Feasibility study of China's electric power sector transition to zero emissions by 2050

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12th IAMC Annual Meeting,

Tsukuba, Japan, 2 - 4 December 2019

Outline

- Brainstorming zero-emissions options for 2050
- Methodology and assumptions
- Major results and conclusions

Electricity decarbonization options

- Carbon capturing and sequestration (**questionable**)
- Biomass (**questionable – emissions, resource?**)
- Nuclear and large hydro (**achievable, but..**)
- Renewables:
  - **Technically feasible?**
  - **Economically viable?**

Strategy

- Evaluate technically and economically feasible share of renewables in electric power generation, optimizing:
  - Solar arrays and Wind farms capacity & locations
  - UHV grid
  - Required storage
  - (and/or) back-up capacity (biomass-to-power)
- Optimize transition from the current capacity to the targeted (optimized on the first step) structure

Methodology

- Hourly weather data for dynamic evaluation of renewables potential
- CHN_ELC_PRO model
  - Capacity expansion, cost minimizing
  - 31 regions (provinces)
  - Two versions of the model:
    - 8760 hours, 1 year (resources balancing)
    - 12 months x 24 hours, from 2015 to 2055 (transition pathway optimization)
- Scenarios:
  - 1 hour balancing for 2050 to evaluate the target
  - Optimized from 2018 to 2050

Step 1: Renewables potential with 1 hour resolution

Based on MERRA-2 data (NASA) of wind speed and solar radiation from 1980 to 2019

Renewables costs

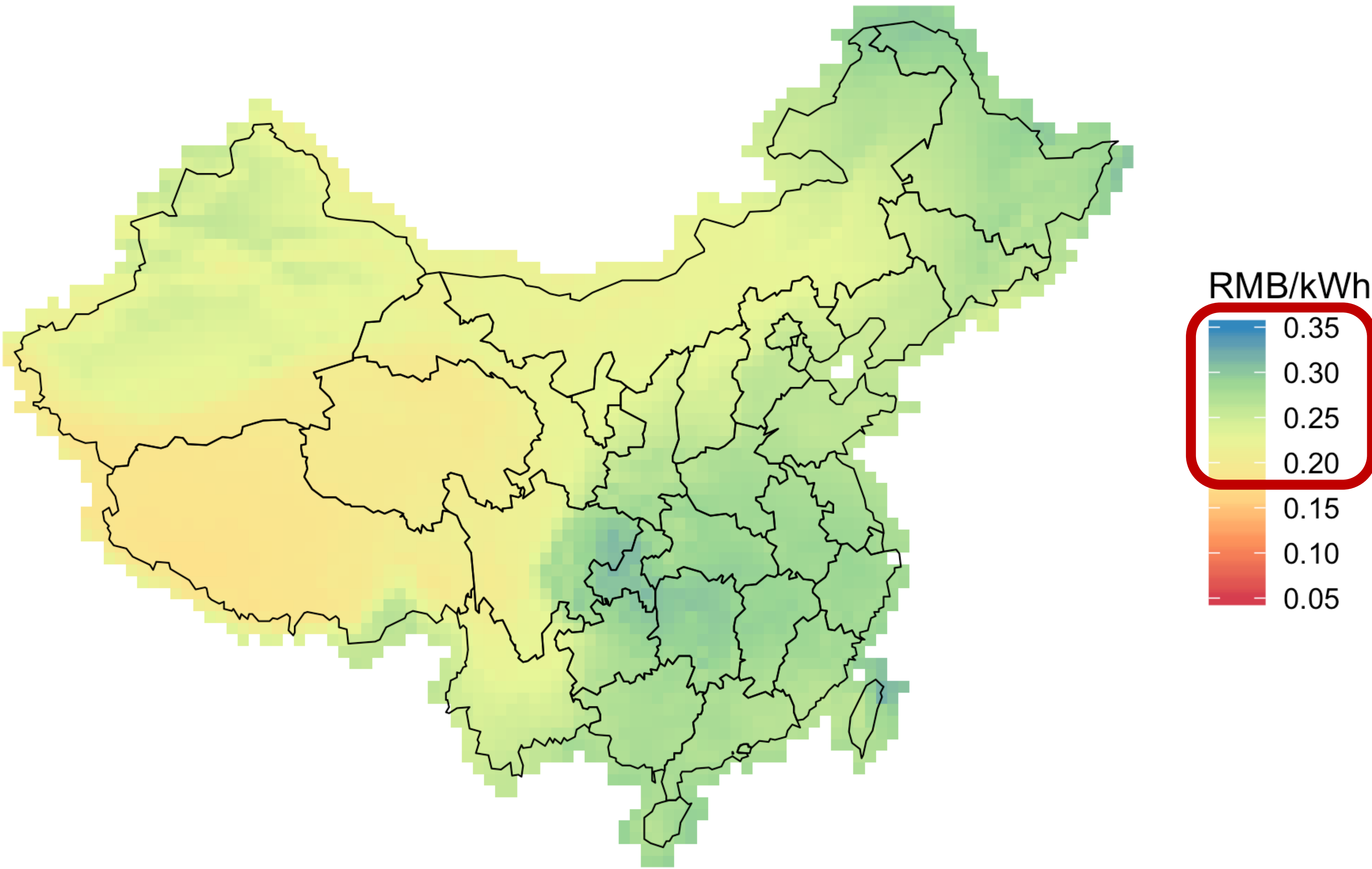
Photovoltaics	Wind turbines
NREL (2018):	Datang P.C. (2019), Onshore:
1 USD/Watt (~6.9 RMB/Watt)	2018: 7.25 RMB/Watt 2023: 6.7 RMB/Watt
Datang Power Corp (2019):	Offshore:
2018: 4.5 RMB/Watt 2023: 3.5 RMB/Watt	2018: 12 RMB/Watt 2023: 11.2 RMB/Watt

