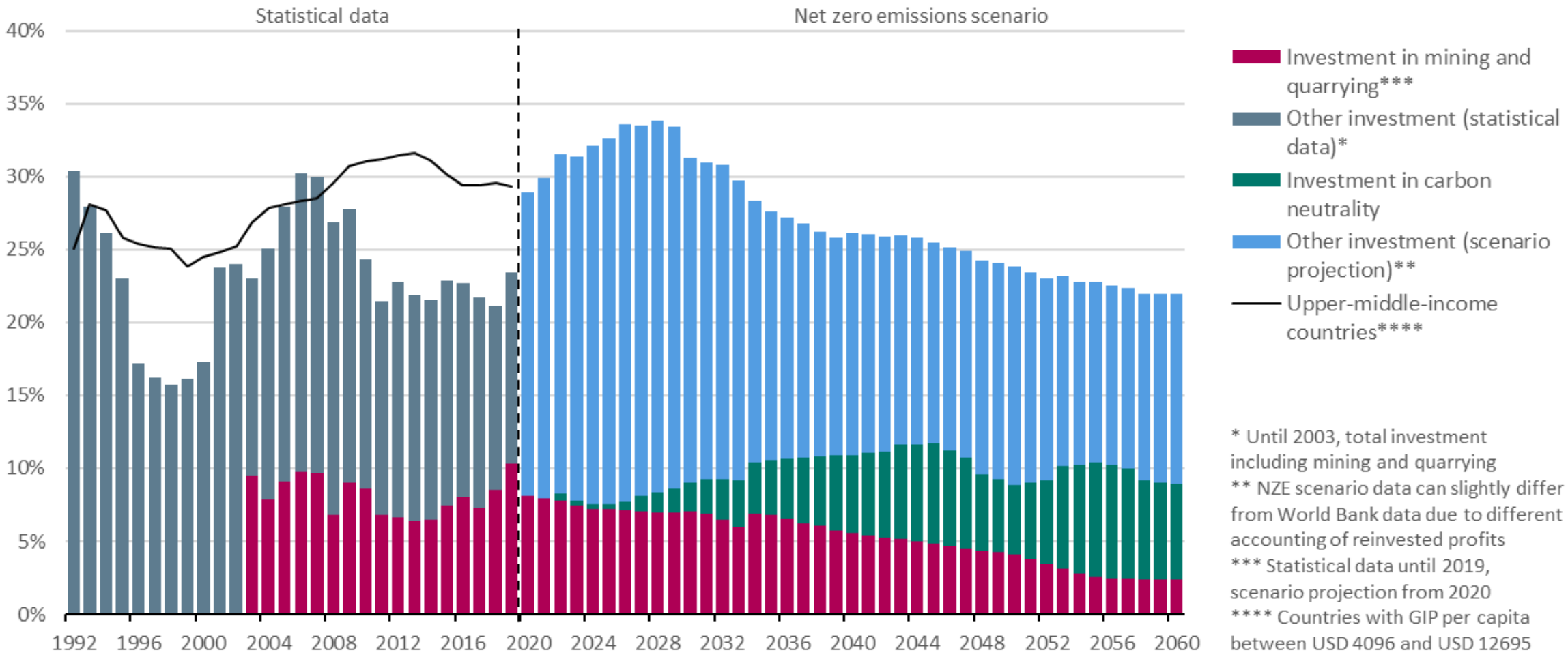
rgy inpu	Food industry	BIO		1	1

Modelling results for carbon neutrality in Kazakhstan: Emission reduction



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



* Until 2003, total investment including mining and quarrying
** NZE scenario data can slightly differ from World Bank data due to different accounting of reinvested profits
*** Statistical data until 2019, scenario projection from 2020
**** Countries with GIP per capita between USD 4096 and USD 12695

Contact

Dr. Lars Handrich
Managing Director
DIW Econ GmbH • Mohrenstraße 58
10117 Berlin • Germany

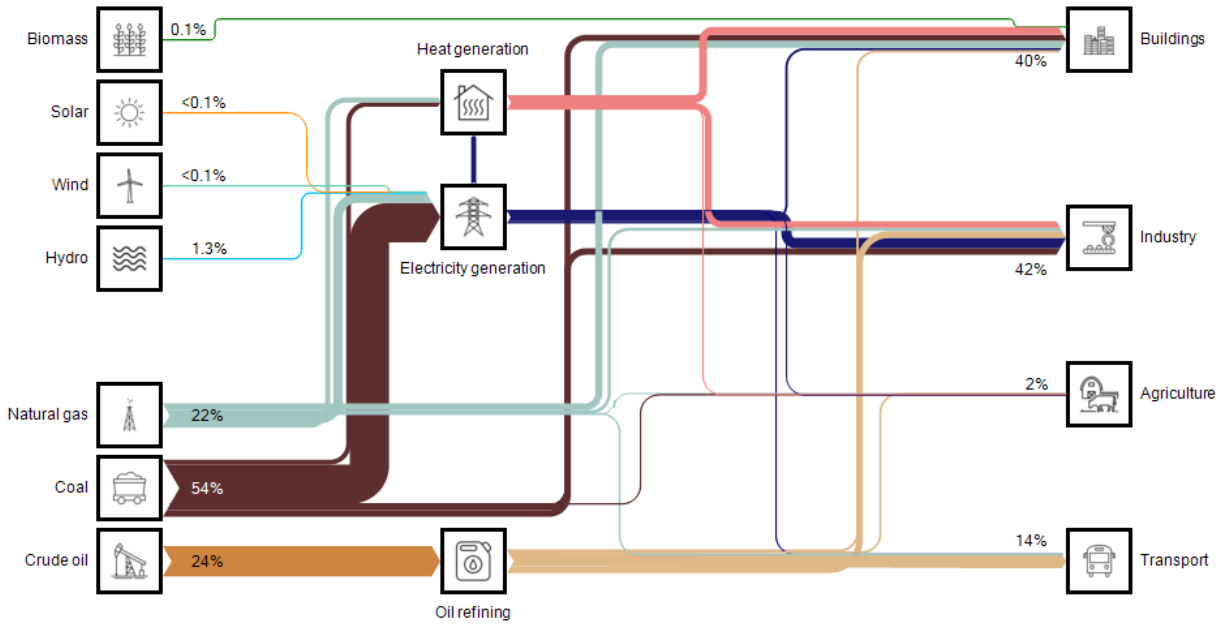
Phone +49.30.20 60 972 0
Fax +49.30.20 60 972 99
E-mail: lhandrich@diw-econ.de
URL: www.diw-econ.com

Head office: Berlin, Germany, Reg.-No.: HRB 108699 B, Local court: Charlottenburg

Thank you for your attention!

Appendix: Modelling results for carbon neutrality of the energy system

2017 reference case



2060 Net zero emissions