Large-scale renewable energies power supply for metropolitan region of China

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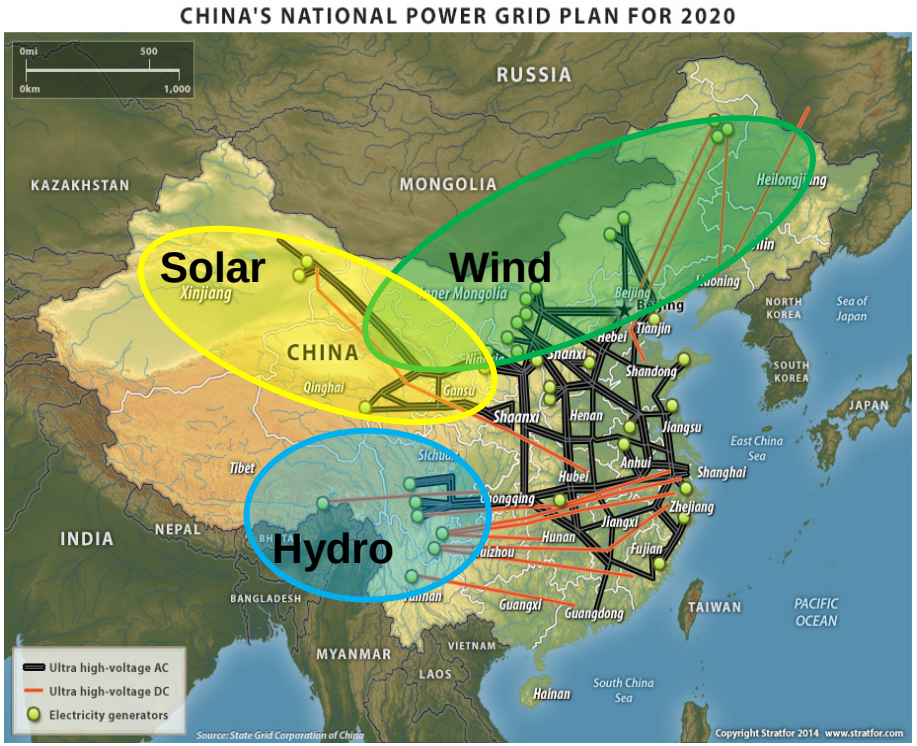
Research focus

- Situation: Regional heterogeneities between renewable energy (RE) abundant regions and metropolitan regions.
- Goal: Cost efficient strategies to implement a power system predominated based on renewable energy resources.
- Analysis: Need for inter-provincial transmission capacity expansion, backup power generation and power storages incl. electric vehicles (EVs)



Map source: State Grid Corporation of China.

- Study region: Beijing-Tianjin-Hebei metropolitan region with Inner Mongolia as supply region.

Current status and policy targets

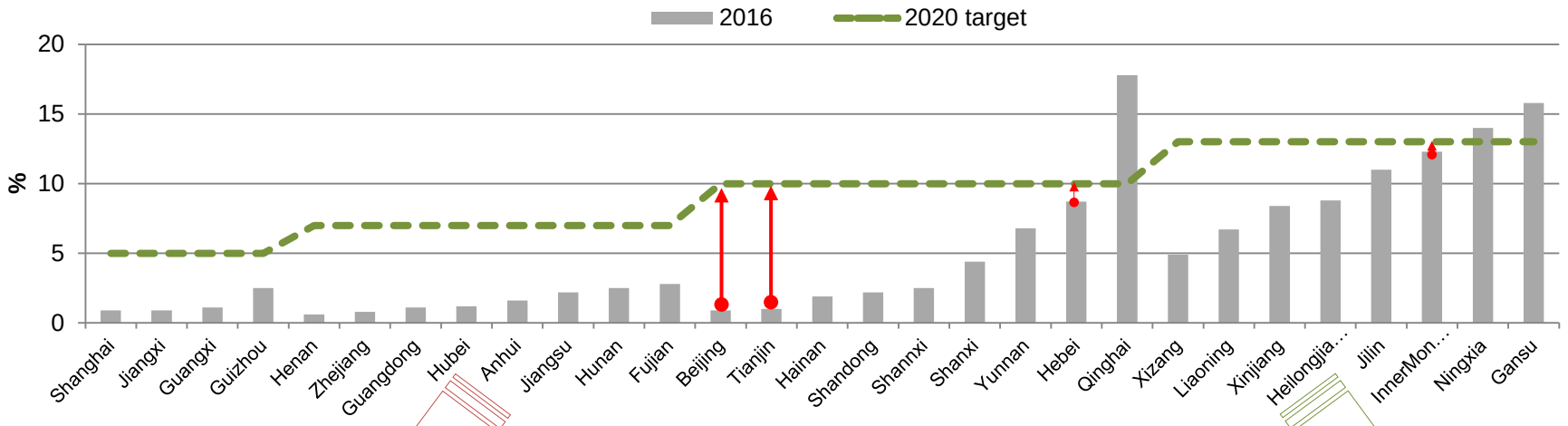


Figure 1: Percentage of non-hydro renewable resources in electricity generation of 2016 and 2020 targets by province.
Data source: Renewable portfolio standard policy (RPS) released on 29.02.2016 by National Energy Administration.

Metropolitan regions

- ❑ Satisfy demand
- ❑ Emissions reduction

Infrastructure planning

Electricity market

CO_2 trading system

RE resource abundant regions

- ❑ Increase utilization
- ❑ GDP growth

Resulting RE Share Of Power Generation	2016	2020	2030	2040	2050
Stated Policies	16%	33%	51%	65%	78%
Below 2°C	16%	45%	68%	80%	85%

Scenario source: China Renewable Energy Outlook 2017. ERI, NDRC; CNREC.

