Regional Teleconnections and Multisector Dynamics: insights from ongoing research and future directions

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GCIMS GLOBAL CHANGE INTERSECTORAL MODELING SYSTEM

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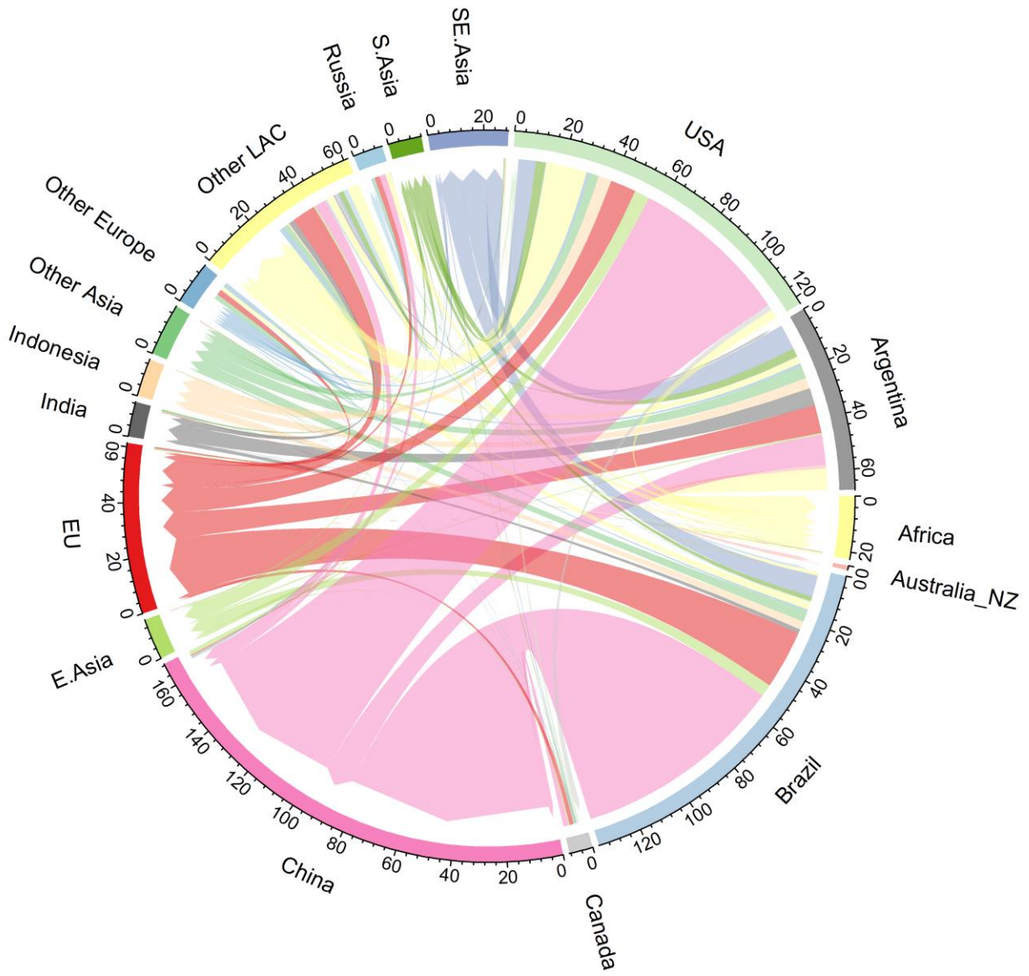
Regional teleconnections are caused by globally traded energy, agricultural, and other commodities

- Regional teleconnections could affect how human and natural systems respond to future stressors
- Regional teleconnections link changes induced by stresses in one place to those of another
- In other words, regional teleconnections could create, amplify, or attenuate responses of human and Earth systems to different stressors
- The ease or difficulty of trade could affect how systems respond to various stressors

Soybean trade flows in 2050



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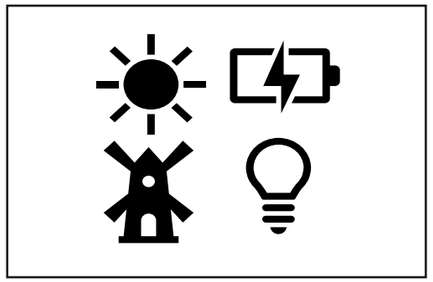
For example, regional teleconnections through minerals trade could affect future evolution of the energy system

