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The role of transportation electrification in the energy transition of urban agglomerations

- A case of Beijing-Tianjin-Hebei region

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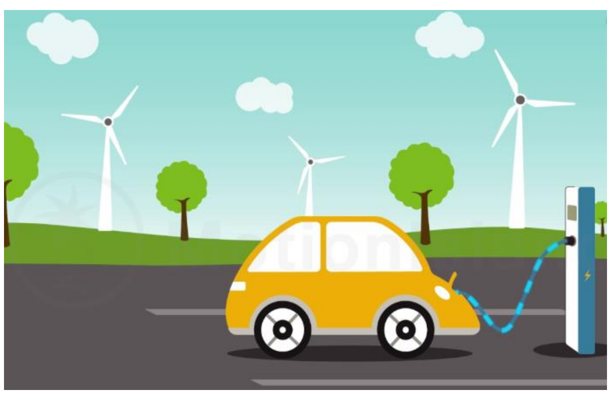
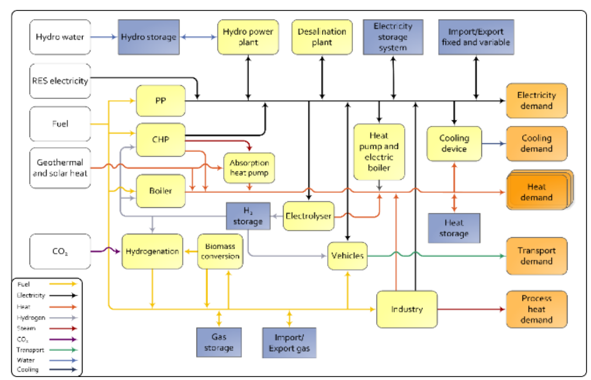
Research question

Objective: Identifying the impacts of *transportation electrification* in the *integrated energy systems* of *multiple interconnected regions*

- Economic, environmental and technical analysis
- Interregional energy collaboration, especially RES