Power system optimization

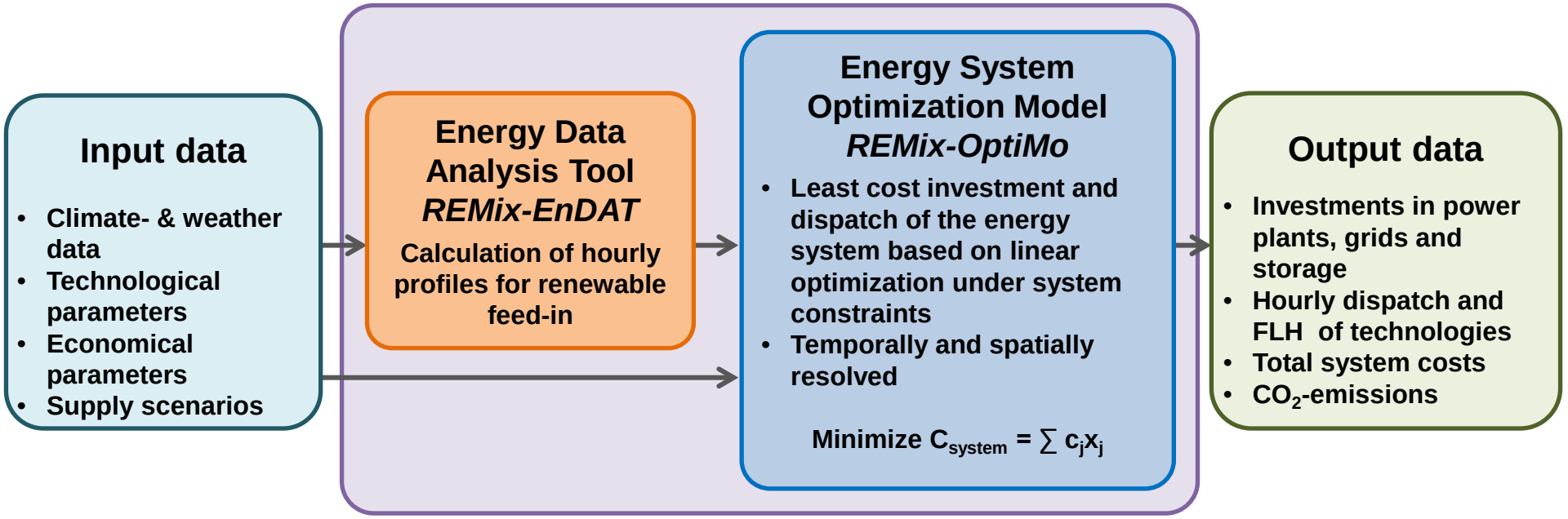


Figure 2: Renewable Energy Mix (REMix) energy system model [1].

[1] Gils, H. C.; Scholz, Y.; Pregger, T.; de Tena, D. L. & Heide, D. Integrated modelling of variable renewable energy-based power supply in Europe. Energy, Elsevier BV, 2017, 123, 173-188

System constraints by 2050

Myopic foresight by 10 years periods

- Limiting regional CO_2 emissions to the level of 1995
- Minimum 60% of renewable power generation

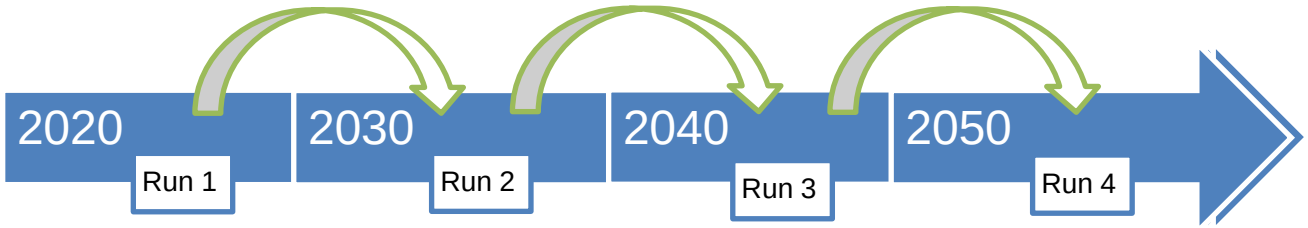


Table 1. Assumption of regional CO_2 constraints and share of RE in power sector.

Regional CO_2 constraints in power sector (Mt) [2] [3]	Min. share of RE in power sector (%)	Beijing	Tianjin	Hebei	Inner Mongolia
700	2020 (targets)	10	10	10	13
470	2030	18	18	18	24
300	2040	38	38	38	43
150	2050	58	58	58	64

[2] Multi-resolution Emission Inventory for China v.1.0. MEIC Dataset.
[3] G. He, A.-P. Avrin, J. H. Nelson, J. Johnston, A. Mileva, J. Tian, and D. M. Kammen, “SWITCH-China: A systems approach to decarbonizing China’s power system,” Environmental science & technology, vol. 50, no. 11, pp. 5467–5473, 2016.

Other flexibility options: passenger vehicles

Table 2. Assumption for energy demand of passenger vehicles with 2 persons/vehicle in average (kWh/P.km) [4] .