Example stresses	Example Energy-system responses
Economic growth 	Expansion of solar photovoltaic systems 
Economy-wide technology transitions 	Expansion of wind technology 

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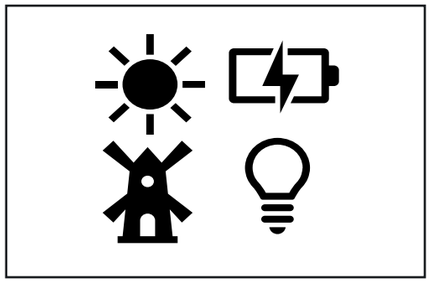
Example stresses

Economic growth

Economy-wide technology transitions



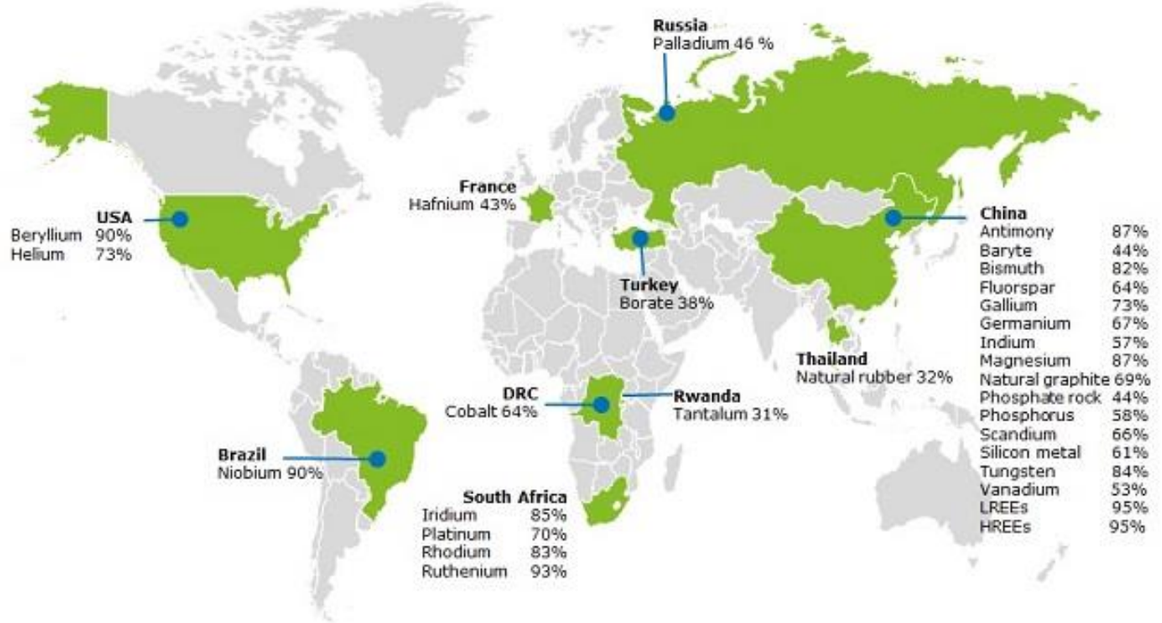
Example Energy-system responses

Expansion of solar photovoltaic systems

Expansion of wind technology

Minerals/Elements Availability and Trade Patterns

Global distribution of minerals and elements



Percentage numbers correspond to share of global production

E.g., import reliance of U.S. on rare-Earth elements, indium, gallium is 100%

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GCIMS Major Experiment 2: Science question

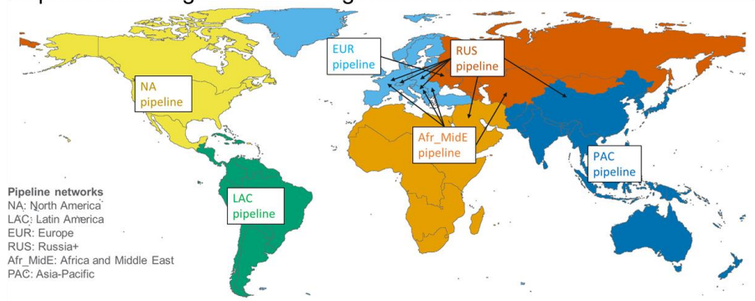
How will regional teleconnections via resource supply networks and trade create, amplify, or attenuate responses associated with different influences in the U.S. and other parts of the world, and how will varying assumptions about the ease or difficulty of trade alter these teleconnections?

