



GCAM-Macroeconomics

Enhancing Feedback and Teleconnection Capabilities

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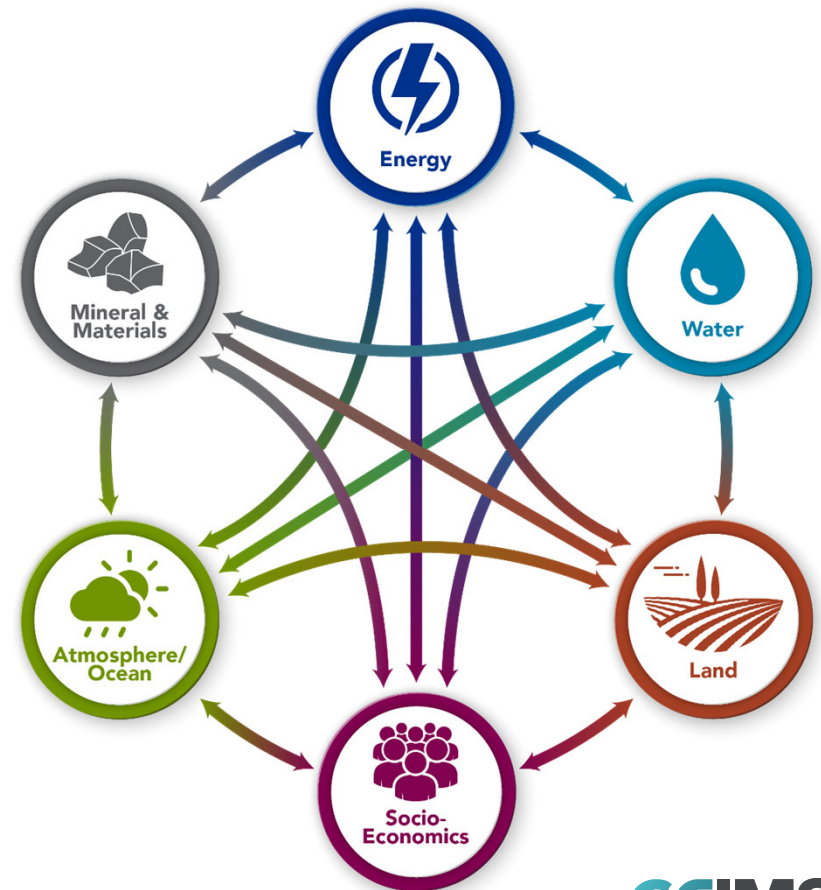
PNNL is operated by Battelle for the U.S. Department of Energy

Acknowledgement:

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Why GCAM-Macro?

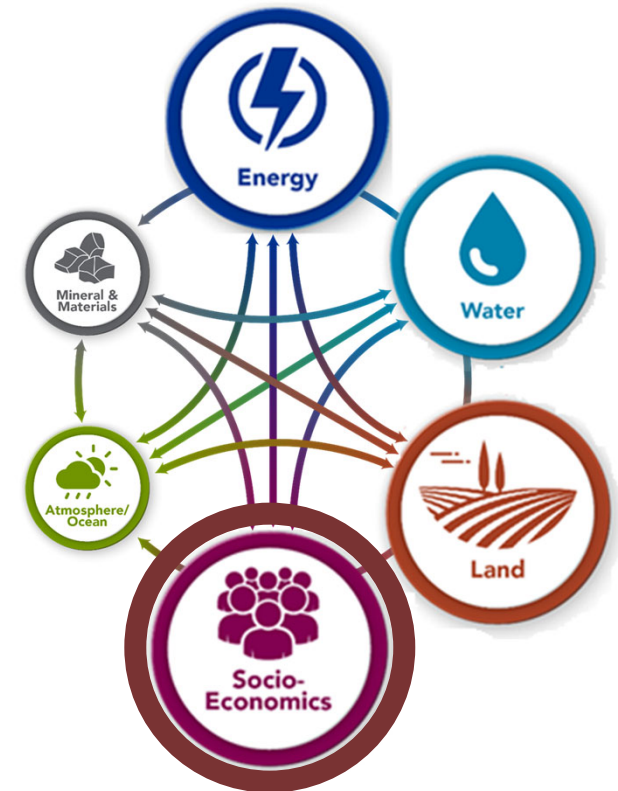
- GDP determined the scale of activity for Energy, Water, Land, Materials & Minerals.
- Before GCAM 7.0, GDP was set exogenously
- GDP NEVER CHANGED THEREAFTER
 - No matter what happened in those other sectors.