2020	2030	2040	2050
0.377	0.329	0.288	0.250

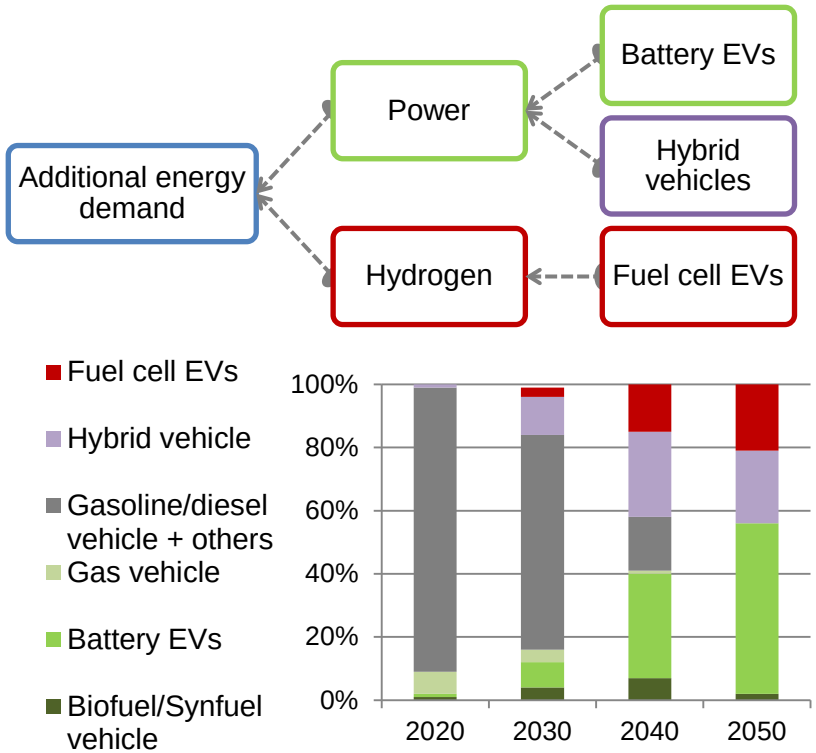


Figure 3. Energy consumption market share of passenger vehicles from scenario assumption[5] .

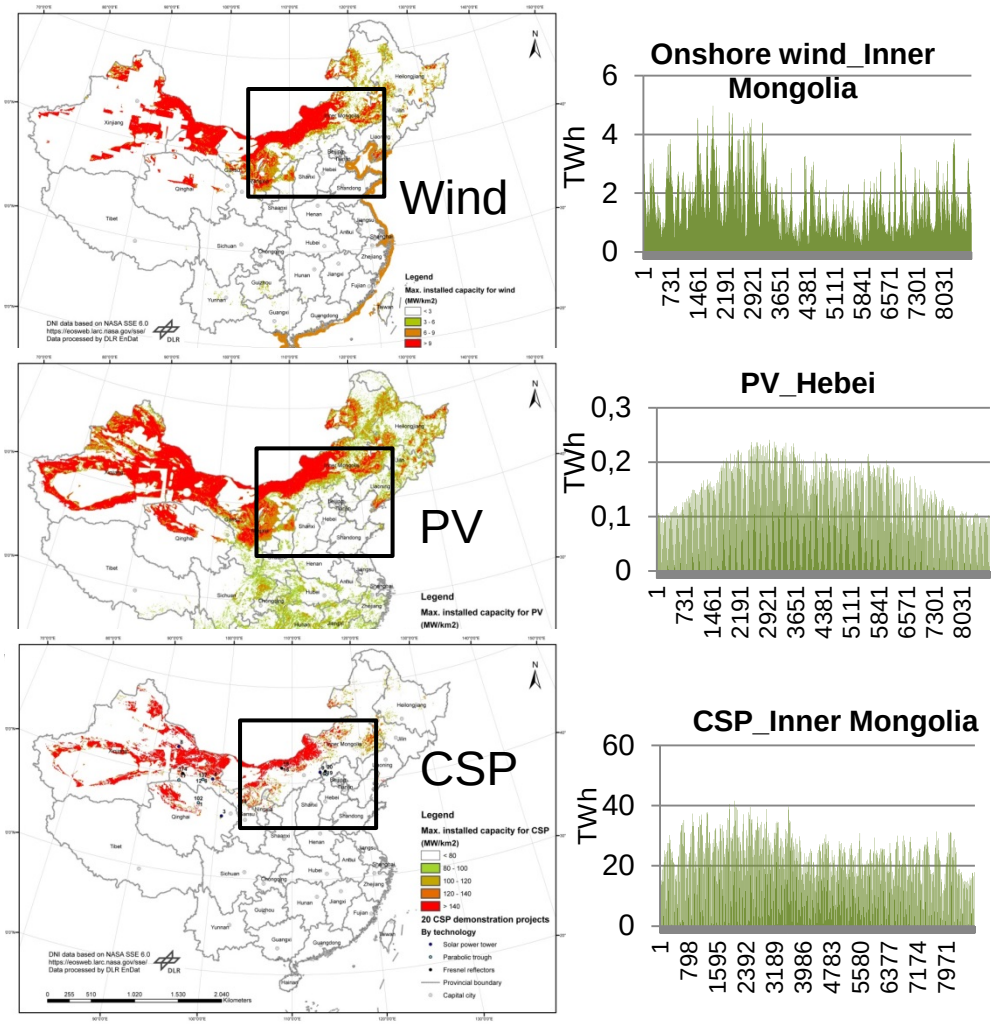
Table 3. Calculated additional power and hydrogen demand for road passenger vehicles in study regions [6].

Power demand: passenger battery EVs (TWh)	2020	2030	2040	2050
Beijing	0.1	0.8	2.4	3.1
Tianjin	0.1	0.9	2.6	3.4
Hebei	0.2	2.9	8.5	10.6
Inner Mongolia	0.1	1.3	3.8	4.8

Hydrogen demand: passenger fuel cell EVs (TWh_chemical)	2020	2030	2040	2050
Beijing	0.0	0.2	1.1	1.4
Tianjin	0.0	0.3	1.2	1.5
Hebei	0.2	0.9	3.9	4.9
Inner Mongolia	0.1	0.4	1.7	2.2

[4] D. Lohse, W. Schnabel, and D. I. N. V, Grundlagen der Straßenverkehrstechnik und der Verkehrsplanung: Band 1 - Straßenverkehrstechnik. Beuth Verlag GmbH, 2011.
[5] Teske, S., Sawyer, S., Schäfer, O., Pregger, T., Simon, S., Naegler, T., 2015. Energy[R]evolution – A Sustainable World Energy Outlook 2015, report 5th edition. Greenpeace/GWEC.
[6] WWF, 2050 Shanghai Low Carbon Development Roadmap Report. WWF Shanghai Low Carbon Development Roadmap Research Team, 2011.