Example 1: Detailed modeling of Natural gas trade within a multisectoral context

- Yarlagadda et al. developed capability within the Global Change Analysis Model (GCAM) to differentiate pipeline gas and LNG trade
- This capability allows for the tracking of natural gas export and import infrastructure investments
- Gas trade is integrated into the broader global energy sector, allowing for competition between these two modes of gas trade with multiple energy supply technologies in meeting multi-sectoral energy demands
- In our modeled scenarios, new LNG export infrastructure ranged from 230 to 840 million tons of gas per annum (MTPA) globally by 2050. New pipeline export infrastructure ranged from 70 to 620 MTPA by 2050.

Global natural gas trade in this study:

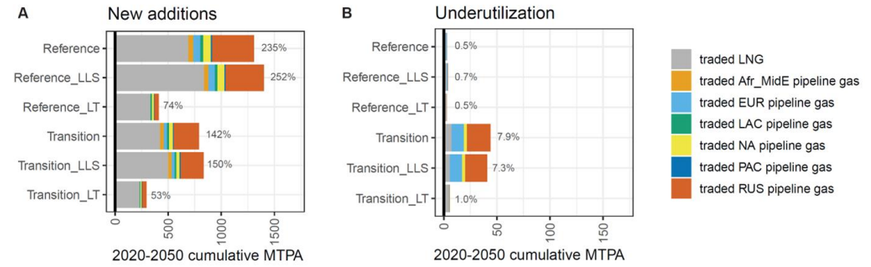
- Pipeline natural gas traded in regional networks:



- LNG traded in a single global pool

Scenario factors explored:

- Economy-wide energy system transitions
- LNG trade infrastructure costs
- Trade scenarios



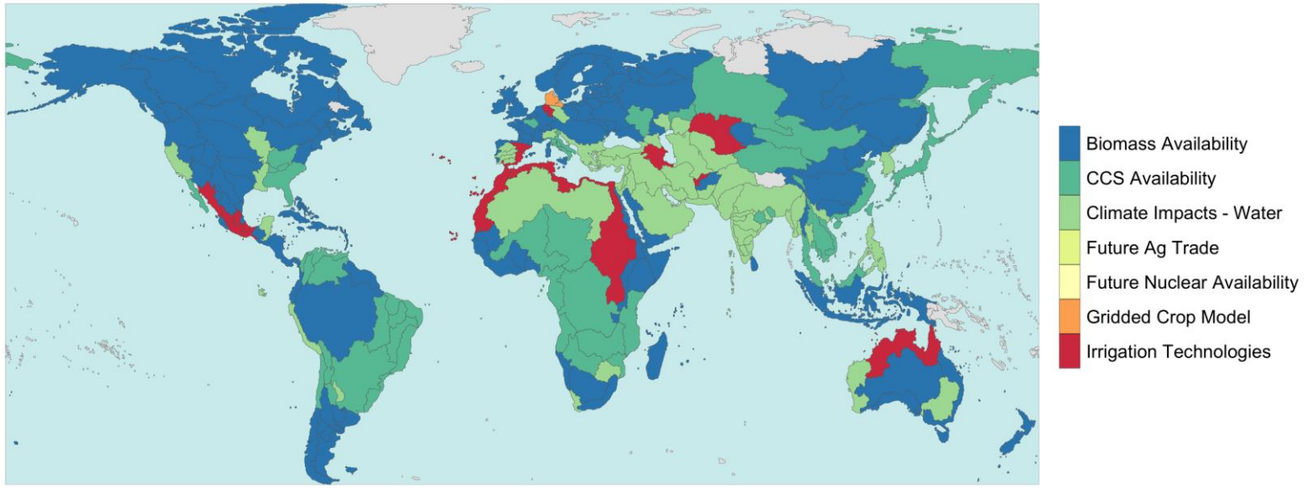
GCAM's new detailed natural gas trade capability differentiates between pipeline and LNG trade and allows for the quantification of new investments and underutilization of gas trade infrastructure.
Scenario factors: LLS = Low liquefaction and shipping costs; LT = Limited trade.
Units: MTPA = million tons of gas per annum (in gaseous form) that can be traded.