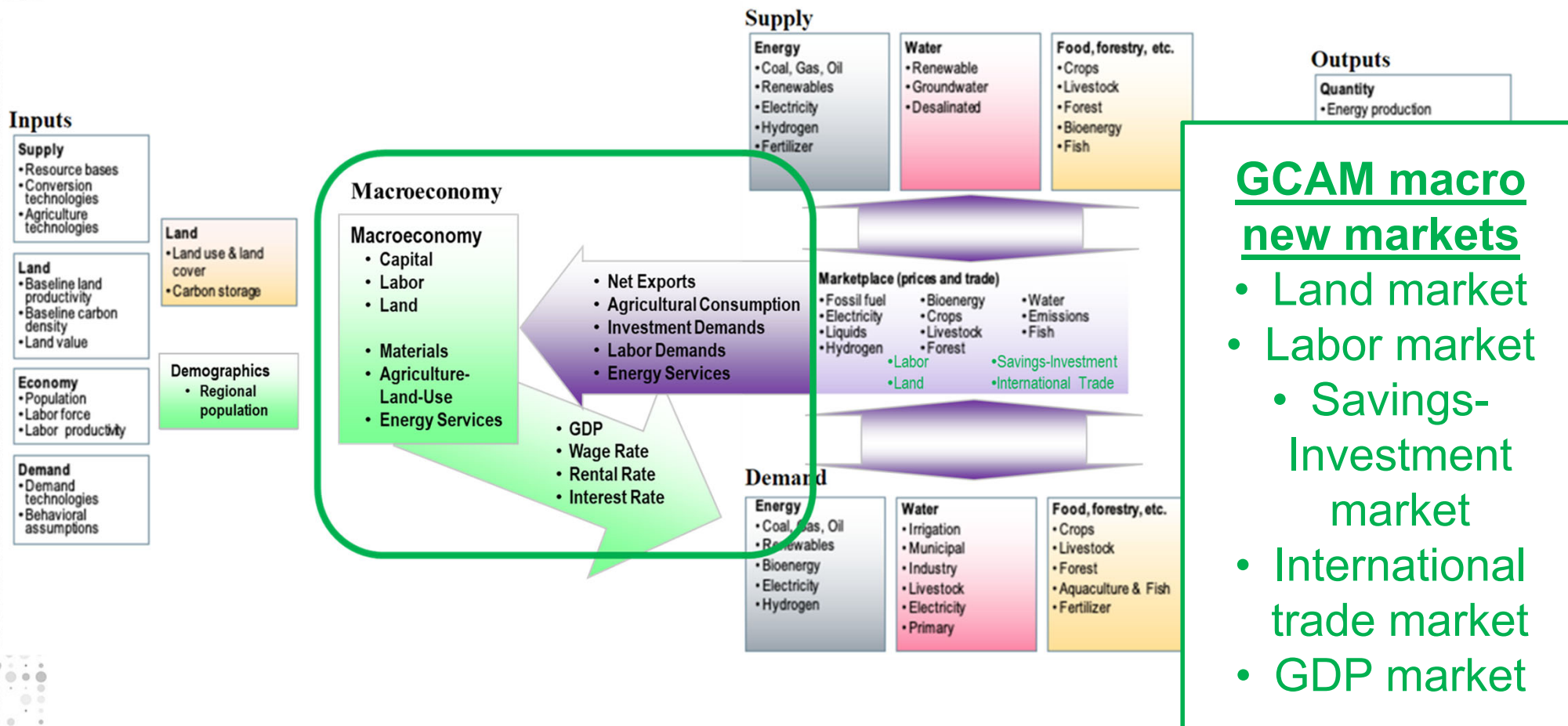
GCAM-Macro Today

The **GCAM** macroeconomic module couples to and interacts with GCAM's energy, agriculture-land-use, and water sectors.

GCAM-macro creates the capability to analyze domestic and international **feedbacks** and **teleconnections**.



GCAM-Macro Creates 5 New Markets to Clear



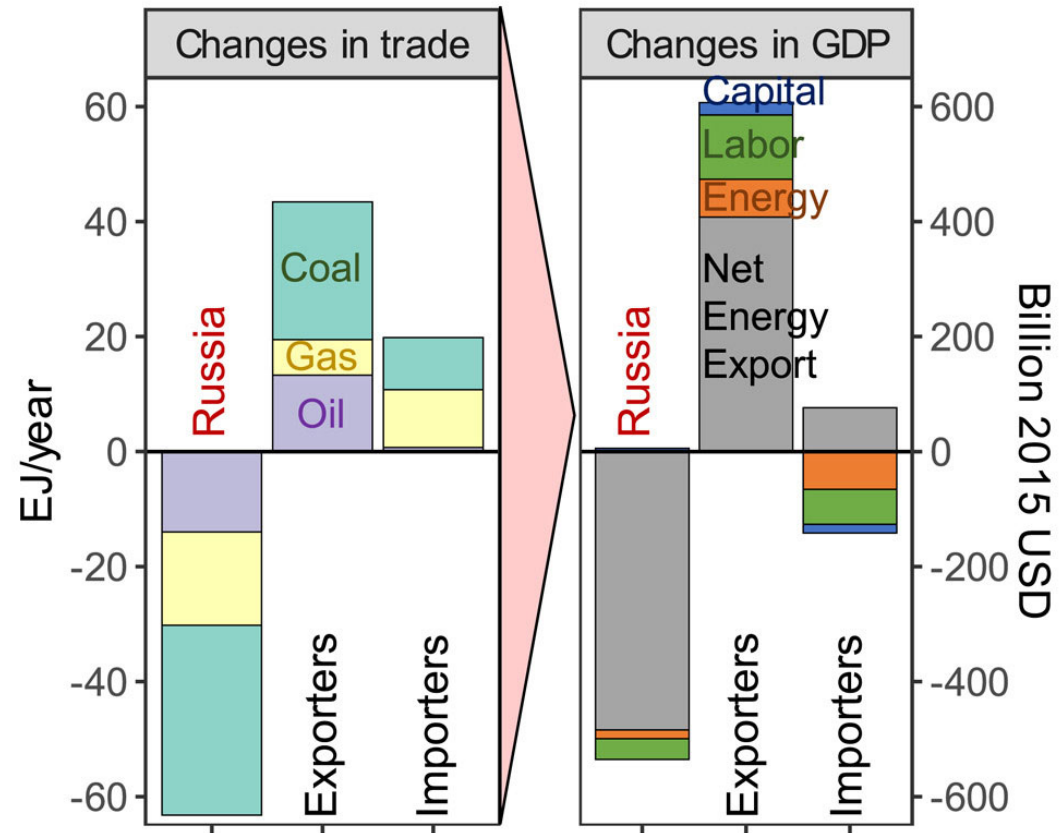
Two Examples of Applications

1. Energy supply disruption
(Edmonds et al., *iScience*, 2025)
2. Heat stress on agricultural crops and workers
(Sheng et al., 2026; under review *Env.Res.Letters*)

GCAM-macro creates the capability to analyze domestic and international **feedbacks** and **teleconnections**.