LCOE assumptions:

5% discount rate, 25 years life span

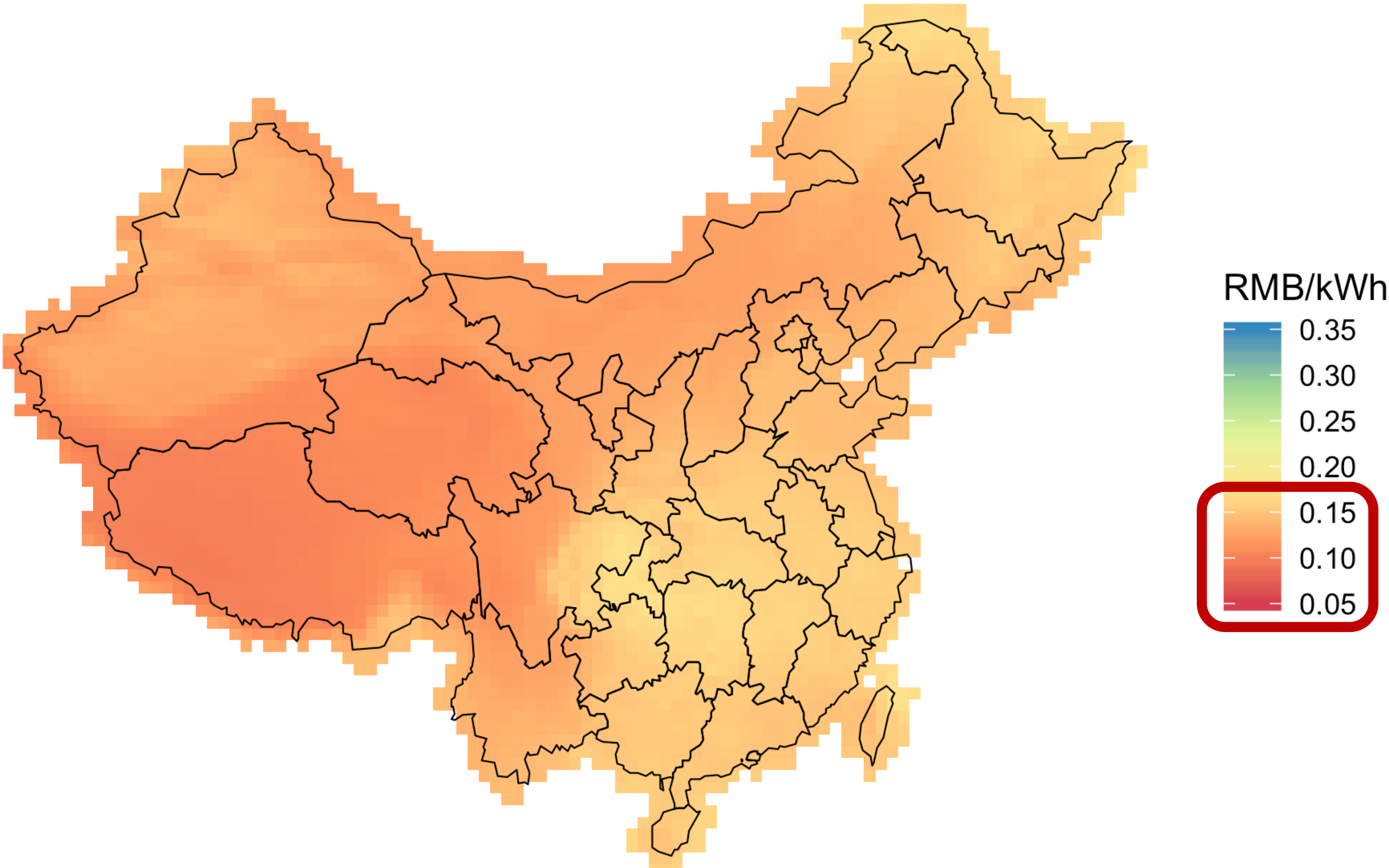
LCOE for solar PVs in 2018 (1980-2018 average)

~ 2.5 - 4.6 US cents per KWh (6.9 RMB/USD)



LCOE for solar PVs in 2025 (1980-2018 average)

~ 1.4 - 2.6 US cents per KWh (6.9 RMB/USD)



