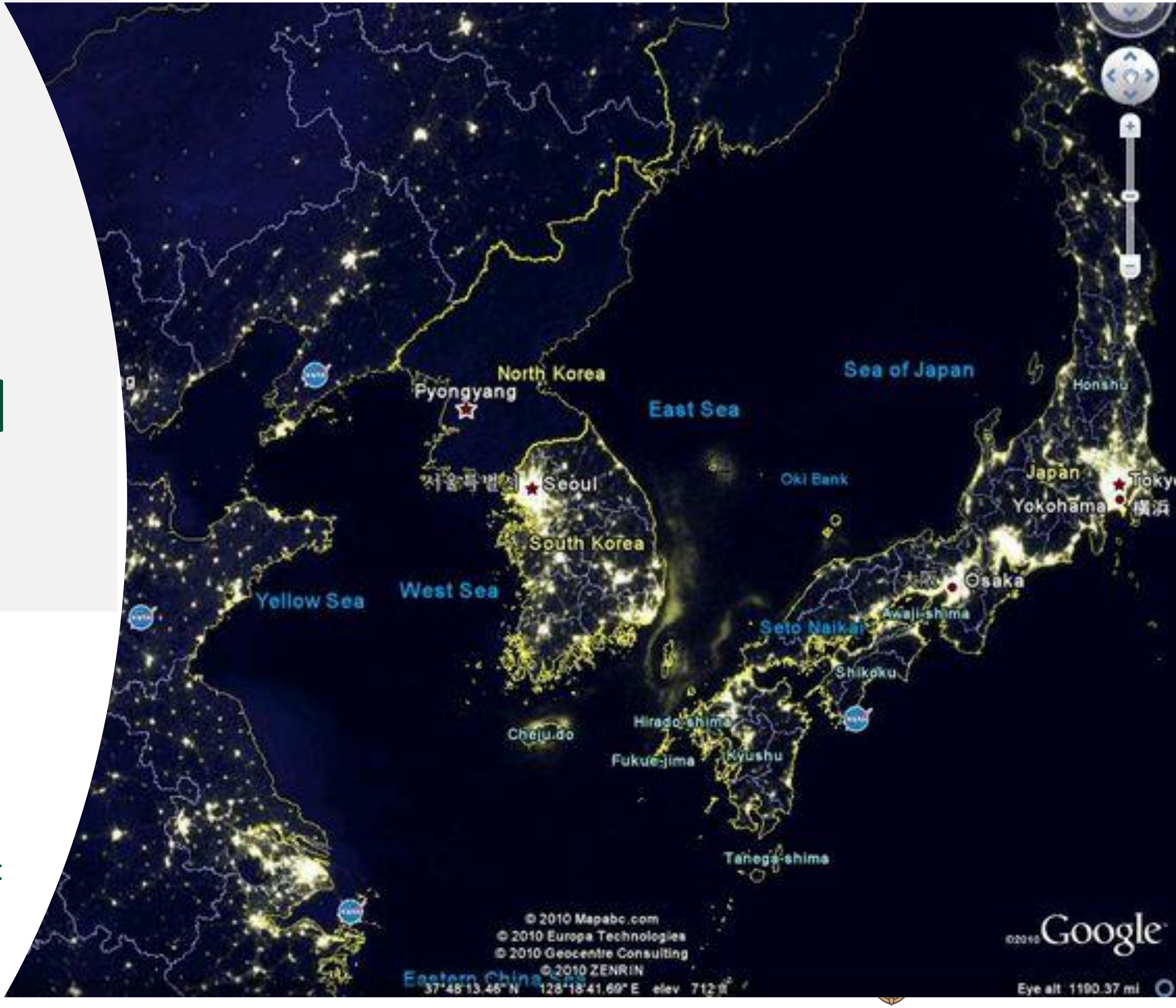
Modeling Grid Interconnections for Energy Cooperation in NEA: Uncertainties and Opportunities