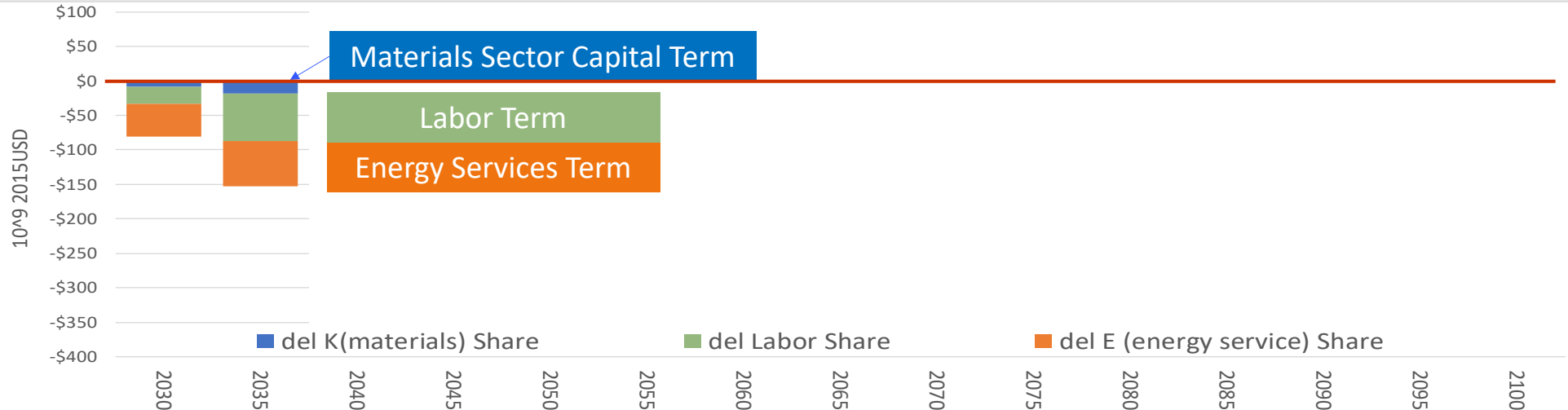
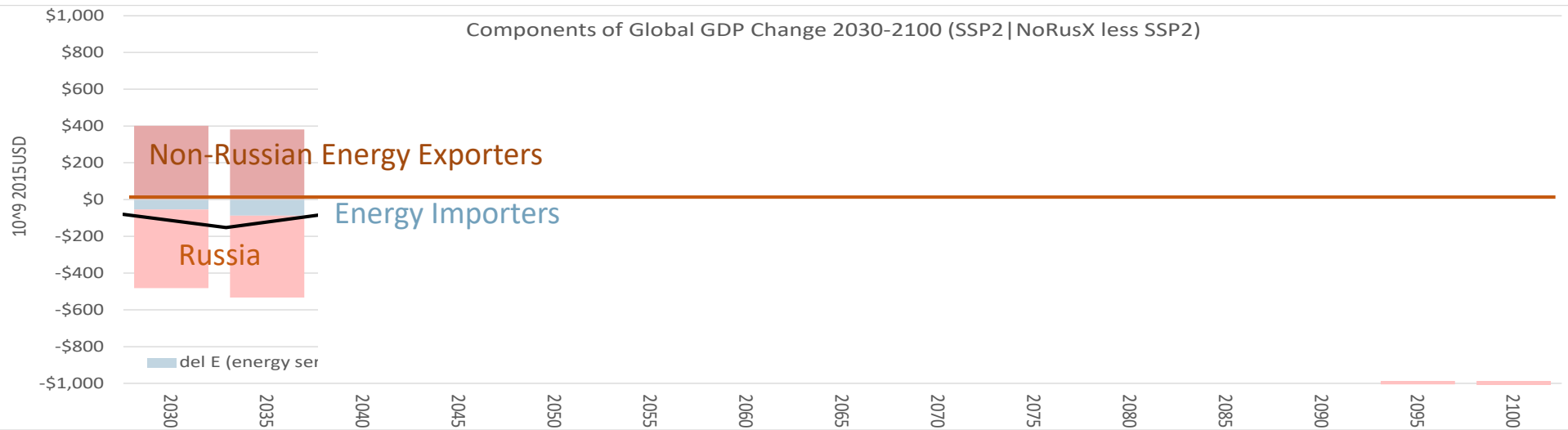
Hypothetical fossil fuel supply disruption of Russian energy exports—domestic feedbacks and teleconnections.

Changes in global energy trade patterns affect GDPs. We showcase how a cession of Russian exports shifts GDP around the world (SSP2; 2050).