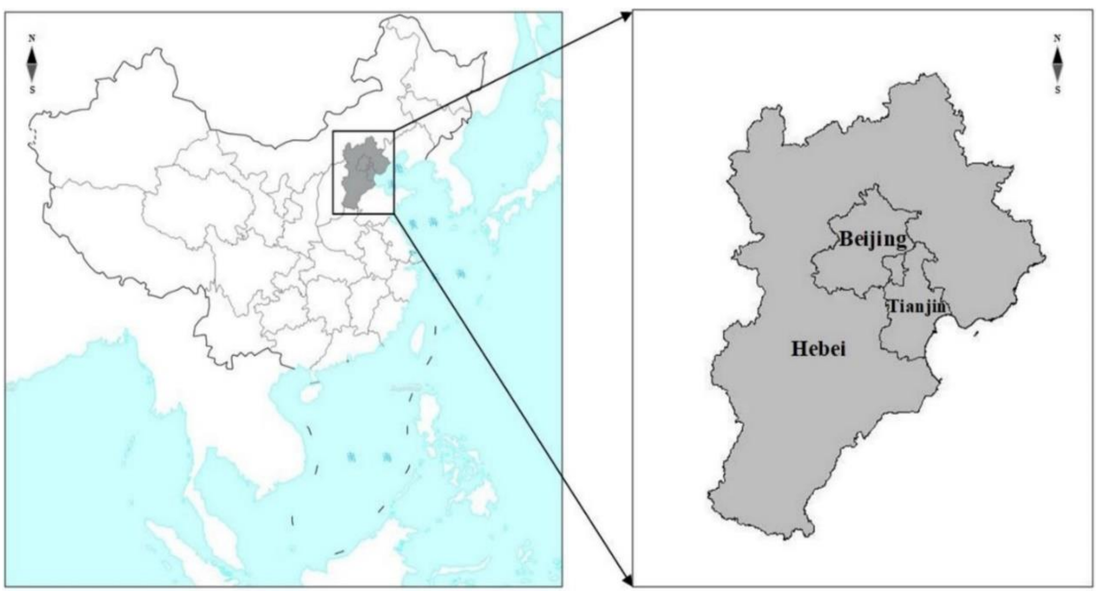




Integrated energy systems in EnergyPLAN

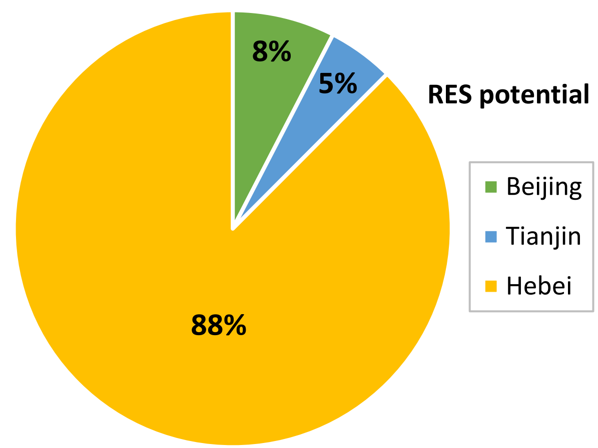
The Beijing-Tianjin-Hebei (BTH) region

- Capital Economic Circle & Important energy consumption center
- Renewable energy resources distributed unevenly
- Penetration rates of EVs remain quite low (<1%)



People's republic of China

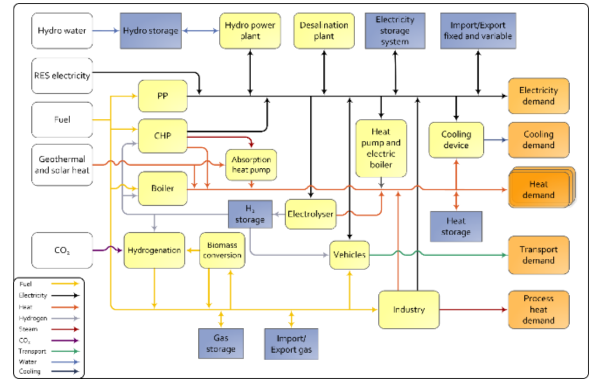
The Beijing-Tianjin-Hebei urban agglomeration



Area 218,000 km^2

Population (2019) 113 million

Methodology



EnergyPLAN energyflow

(1) Fuel demand determination

Inputs

- Vehicle historical stock by type
- Economic development
- Local population growth
- EV penetration rate

Vehicle stock forecast

Cars
- Non-taxi passenger cars
- Taxies

Buses
- Urban transit buses
- Non-urban transit buses

Trucks
- Light-duty trucks
- Medium-duty trucks
- Heavy-duty trucks

Annual energy demand forecast

- Fuel economy by vehicle type
- Vehicle miles traveled by vehicle type

Bottom-up model for road transportation sector

(2) Energy system modeling

Reference models

Data of heating, electricity & transportation sectors in respective Beijing, Tianjin & Hebei

- Demand
- Supply
- Cost
- Simulation strategy

Future scenario models

Strategy comparison

- Charging strategy
  Dump charge vs. Smart charge
- Planning strategy
  Independent planning vs. Integrated planning

Different EV purchase prices

Different EV penetration rates

EnergyPLAN software

(3) Energy system analysis

- Primary energy consumption
- CO_2 emissions
- Annual cost sensitivity analysis
- System operation results: electricity import and export, CEEP curtailment & RES share
- Impacts of vehicle types

Outputs

Planning strategies:

Independent planning vs. Integrated planning [1]

Non-cooperative

- Draw up energy development plan locally
- Operate energy system independently

Three energy system models

Interregional energy cooperation

- Make development plans together to seek mutual benefits
- Allow cross-regional energy interaction