International Workshop on Power Supply Modeling in Northeast Asia

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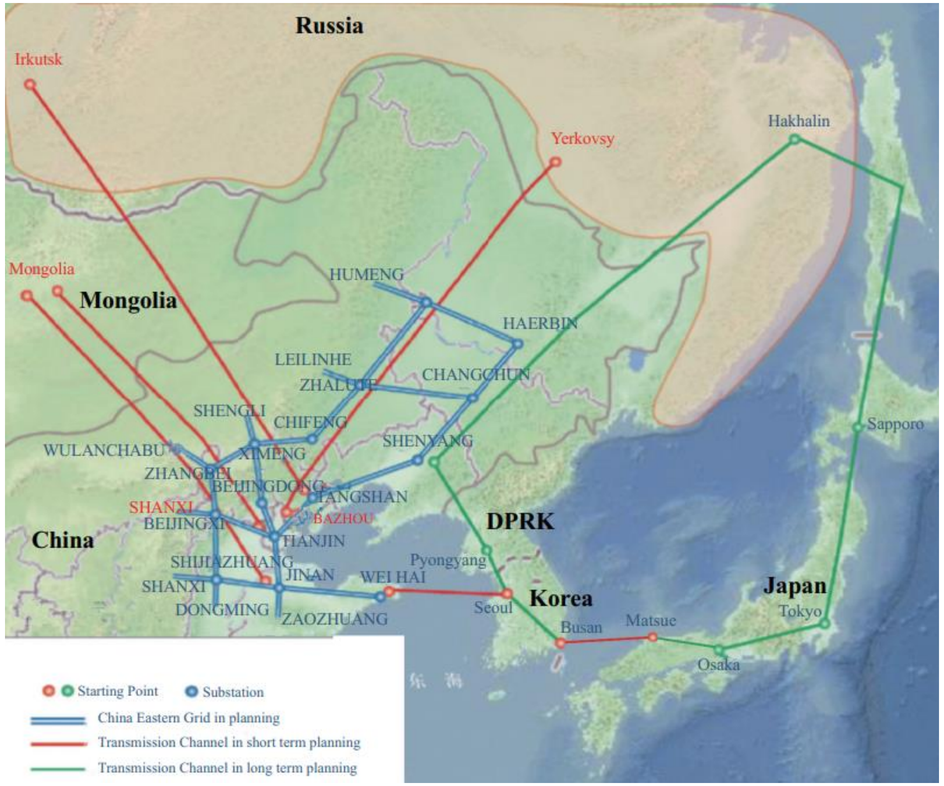
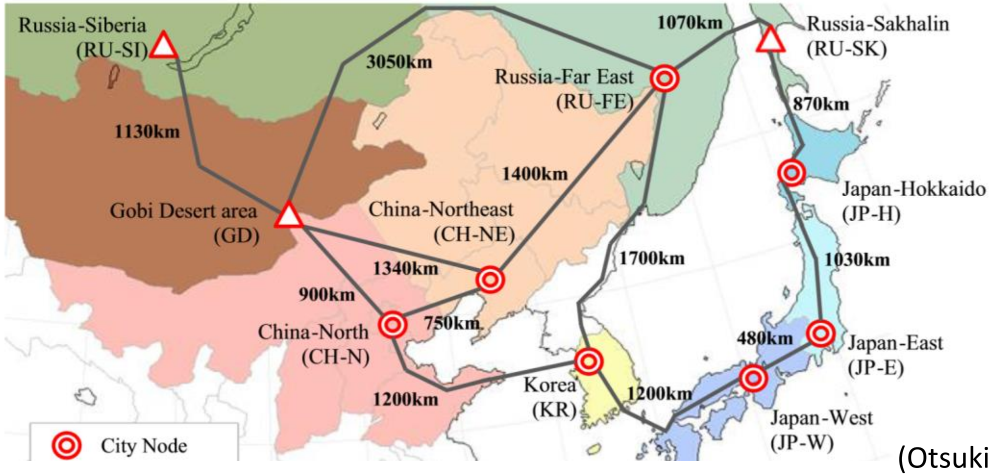
Recap (12/20) & Discussion

- Existing studies on Asia Supergrid
- Model specification
  - Methodology
  - Major findings
- Drivers of trade benefits
- Important data and modeling assumptions/ research questions to be considered for research collaboration

Economic benefits found for Asia wide grid interconnections (Mismatch in Resource Availability and Power Demand)



(Liu et al. 2016)



(Otsuki et al 2016)

(Bogdanov &Breyer, 2016)