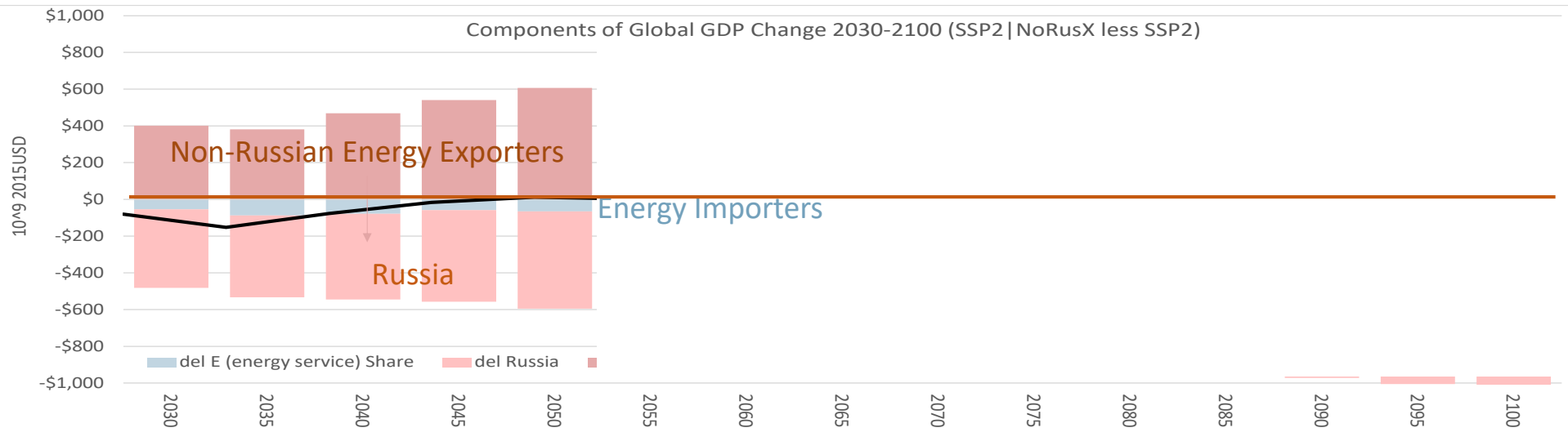
Global GDP Change—Near-term

Components of Global GDP Change 2030-2100 (SSP2 | NoRusX less SSP2)