Yarlagadda, B., G. Iyer, M. Binsted, P. Patel, M. Wise and J. McLeod (2024). The future evolution of global natural gas trade. iScience. https://doi.org/10.1016/j.isci.2024.108902

Example 2: Modeling and analysis of Virtual water trade

- Traded agricultural and energy commodities redistribute water virtually around the world
- In a series of studies, Neal Graham et al. have studied water implications of electricity trade within the U.S. and agricultural trade globally
- In ongoing research, Graham et al. leverage a scenario discovery framework to understand the main drivers of change for global and regional agricultural water use utilization and future virtual water trade across a large ensemble (>7000 simulations) of uncertain futures

Main Driver of Virtual Blue Water Exports in 2100 under SSP2/RCP6.0 across >7000 simulations



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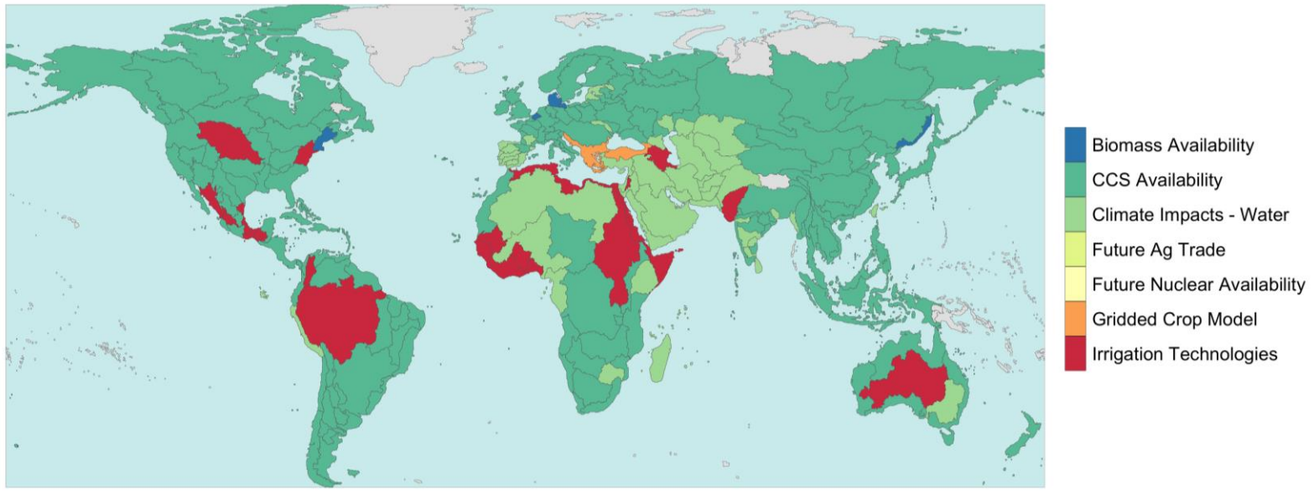
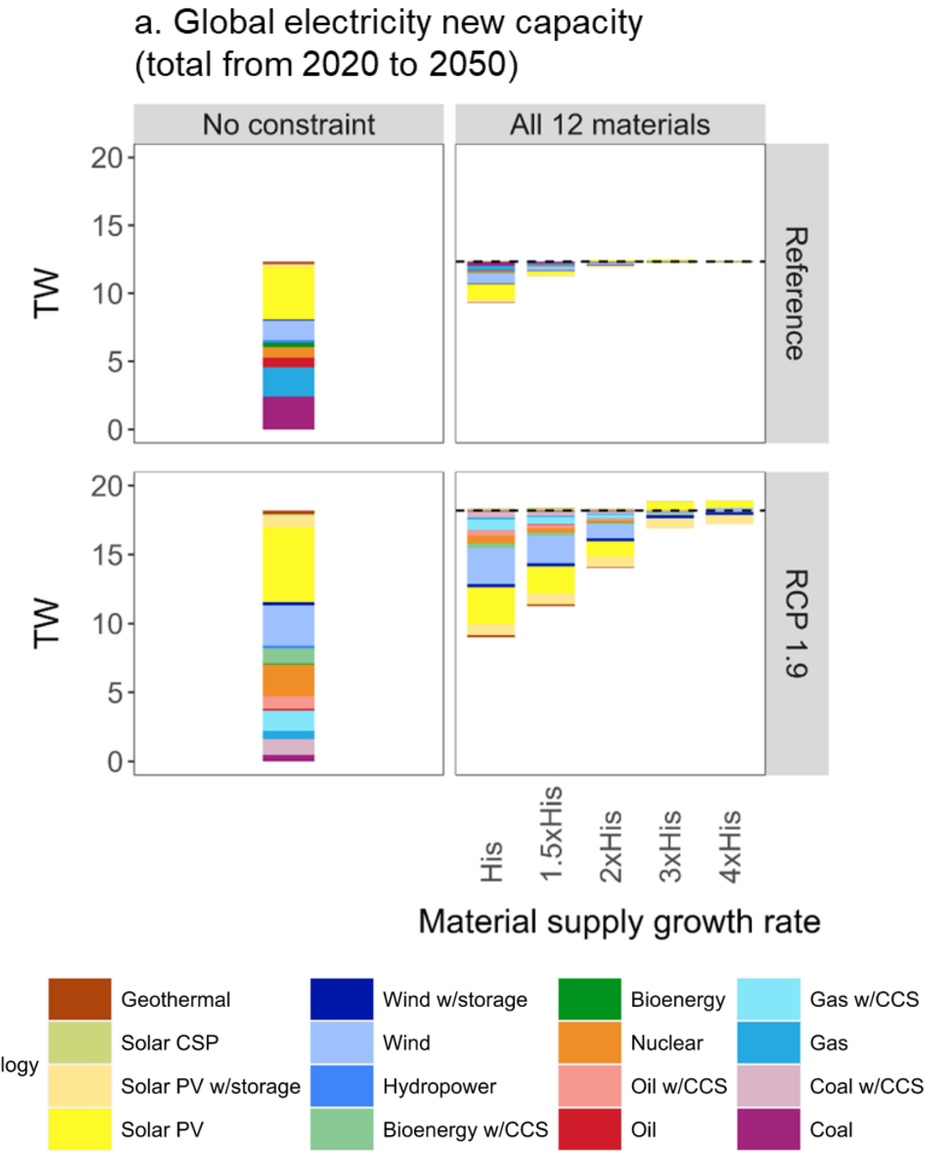