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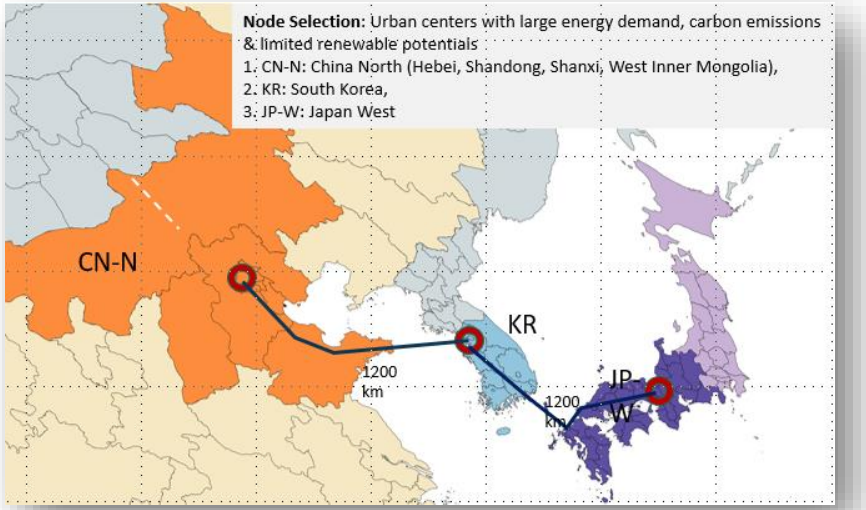
Economic benefits found for Asia wide grid interconnections (Mismatch in Resource Availability and Power Demand)

- A large profit margin for delivering clean energy from Russia and Mongolia to East China, Korea, and Japan (Liu et al. 2016).
- Access to Gobi Desert and hydro resources in eastern Russia promotes sustainable generation mix with emission reduction of 5.4% (Otsuki et al. 2016)
- Transmission grid leads to a cut-off storage utilization and significantly reduced generation capacities (Bogdanov &Breyer. 2016).

Trilateral Electricity Trade ALSO favorable China North- Korea- Japan West

Least cost technology pathways for achieving carbon neutrality in NEA

- Three supply/demand nodes: China north grid, Korea, Japan west grid
- Gaps in technology cost and resource availability across three nodes makes trade beneficial for achieving carbon neutrality targets at a lower cost
  - Economic
- Enables faster coal phaseout with ambitious carbon pricing
  - Environmental



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Methodology: Bottom-up Dynamic Optimization for Capacity Expansion & Hourly Dispatch Decisions

- Objective: Minimize total power system cost (Linear Programming) for power supply in three nodes
  - Investment
  - Operation and maintenance
  - Fuel
  - Penalties on carbon emissions
- Constraints
  - Supply and demand balance on an hourly basis
  - Hourly power output bound to size of installed capacity
  - Upper bound on renewable availability (power output and capacity expansion)
  - Upper bound on CO_2 emissions
  - Trade limits (net inflow under 15% of local demand size)
  - Etc.

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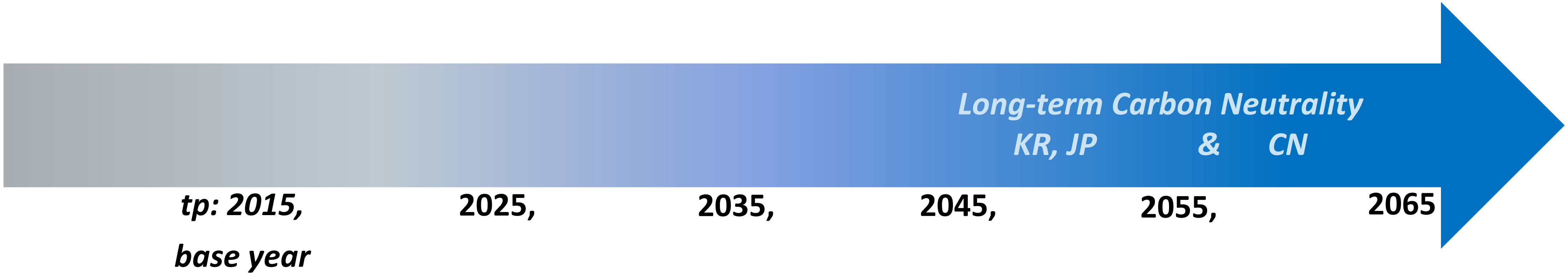
Bottom-up Dynamic Investment Model (2015-2065)