One energy system model

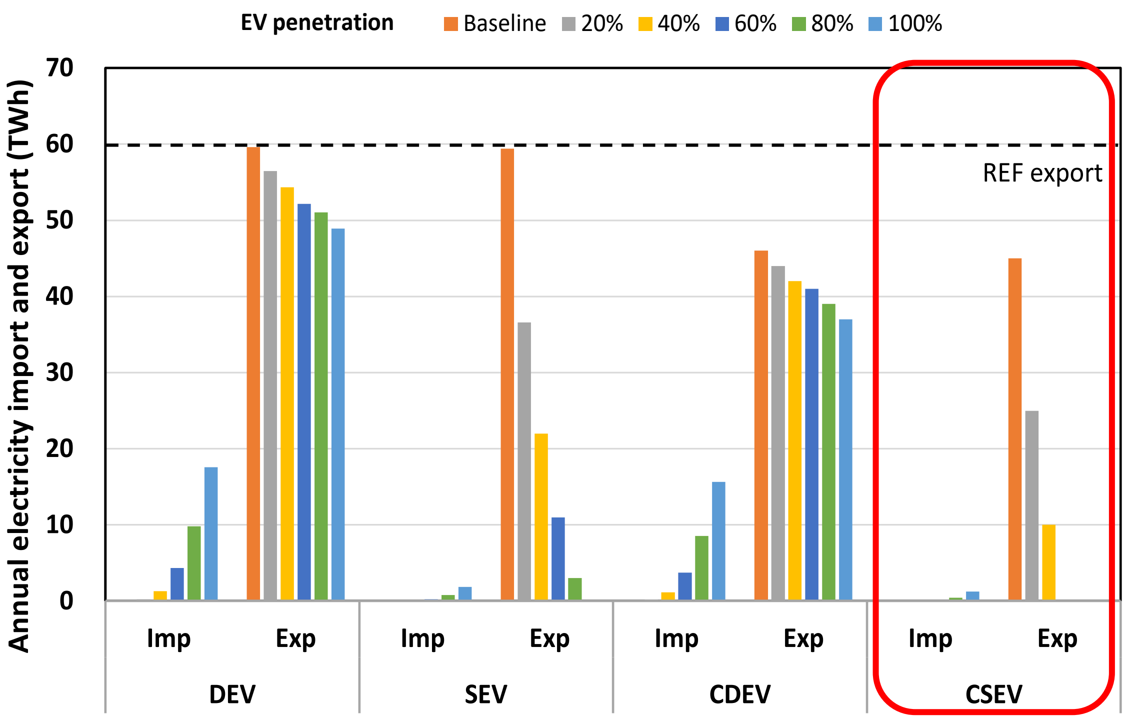
- Integrated model for BTH region

[1] M. Yuan, J. Zinck Thellufsen, H. Lund, Y. Liang. The first feasible step towards clean heating transition in urban agglomeration: A case study of Beijing-Tianjin-Hebei region. Energy Conversion and Management. 223 (2020) 113282.

2050 Scenarios

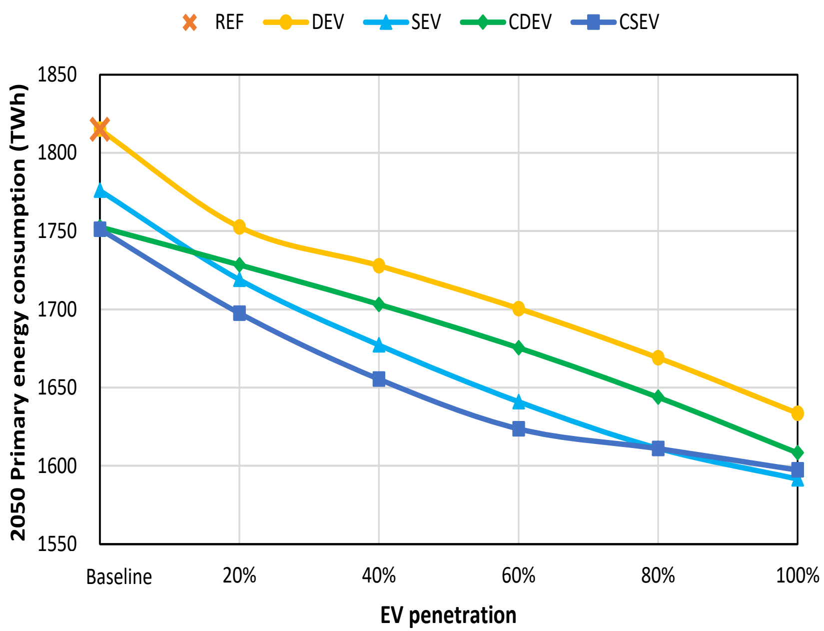
Name	Descriptions	Planning strategy		Charging strategy	
		Independent	Integrated	Dump	Smart
REF	Reference scenario	√		√	
DEV	Dump charge-based independent scenario	√		√	
SEV	Smart charge-based independent scenario	√			√
CDEV	Dump charge-based collaborative scenario		√	√	
CSEV	Smart charge-based collaborative scenario		√		√