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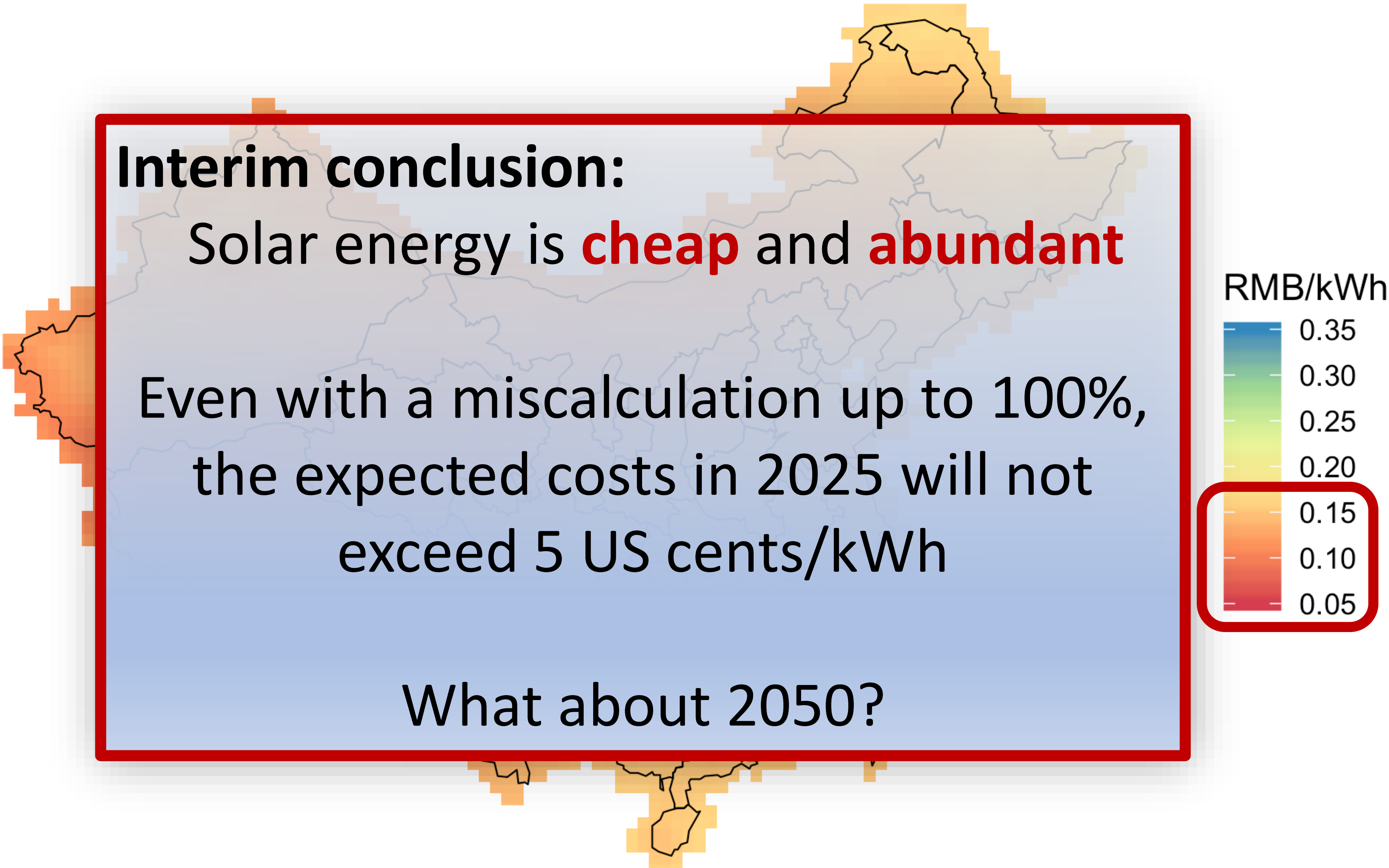


Interim conclusion:

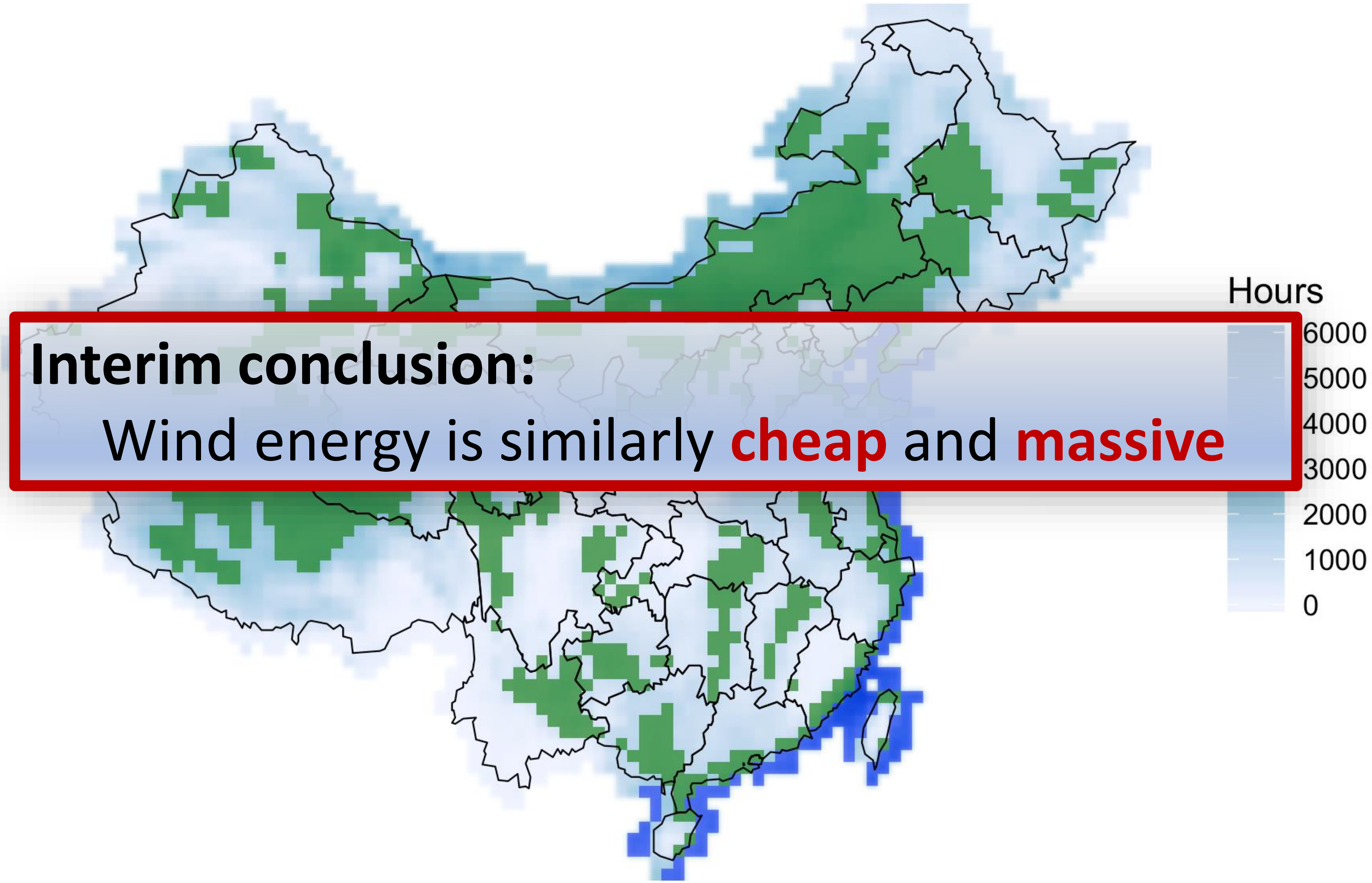
Solar energy is **cheap** and **abundant**

Even with a miscalculation up to 100%, the expected costs in 2025 will not exceed 5 US cents/kWh

What about 2050?

Selected best locations for on/offshore windfarms

~ 1.5 - 25.5 US cents per KWh (6.9 RMB/USD)



Interim conclusion:

Wind energy is similarly **cheap** and **massive**

Step 2: Optimization of electric power system in 2050

Using weather data (39-years) and capacity expansion model CHN_ELC_PRO, balancing version

Why 1h balancing is important?

- Matching Electric Power System structure with historical weather

- Optimized energy system structure:
  - Capacity structure and locations
  - Energy storage
  - Long-distance power grid