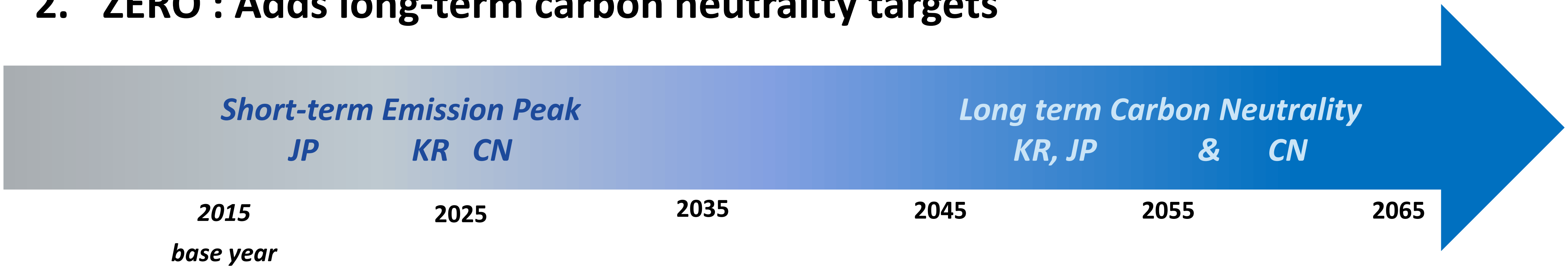


- **Bottom-up optimization:** Detailed technology options considered for power system analysis
- **Dynamic**: Evolution of the power system until the target year
  - Capacity investment decisions of time periods tp, and tp+1 linked to each other
  - The optimization within tp (energy system dispatch) follows a static manner

Methodology

Two Emission Scenarios

1. BAU : Short-term emission peak
2. ZERO : Adds long-term carbon neutrality targets



- Trade impacts at different carbon prices
  - Apply a flat carbon price over the time horizon to affect cost competitiveness of generation technologies
  - P0, 100, 200, 300 (USD/tCO2)

Scenarios

*ALL scenarios assume **limited nuclear deployment** for KR, JP-W

Trade option	Emission targets	Carbon price (USD/tCO2)	Scenarios
Trade	BAU (short term goal)	0	TBAUP0
		100	TBAUP100
		200	TBAUP200
		300	TBAUP300
	ZERO (long term goal)	0	TZEROP0
		100	TZEROP100
		200	TZEROP200
		300	TZEROP300
No Trade	BAU	0	NTBAUP0
		100	NTBAUP100
		200	NTBAUP200
		300	NTBAUP300
	ZERO	0	NTZEROP0
		100	NTZEROP100
		200	NTZEROP200
		300	NTZEROP300

Major findings:

For achieving carbon neutrality,

- **Trade further increases clean power output when/where cheaper & available -> reducing investment needs in costly hydrogen and accelerating thermal phaseout.**
- **Harsh penalization of carbon emissions further increases interstate trade flows**
- **Diversification in clean technology portfolio needed**

Recall the Cost Minimization Approach

- **Gaps in electricity generation cost between nodes** decide trade flows
    - Nodal electricity generation cost (electricity price) fluctuates on an hourly basis (4 seasons*24 hours for each year)
    - China -> Korea -> Japan
    - **Several factors affecting the generation cost/electricity price: technology cost, resource endowment/availability, policies, time difference**
        - Carbon neutrality target affects trade flows
        - Japan <-> Korea <-> China **TWO-WAY FLOWS**