RE resources assessment



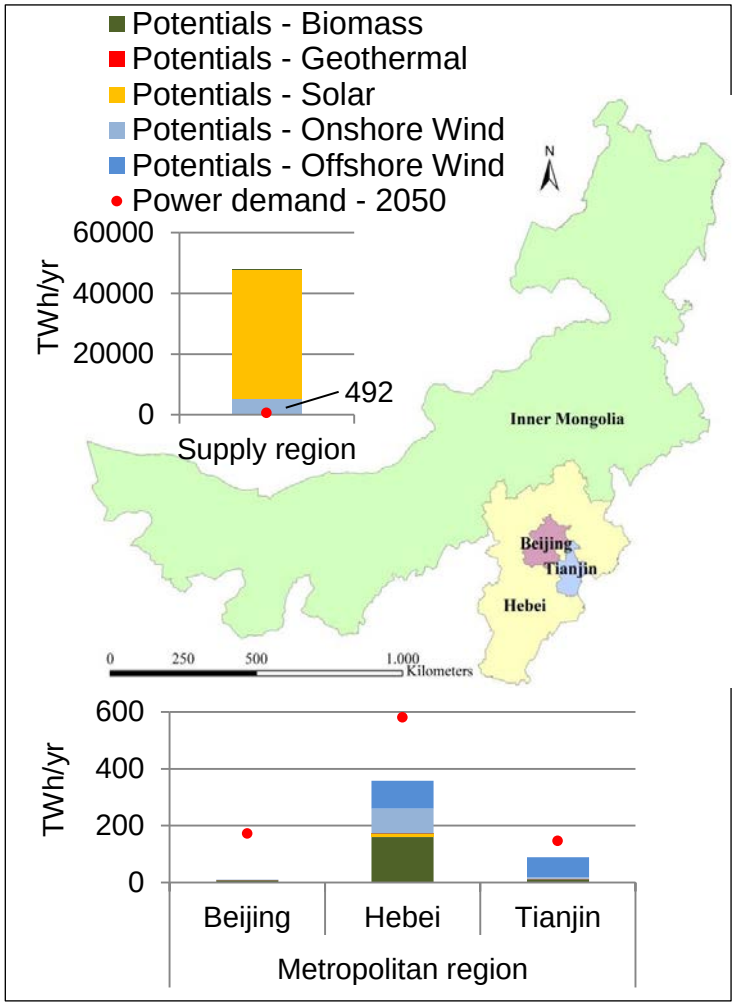