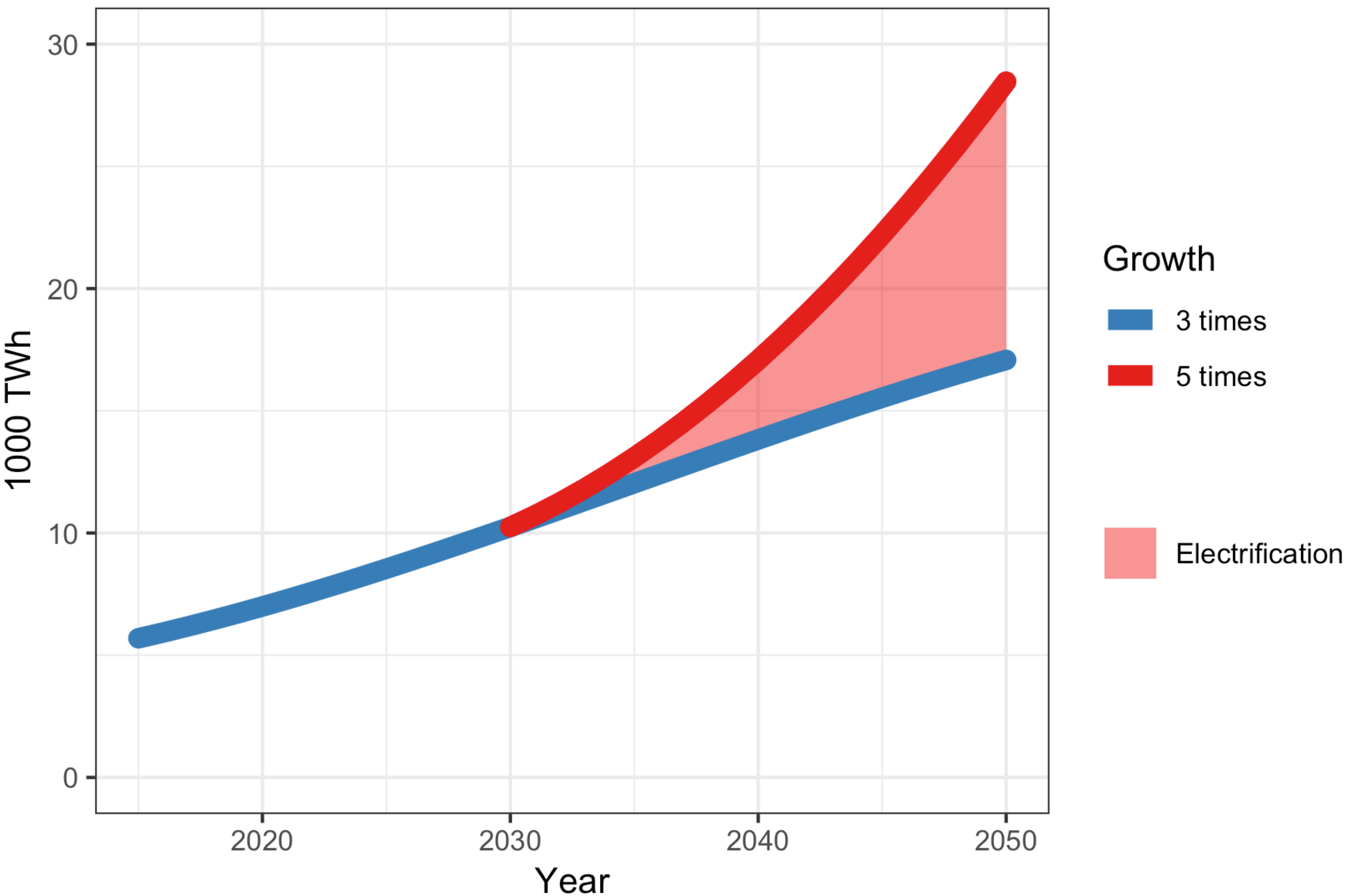
- “Let the weather decide…”*

* Borrowed from Prof. Martin Greiner, Aarhus University talk at OpenMod 2019

Assumptions:
Or what do we know about 2050?

- Demand is going to grow
- Electrification trends may induce demand growth

Electricity demand growth assumptions, 2015-2050



Assumptions:
Or what do we know about 2050?

- Demand is going to grow
- Electrification trends may induce demand growth
- Structure of demand is going to change:
    - End-use batteries (incl. electric transport) – i.e. more flexible
    - Robotization of industry, transport, etc. – again more flexible (no day/night shifts, stop and go mode…)
    - This will affect the load curve (flexible? manageable?)