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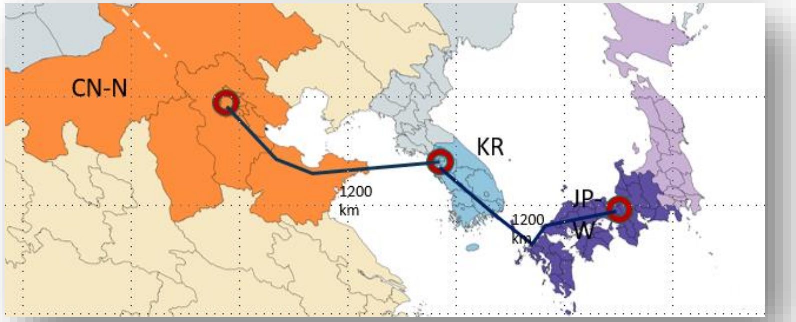
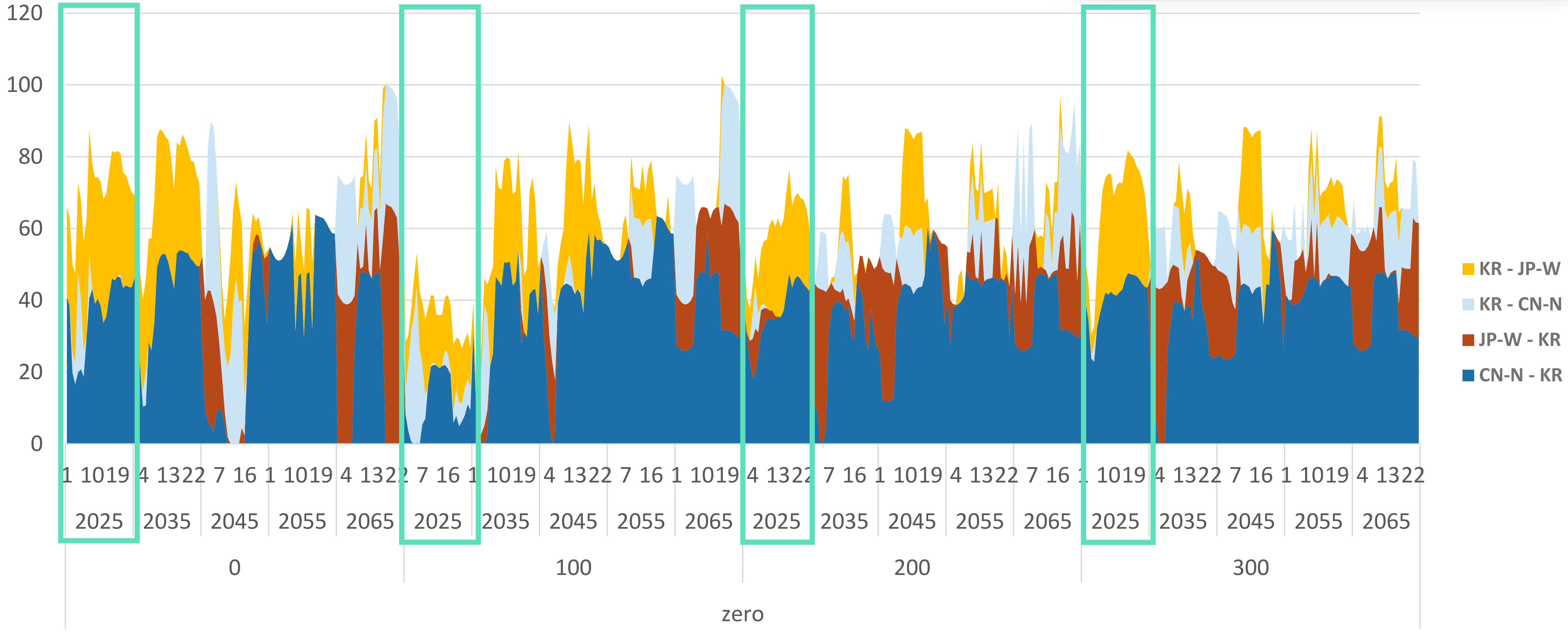
Result 1. **Cost savings and trade dynamics over time**

1 way (CN->KR->JP) in the earlier years,



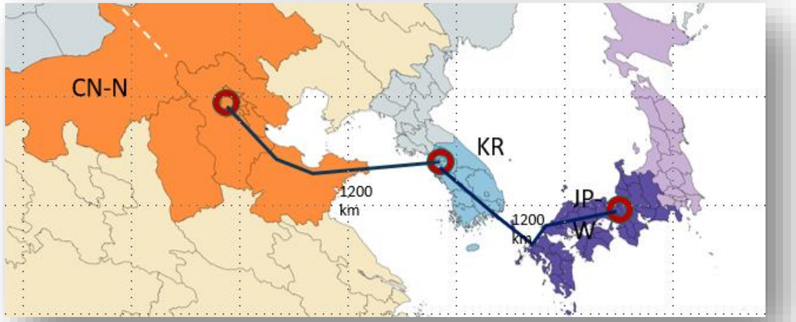
Transmission volumes over time periods (4 days aggregated, GWh)