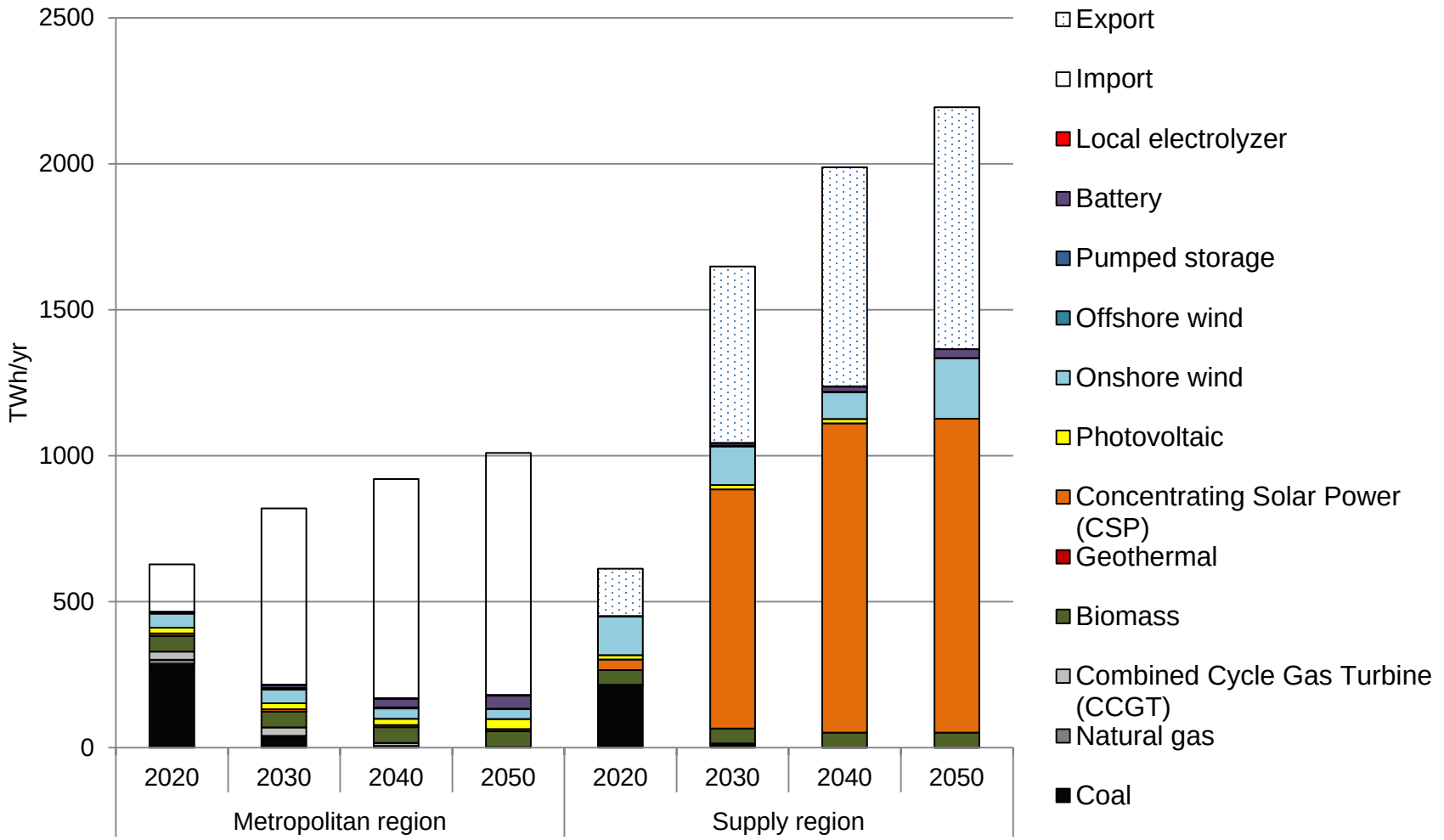
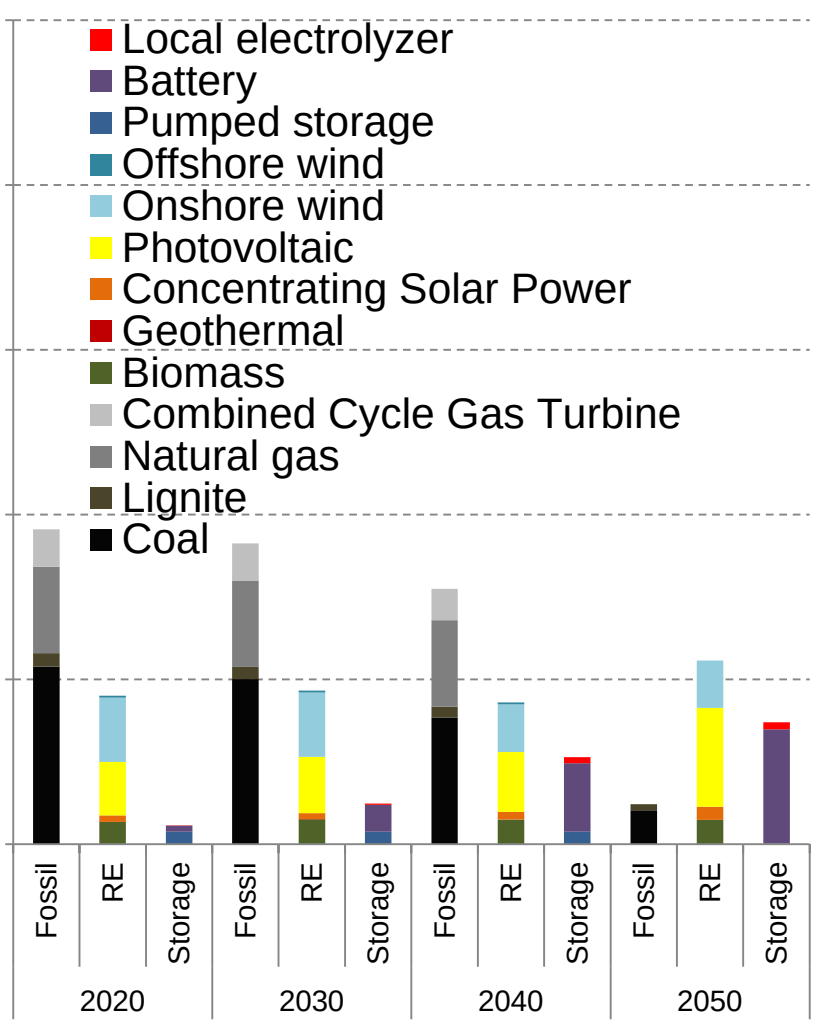