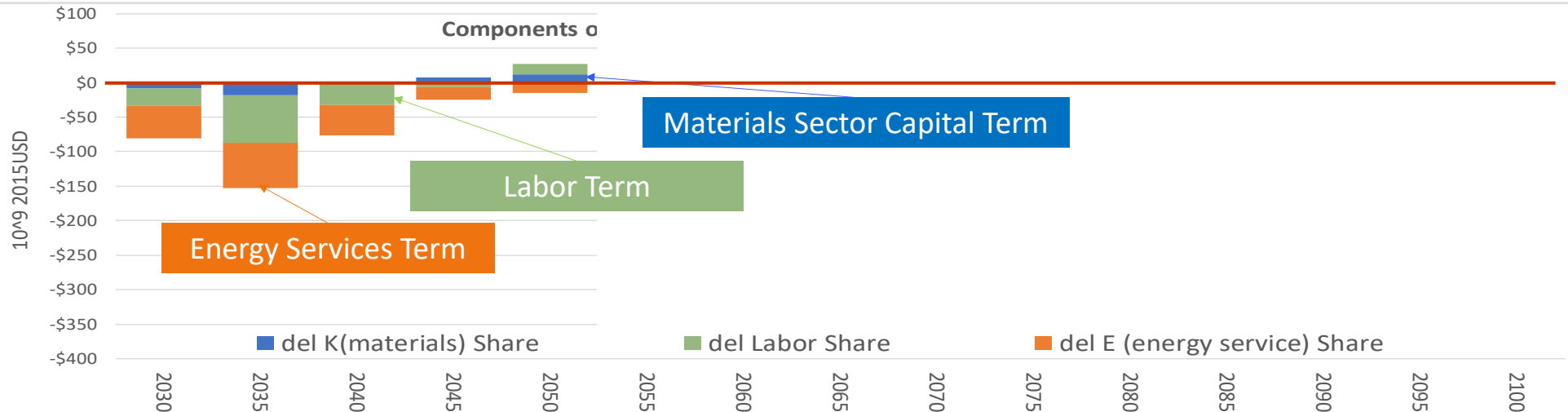


Global GDP Change—2050

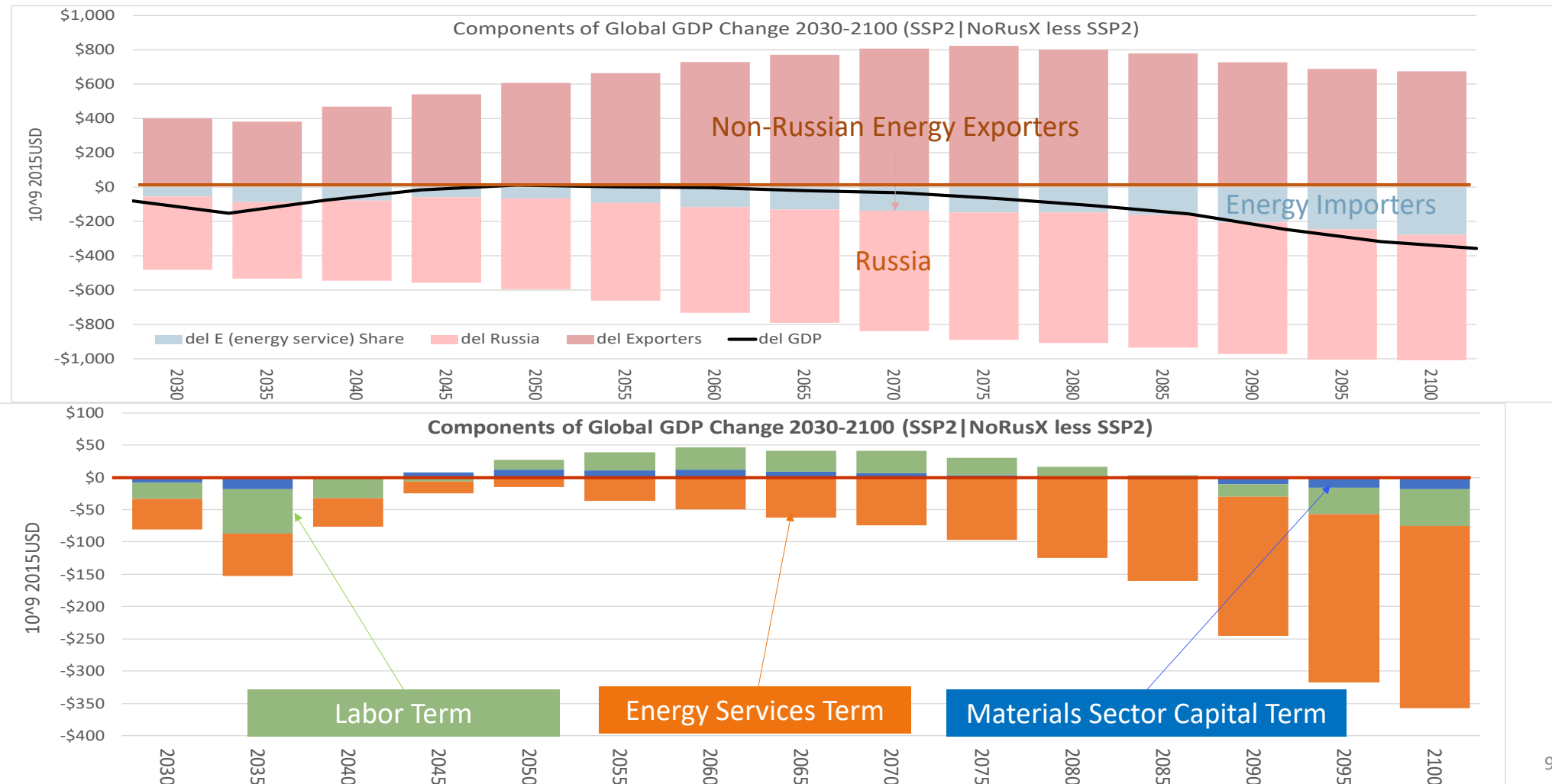
Components of Global GDP Change 2030-2100 (SSP2 | NoRusX less SSP2)