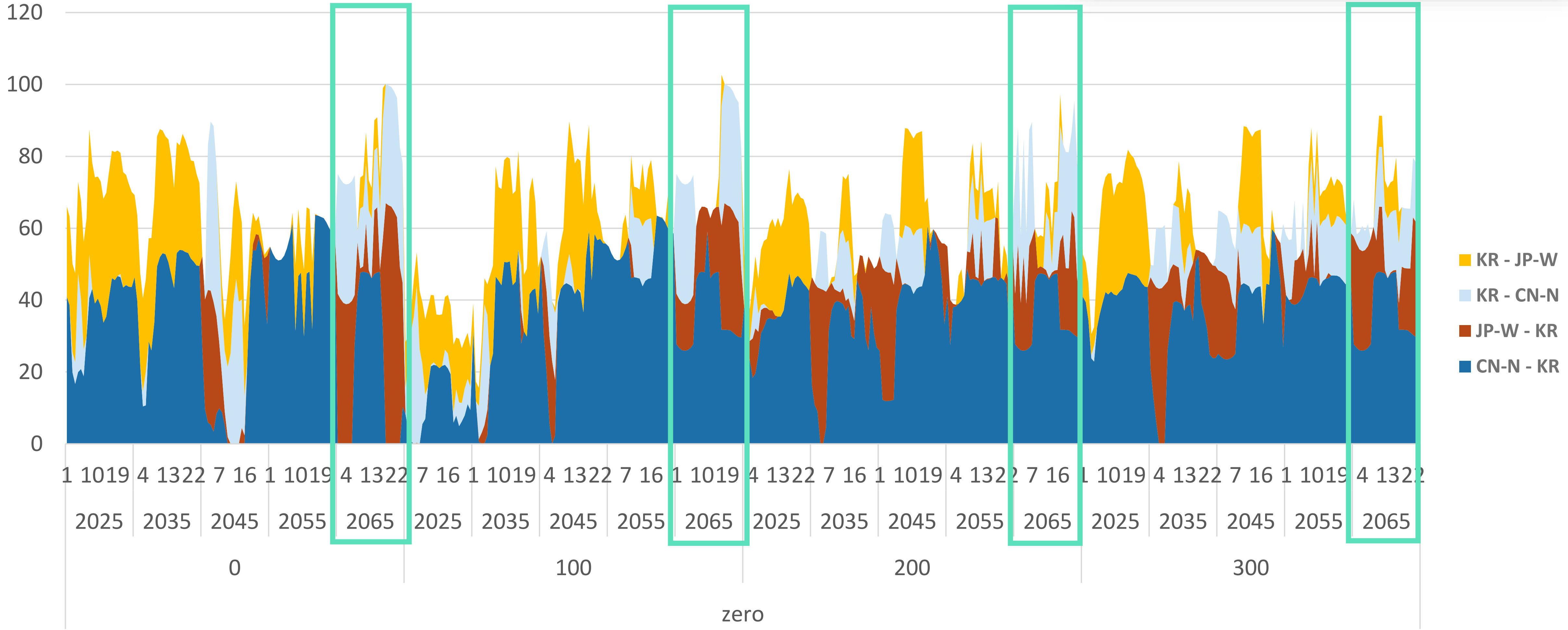


Result 1. **Cost savings and trade dynamics over time**

1 way (CN->KR->JP) in the earlier years,

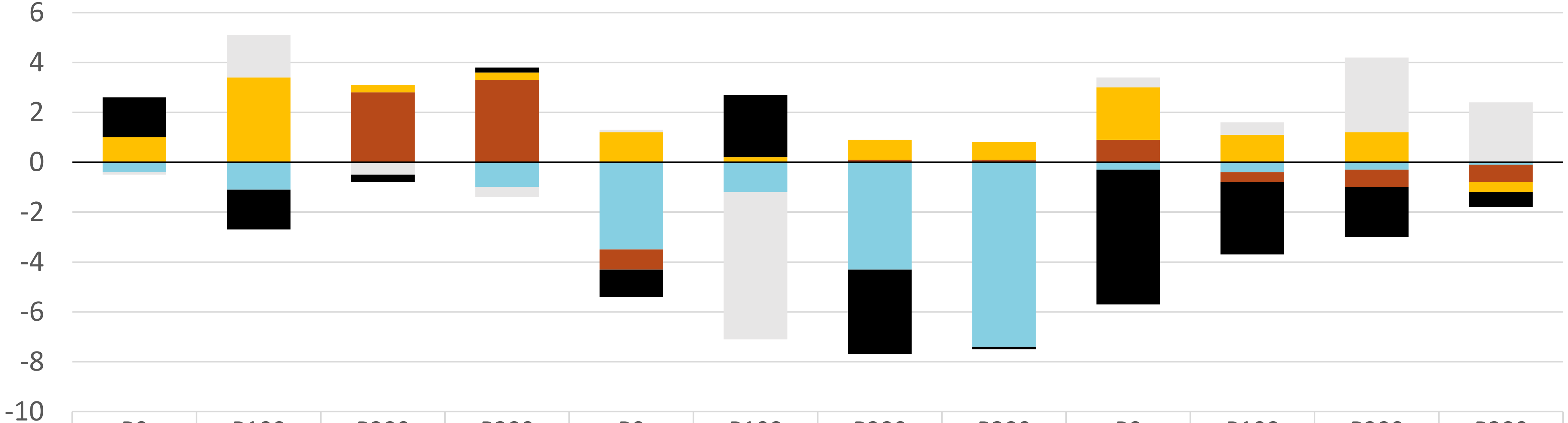
to 2-way transmissions (CN<->KR<->JP) for achieving Carbon Neutrality





Trade impacts on Technology Substitution for Carbon Neutrality

Technology Composite of Nodal output changes (% change compared to no trade total)



	CN-N				KR				JP-W			
	P0	P100	P200	P300	P0	P100	P200	P300	P0	P100	P200	P300
thermal	1.6	-1.6	-0.3	0.2	-1.1	2.5	-3.4	-0.1	-5.4	-2.9	-2	-0.6
thccs	-0.1	1.7	-0.5	-0.4	0.1	-5.9	0	0	0.4	0.5	3	2.4
rnw	1	3.4	0.3	0.3	1.2	0.2	0.8	0.7	2.1	1.1	1.2	-0.4
nuc	0	0	2.8	3.3	-0.8	0	0.1	0.1	0.9	-0.4	-0.7	-0.7
hdrg	-0.4	-1.1		-1	-3.5	-1.2	-4.3	-7.4	-0.3	-0.4	-0.3	-0.1
beccs	0	0	0	0	0	0	0	0	0	0	0	0

Key Drivers and Determinants of cost
- hourly generation cost/ electricity price affected by

1. Supply side
   - Cost of technology options
   - Resource endowment/availability
2. On the policy side
   - Limits on trade volumes
   - Limits on CO_2 emissions
   - Penalties on CO_2 emissions
3. Demand side issues

Key drivers =

important data/ assumptions for modeling & R questions

1. Cost related data
   - By technology (generation, storage, transmissions, etc.)
     - What technologies to include? (dispatchable renewables, hydrogen, BECCS etc.)
     - Technical characteristics/ parameters
     - Future prices?
   - By cost component
   - By grid
     - What regional grids to include?
     - Grid level vs. Plant level?

Key drivers =
important data/ assumptions for modeling & R questions

2. Resource endowment
   - Maximum deployable capacity
   - Hourly output profile
   - By grid

   - to account for local characteristics

Key drivers =
important data/ assumptions for modeling & R questions

3. On the policy side

- Trade limits: How much interstate flows we allow?
  - Study findings: more allowance-> lower TC at all CO2 level tested, faster coal phaseout at higher carbon prices
  - Energy security

- Incentivizing renewable deployment
  - Tested different levels of emission penalties as part of TC
  - How to reflect existing/planned measures

4. Demand side: Uncertainties & Opportunities

- Fixed demand (4 days*24 hours* 6 time periods*3 nodes)
- Price responsive?
- Assumptions on changes in future electricity consumption patterns
  - Demand projections
  - Electrification
  - Energy efficiency improvement

Incorporating uncertainties

- Hourly prices decided with many direct/indirect factors combined
- Discussion for future collaboration
  - Data (represents energy environment of each country)
  - Level of analysis
  - Trade regulations (transmission volumes/capacity)
  - (future steps) Environmental impacts – air quality