Figure 4. Renewable energy potentials assessment and power demand in 2050 (including the demand from passenger EVs).

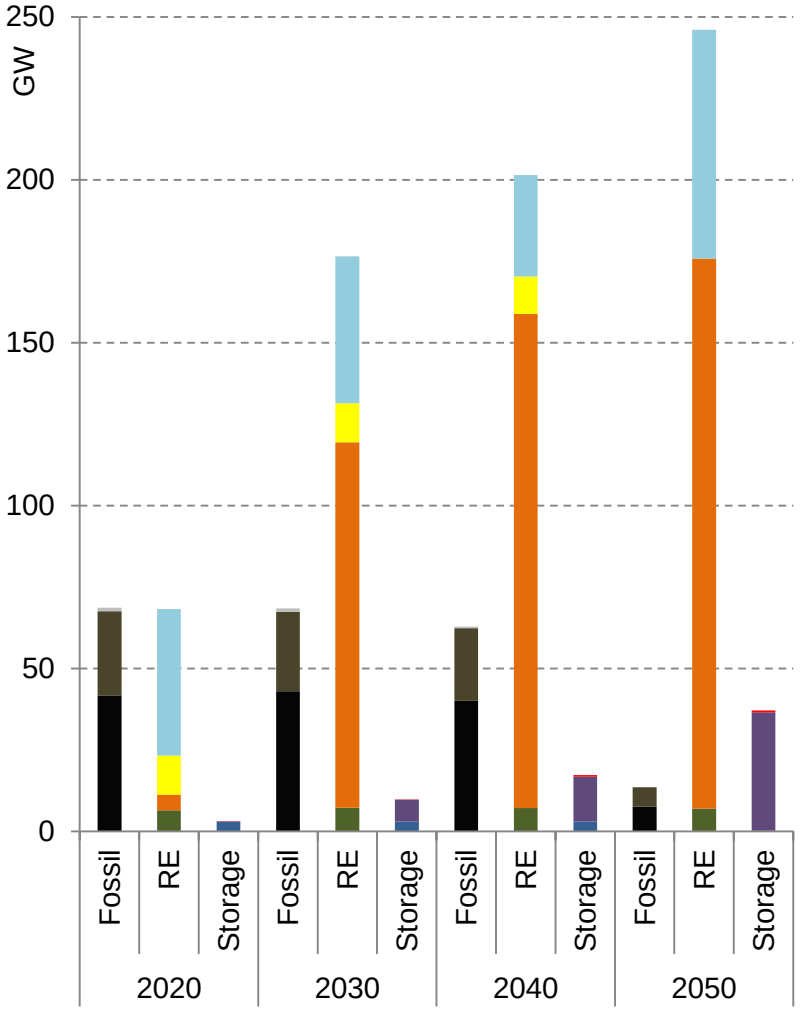
Annual power supply



Total installed capacity: generation & storage

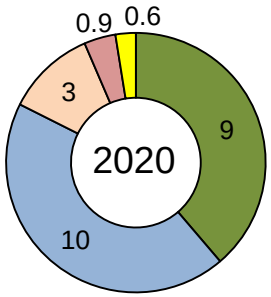


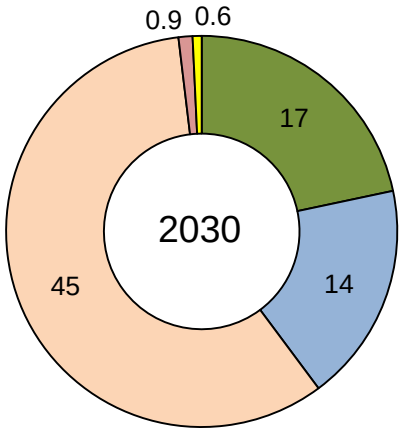
Metropolitan region