Types of demand and the load curve

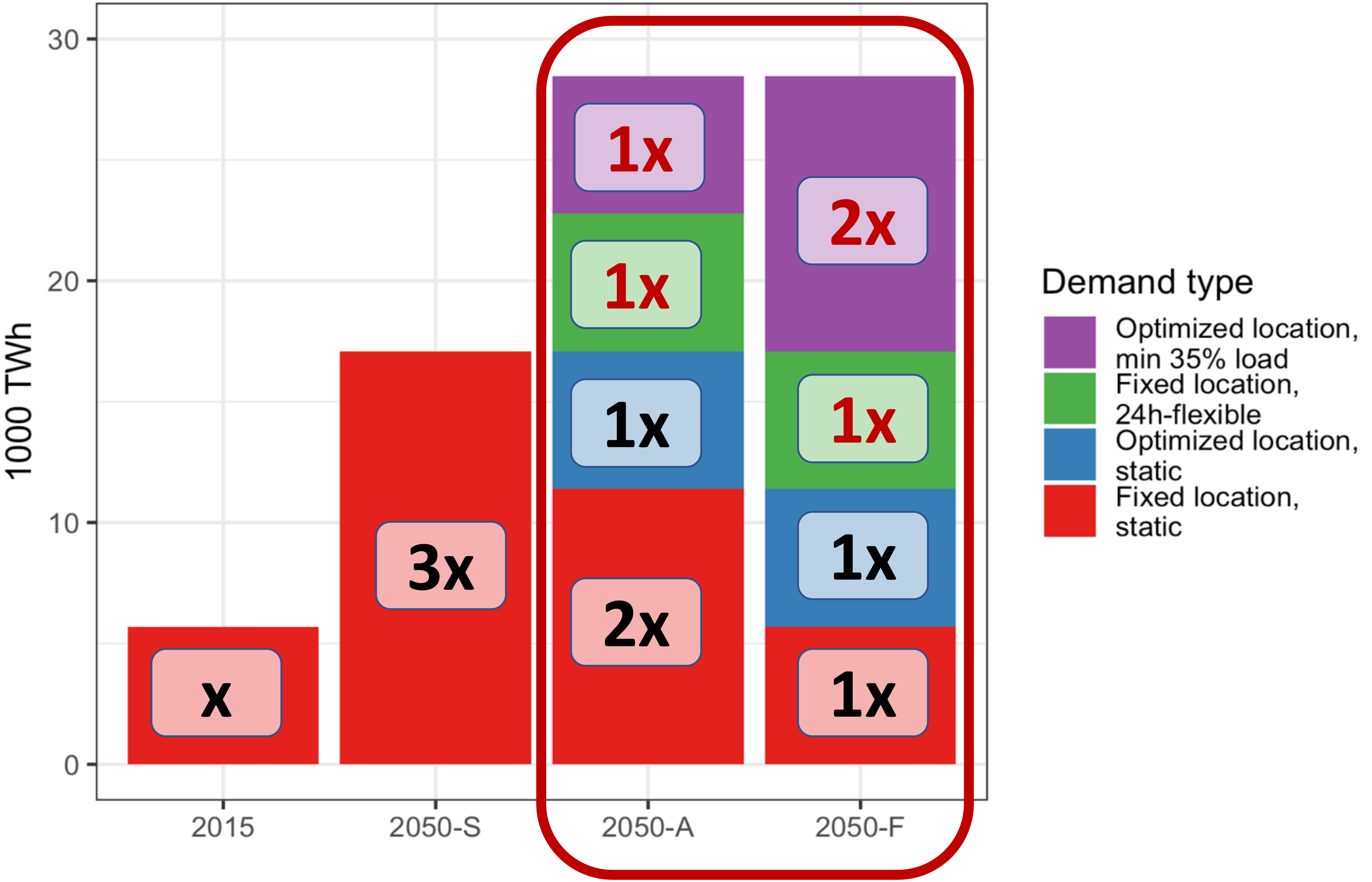
- **Fixed location (same as in 2015), Static**
  - Location and the level of consumption are fixed

- **Optimized location, Static**
  - Territory/location is to be optimized by the model
  - Once built - static

- **Fixed location (same as in 2015), flexible within 24h**
  - Can be shifted within a day
  - Territory/location is fixed

- **Optimized location, flexible load, minimum 35% a year**
  - Territory/location is to be optimized by the model
  - May vary in time

Electricity demand structure assumptions



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  - Robotization of industry, transport, etc. – again more flexible (no day/night shifts, stop and go mode…)
  - This will affect the load curve (flexible? manageable?)
- Most of the new capacities from both ends (demand and supply) are to be built, the current thermal power plants capacity will mostly retire

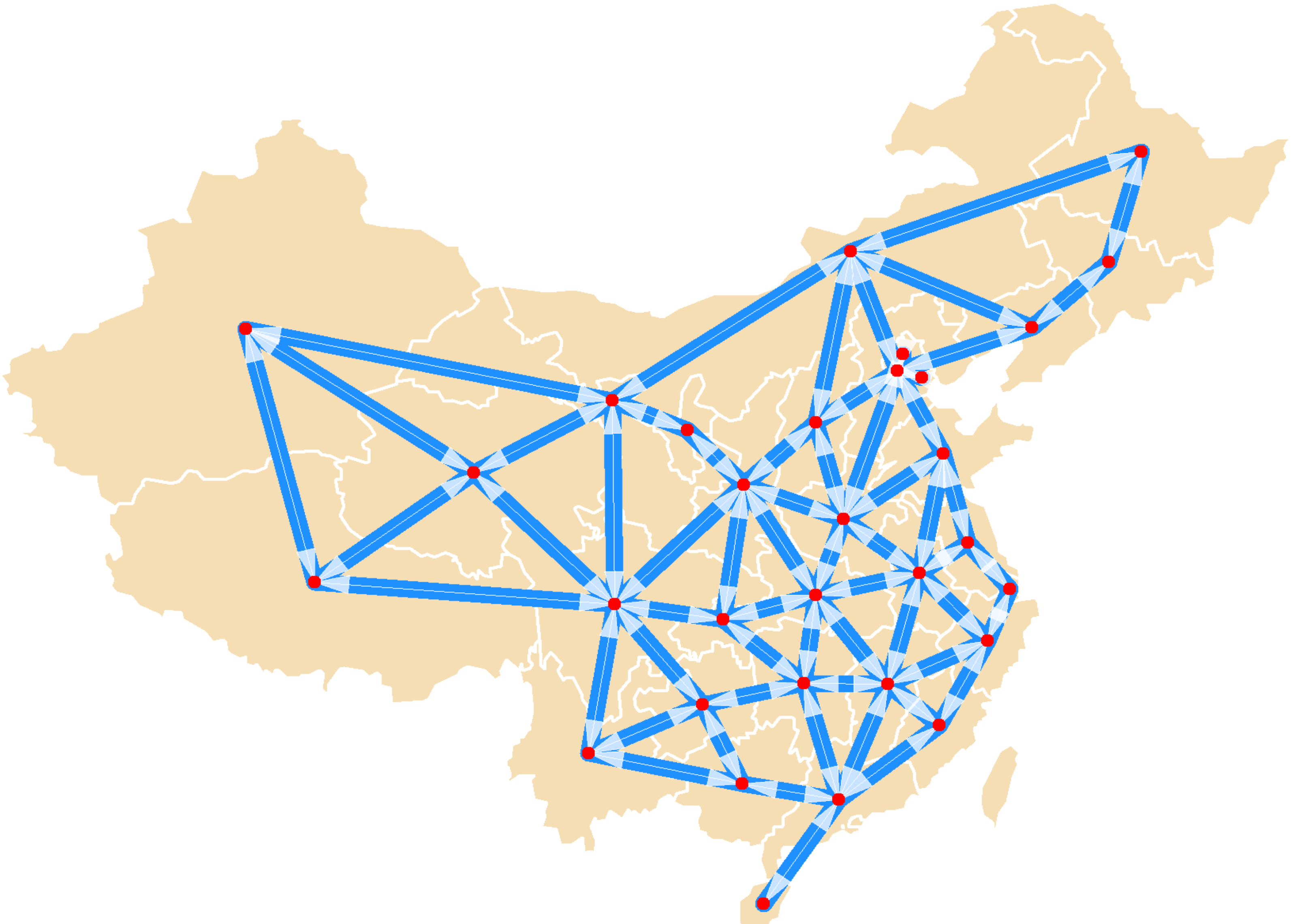
More key assumptions:

- Load curve 2050:
  - flat + flexible (40% or 60%) = weather driven
- Intraday storage
  - $100 USD/kWh capacity,
  - Operational life: 10 years
  - Round efficiency 80%
- Long-term storage (a la P2X):
  - 0.5 RMB/kWh (~7.5 US cents / kWh)
- UHV grid (UHVDC in mind):
  - ~ 3 Million RMB / GW of 2000km line total costs
  - 2% transformation losses, 1% per 1000 km

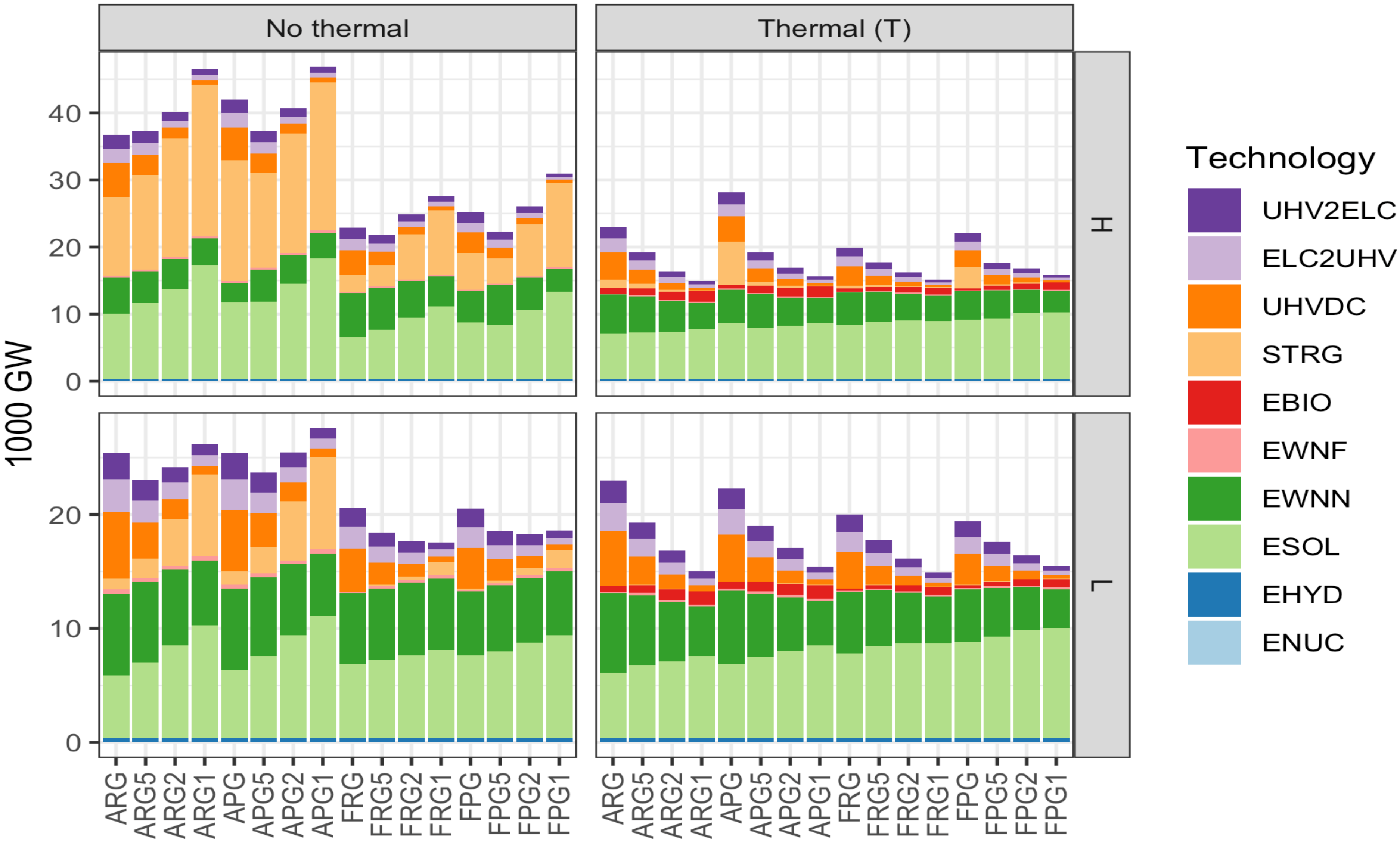