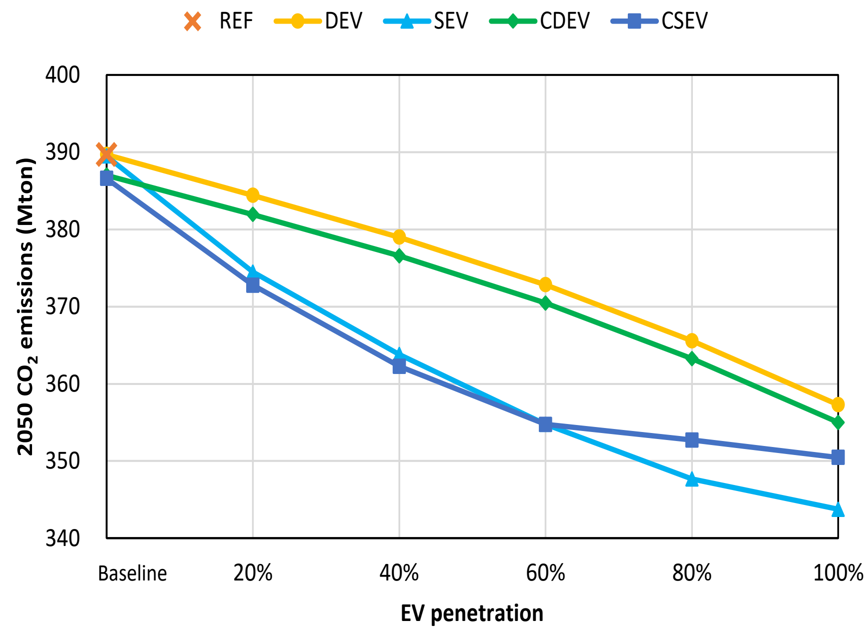
Results: Electricity system operation



- Smart charge (SEV & CSEV) > Dump charge (DEV & CDEV)
- Integrated planning (CDEV & CSEV) > Independent planning (DEV & SEV)
- CSEV scenario can realize a 100% CEEP curtailment

Results: PE consumptions & CO_2 emissions





- Under a 100% electrification, both energy-saving and CO_2 emission reduction will be above 10% compared to the baseline