Graham, N., Wild, T., Iyer, G., Lamontagne, J., Patel., P. Uncovering Key Drivers of Future Virtual Water Trade and Global Water Use. In prep

Example 3: Modeling of minerals and materials

- In new model development, we are incorporating minerals and materials into GCAM, starting from the power sector and expanding to other sectors
  - We currently model demands for 12 materials
- Our modeling incorporates economic feedbacks of minerals and materials supply chains with technology competition in various sectors within the energy system
- Initial research shows that mineral supply constraints could reduce power sector investments and affect their composition
  - If future supplies of the 12 materials in the global power sector are constrained to historical growth rates (His), investments in the global power sector through 2050 reduce by 12% relative to an unconstrained supply case.
  - Under a low-carbon transition, investments reduce by 34%
- Constraints on different minerals could have different implications
  - A supply constraint on copper would be impactful since copper is used in all power sector technologies
  - Supply constraints on lithium and graphite could impact storage technologies



Qiu, Y., Iyer, G., Graham, N., Binsted, M., Wise, M., Patel, P., Yarlagadda, B. Cell Reports Sustainability, Forthcoming

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Looking ahead: Priority areas for future research and capability developments

- Improved modeling of trade and its multisectoral implications
  - E.g. Bilateral trade in energy, materials/minerals, and agricultural commodities
  - E.g. Macroeconomic implications of trade

- Improved modeling of emerging supply chains and resources
  - E.g. Expanded set of minerals and materials (e.g. concrete and lumber, carbon fiber), recycling, substitution across materials and their multisectoral implications

- Expanded set of stressors and their interactions with trade
  - E.g. Extreme events such as droughts, wildfires, etc.

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Thank you

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