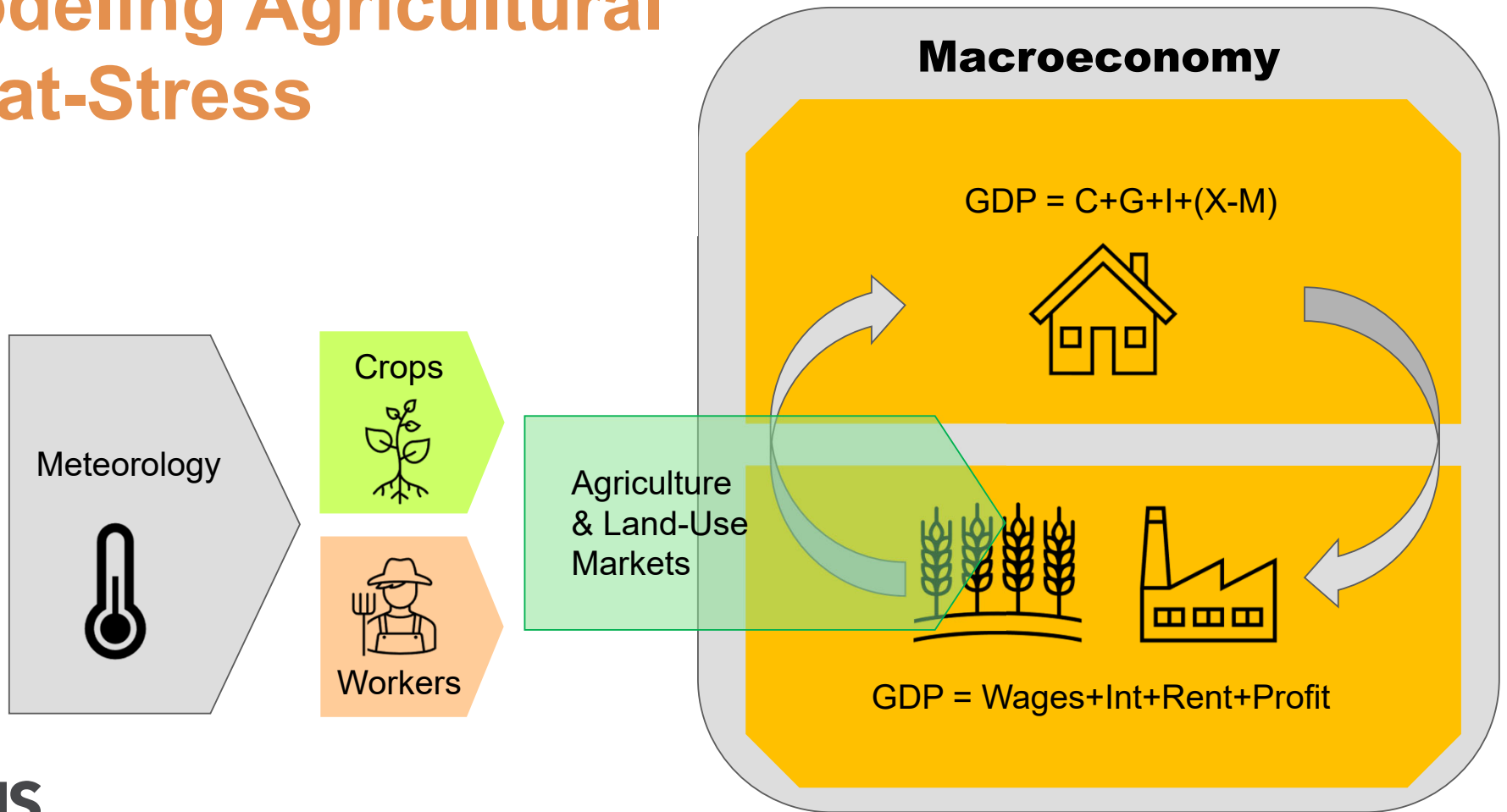
Components of



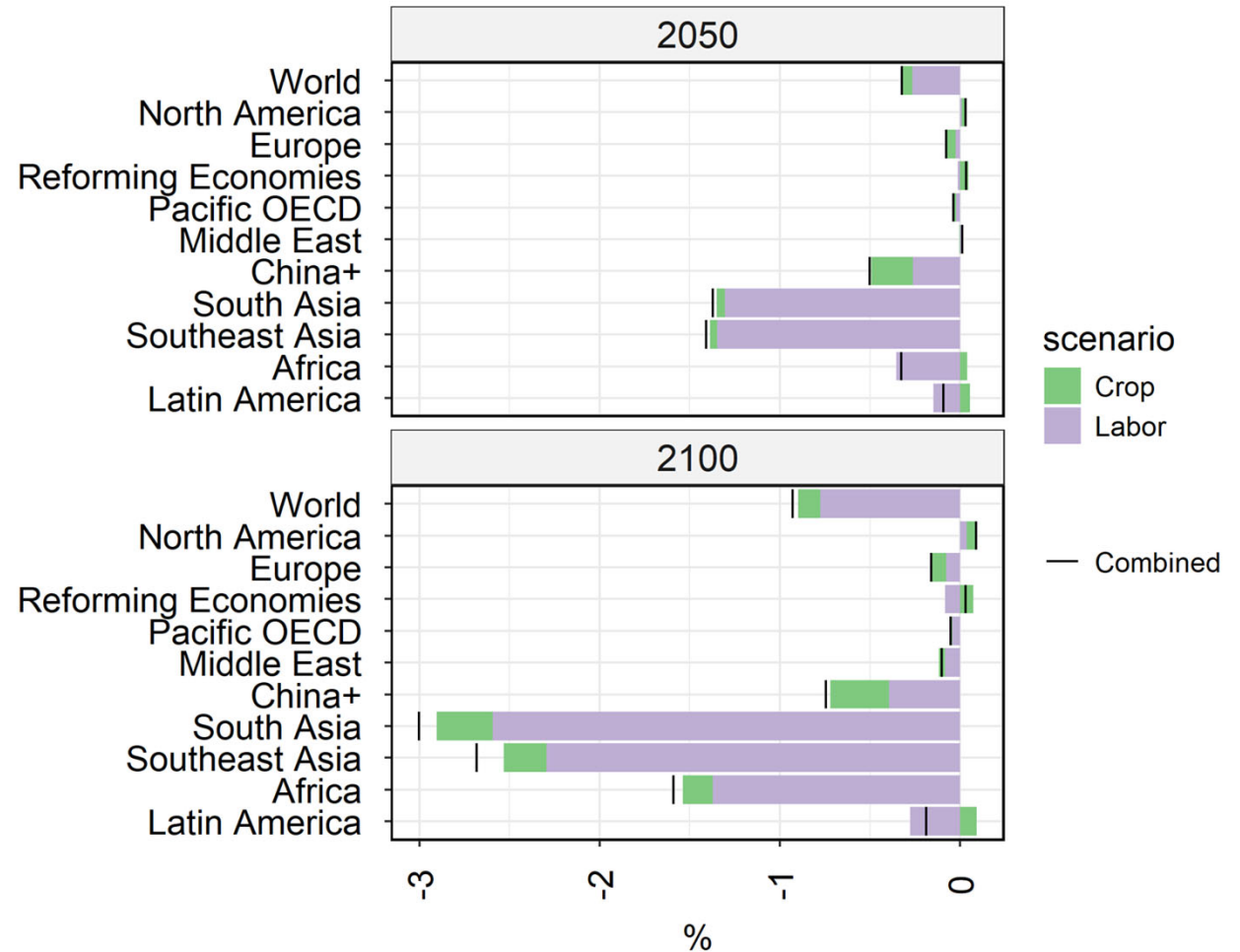
Global GDP Change—Long-term



Modeling Agricultural Heat-Stress

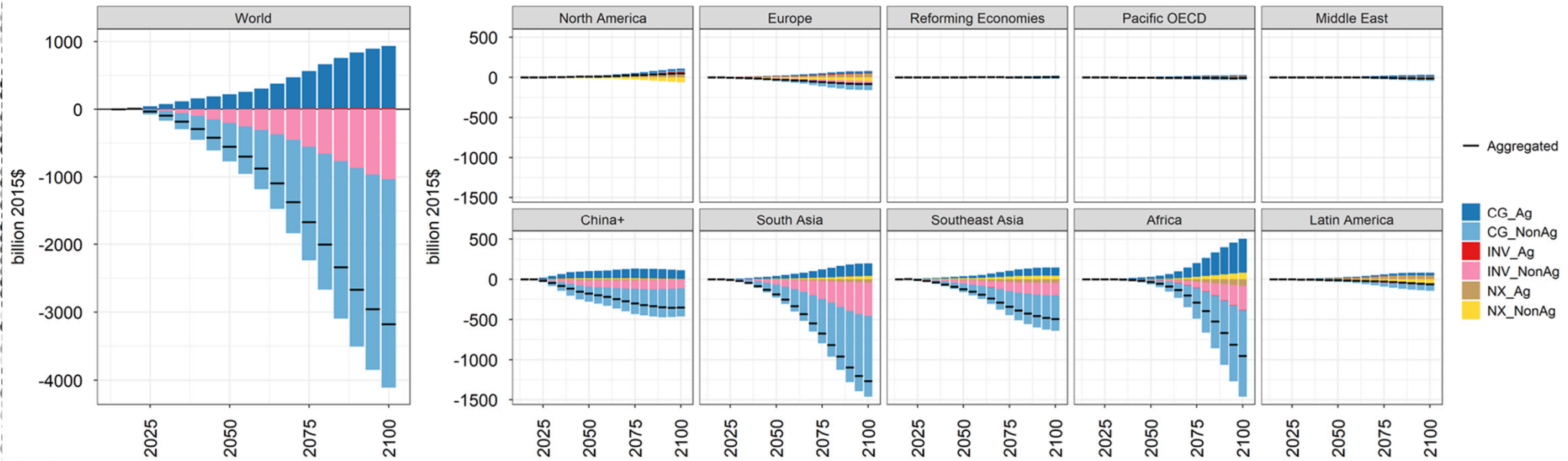