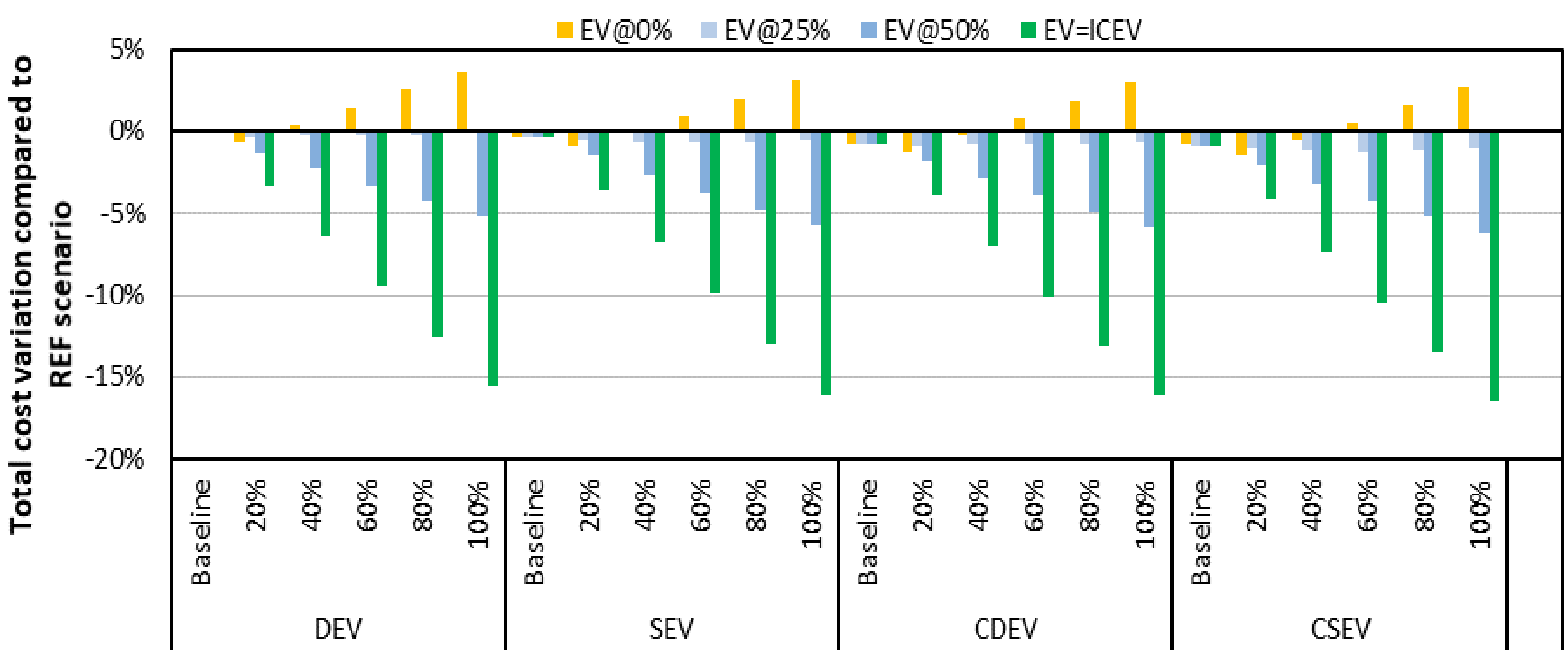
Results: Cost sensitivity analysis

EV price decrease factor (α)

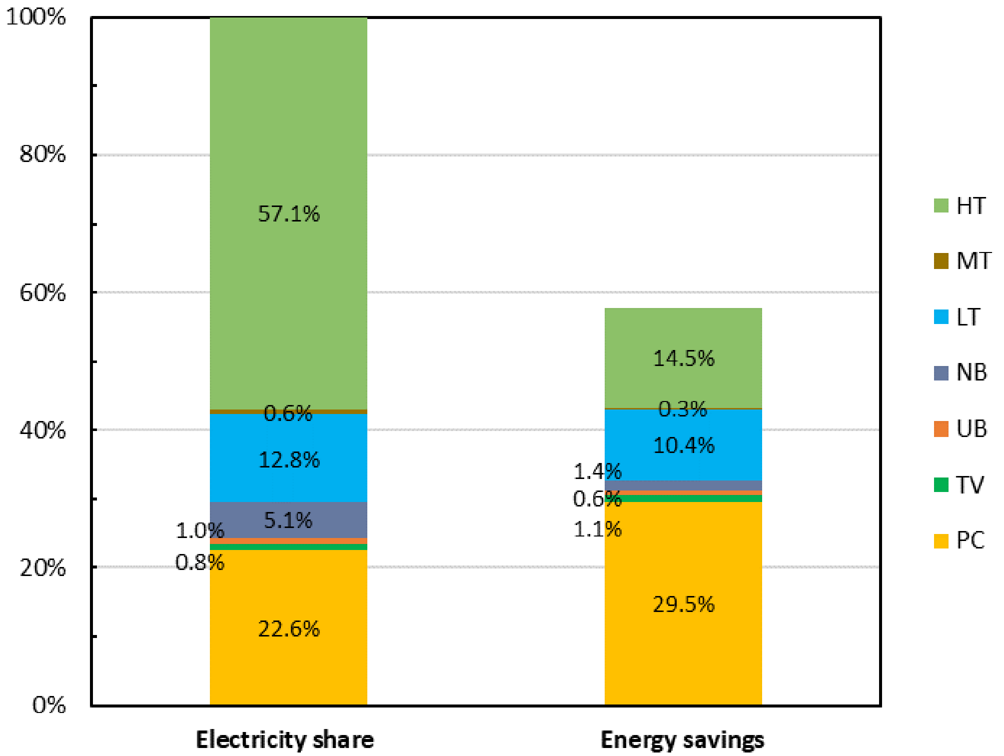
$$P_{EV}^{future} = P_{ICEV} + (1-\alpha)\times(P_{EV}^{current} - P_{ICEV})$$

- P_{EV}^{future}: Future EV purchase price
- $P_{EV}^{current}$: Current EV purchase price
- P_{ICEV}: Current ICEV purchase price

Price decline level	Descriptions
EV@0%	α=0
EV@25%	α=25%
EV@50%	α=50%
EV=ICEV	α=100%



Results: Impacts of vehicle types



Car	PC	Non-taxi passenger cars
	TV	Taxies
Bus	UB	Urban transit buses
	NB	Non-urban transit buses
Truck	LT	Light-duty freight trucks
	MT	Medium-duty freight trucks
	HT	Heavy-duty freight trucks

- PC, LT and HT are the largest contributors to energy savings

Conclusions

- The vehicle electrification could contribute greatly to sustainable energy transition without any significant cost increase
- Interregional energy cooperation and smart charge should be given priority

Thank you for your attention!
Questions?

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