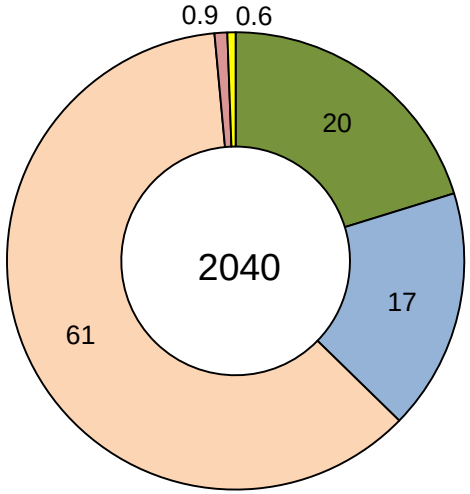


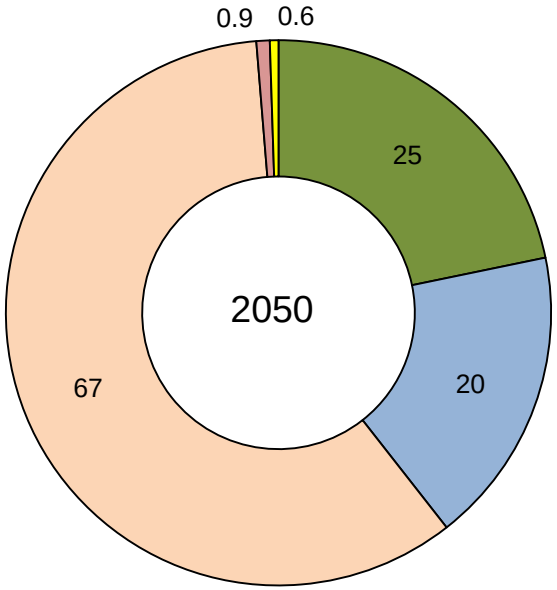
Supply region

Grid expansion: from supply region to metropolitan region

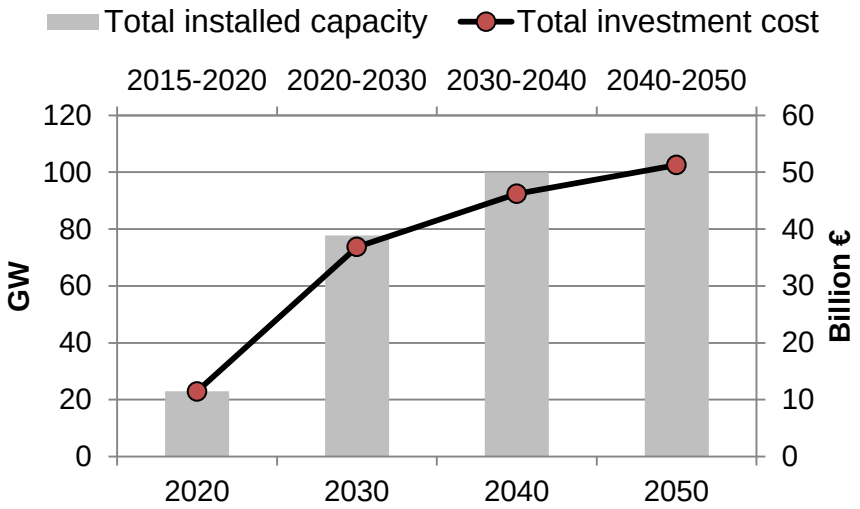




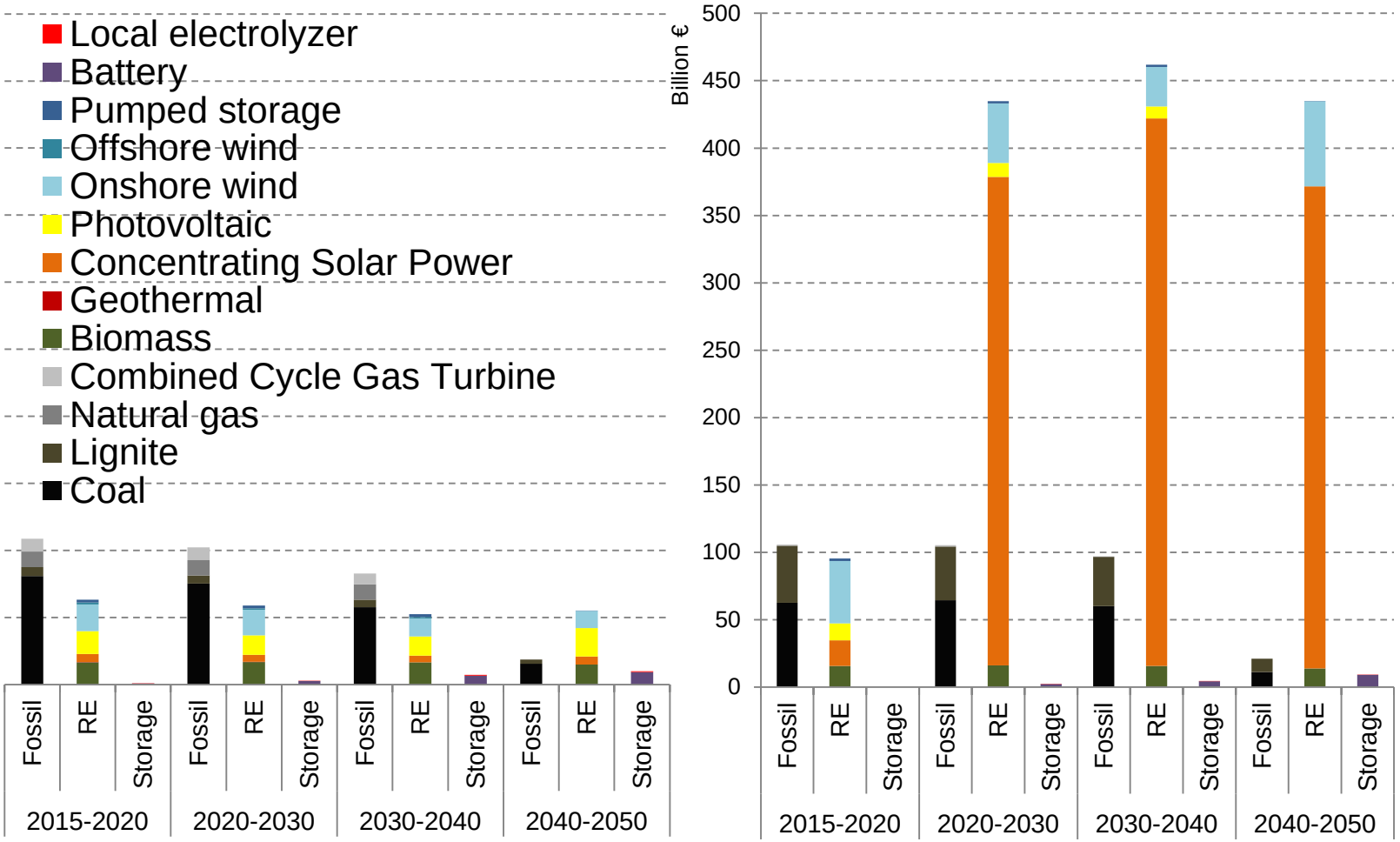




- InnerMongolia-Beijing
- InnerMongolia-Tianjin
- InnerMongolia-Hebei
- Hebei-Beijing
- Tianjin-Beijing