GDP response through three heat stress pathways: Crops, Labor, and combined



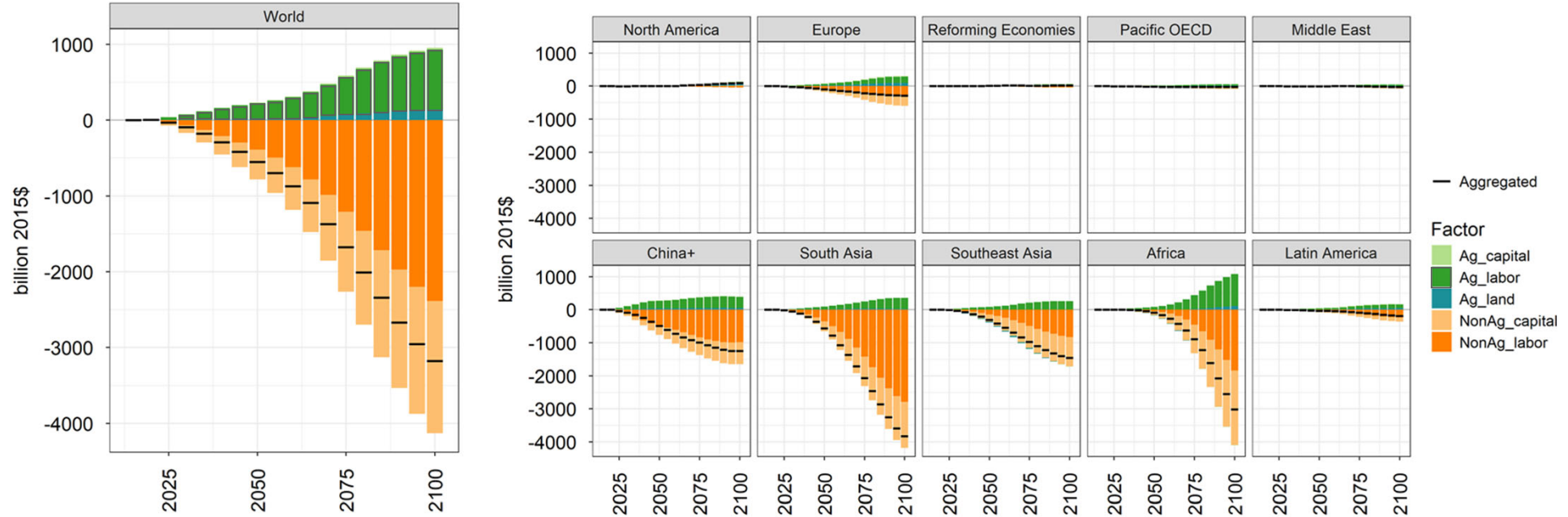
Decomposition of regional and global GDP changes due to heat stress by product category

a. Decomposition of absolute GDP changes with the expenditure method



Decomposition of regional GDP changes in value added due to heat stress

Decomposition of absolute GDP changes with the income method

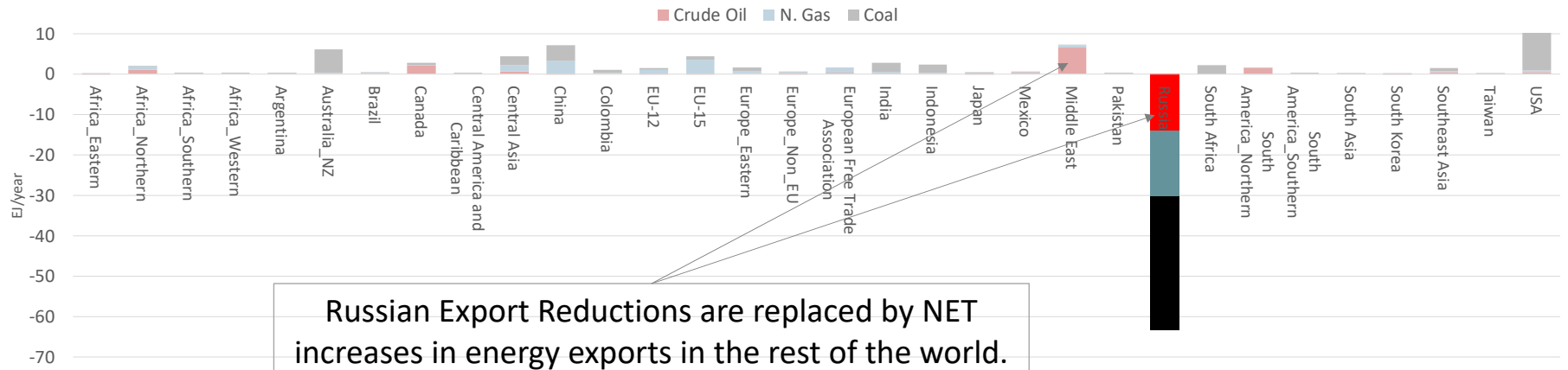


Future Directions for GCAM-Macro

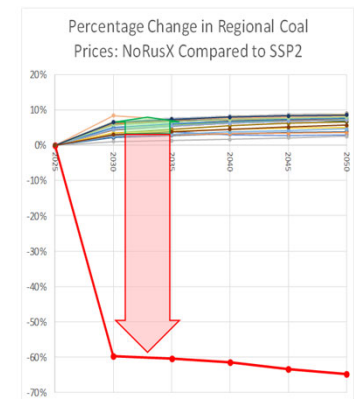
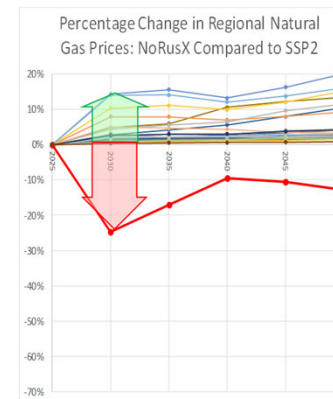
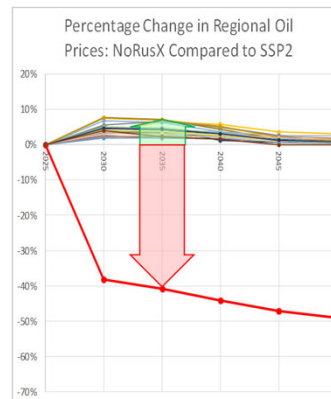
- **Improved labor market modeling:** Integrate labor and materials demands for **energy technologies**—distinguishing labor needed to build the capital equipment and labor needed for operations and maintenance, workers.
- **Long-term goal is to couple all of GCAM in a general integration framework to better identify feedbacks and teleconnections.**

Discussion

Change in Net Fossil Fuel Exports: SSP2 | NoRusX less SSP2: 2050 (EJ/year)



Experimental Design With SSP2

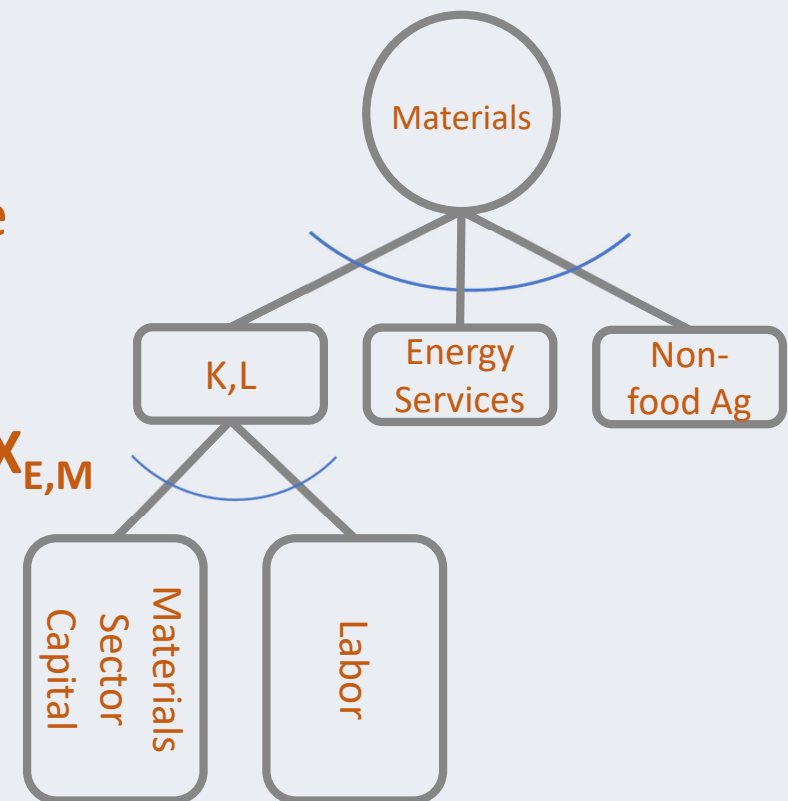


The KLEAM Materials Sector

$$\text{Materials } X_M = (\sum_i^N (\sum_j^N a_{i,j} X_j^{\eta_i})^{(\rho/\eta_i)})^{(1/\rho)} \quad j=K,L,E,A, N=4$$

The Materials sector is homogeneous of degree one.

$$P_M X_M = P_K X_{K,M} + P_L X_{L,M} + P_E X_{E,M} + P_{Anf} X_{Anf,M}$$



The KLEAM SAM

	Agriculture	Energy	Materials	Household +Gov	Investment	Trade	Σ
Land	Ag Land						GDP
Labor	Ag Labor		Ma Labor				
Capital	Ag Capital	En Capital	MA Capital				
Agriculture			Ag Non-food	Ag Food		Ag-net exports	Ag-Gross output
Energy			Energy Services			En Net Exports	EN-Gross output
Materials				Non-food-C+G	Investment	Ma Net Exports	MA-Gross output
Savings				Net Savings			
Trade					Foreign Investment		
Σ	Ag-Gross output	En-value added	MA-Gross output	GDP = C+I+G+NX			

The
KLEAM
GDP

New Final Goods & Services
$$GDP = P_M X_M + \sum_j^N P_{A,j} X_{A,j} + P_E X_{E,NX} + P_A X_{A,NX}$$

Returns to Primary Factors of Production
$$GDP = P_L X_L + P_{Land} X_{Land} + P_K X_K$$