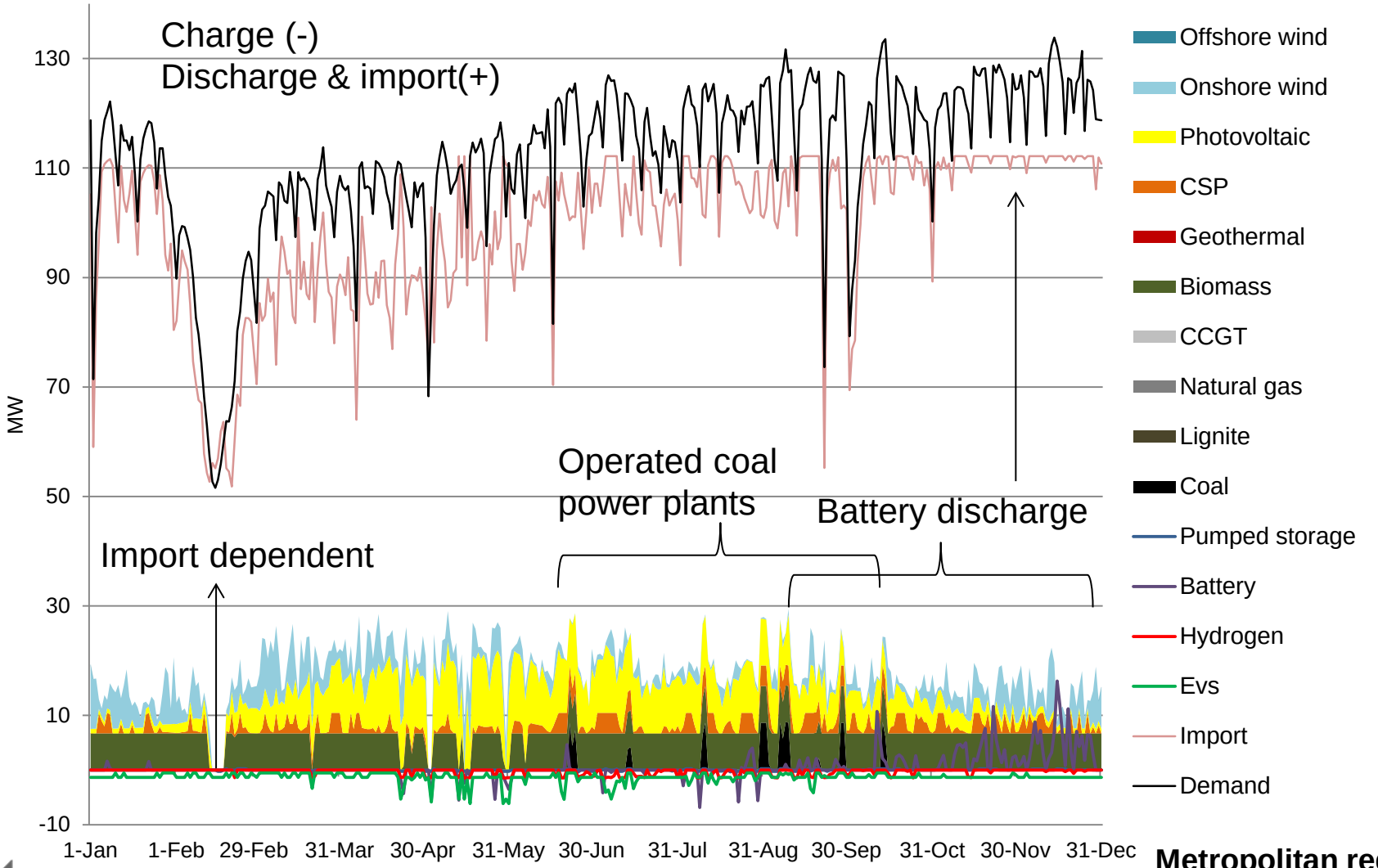


Investment costs of total installed capacity



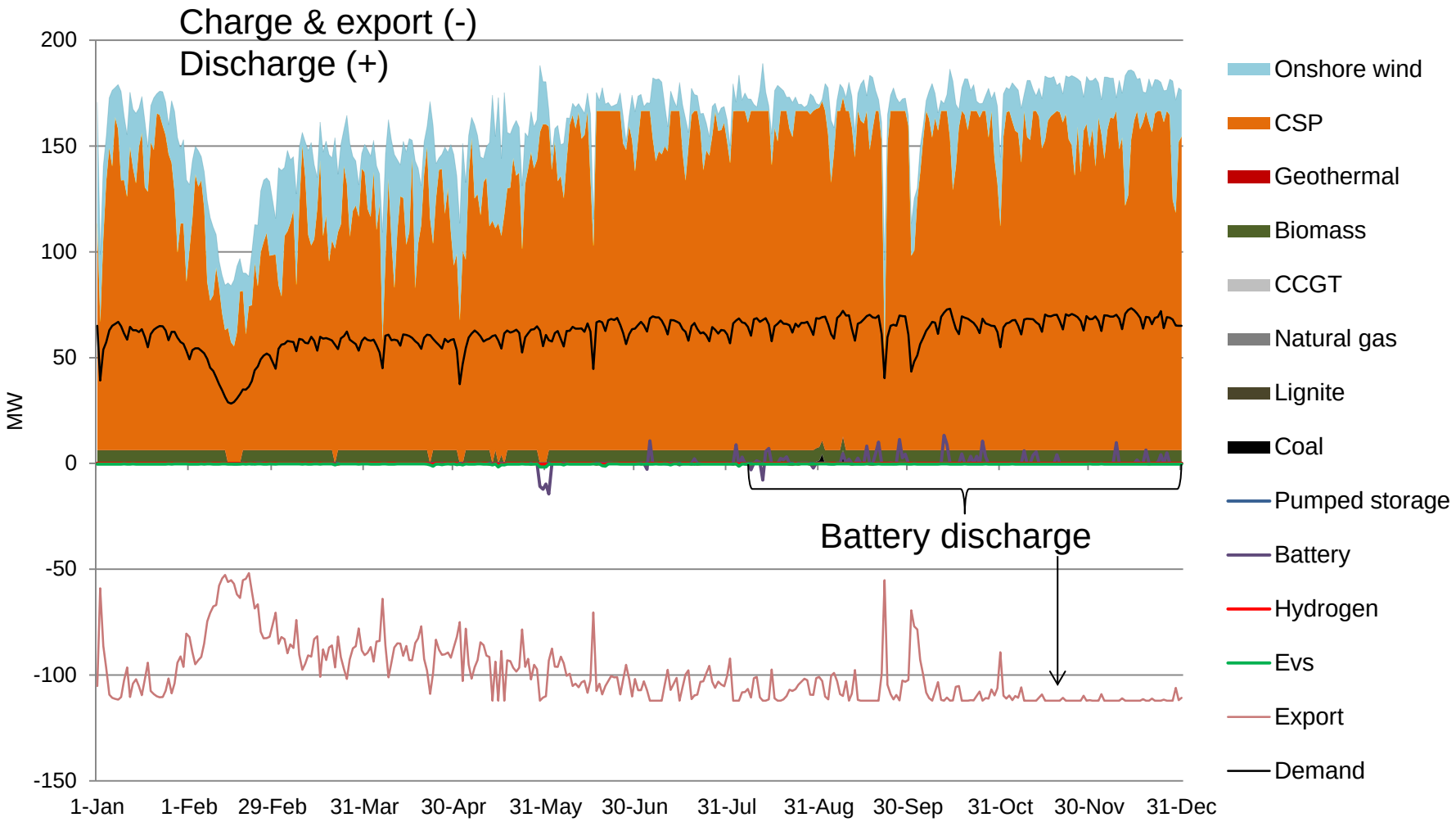
Metropolitan region **Supply region**

Hourly generation, storage, transmission & demand (2050)



Metropolitan region

Hourly generation, storage, transmission & demand (2050)



Supply region

Conclusion

- Analysis reveals, that a successful energy system transition in China needs different regional strategies and strong interrelations of metropolitan regions and RE abundant regions.
- Wind power and CSP in northern resp. western regions can play an important role for the future power supply of eastern metropolitan regions.
- Transmission capacity expansion and local storage installation are necessary to balance fluctuating power generation from RE and power demand.
- Regional integrated modelling of power systems supports decision making regarding the implementation of new technologies and infrastructures for metropolitan regions towards long-term climate targets.
- Coordination and governance are critical factors for both national and regional energy system transition.

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