64 core scenarios

- 3 types of the final demand structure (S, A, F)
- Investment costs (R – current, P – perspective)
- Biomass to power option (T – thermal)
- Limits on investment into UHVDC grid (no limits, 50%, 25%, 10% of cost-optimal)
- Relatively higher (H) or lower (L) reliability of power system

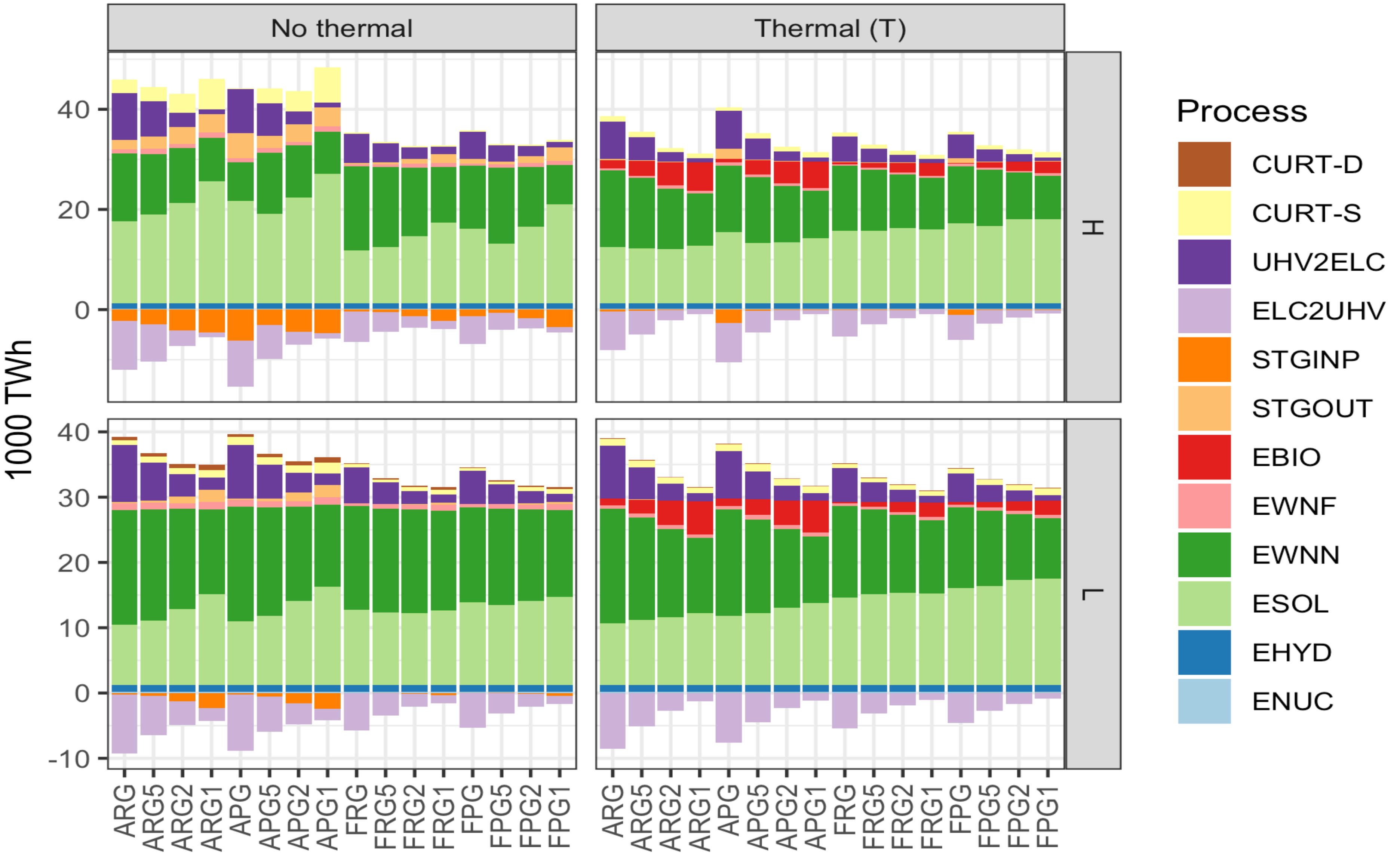
Modeling long-distance grid



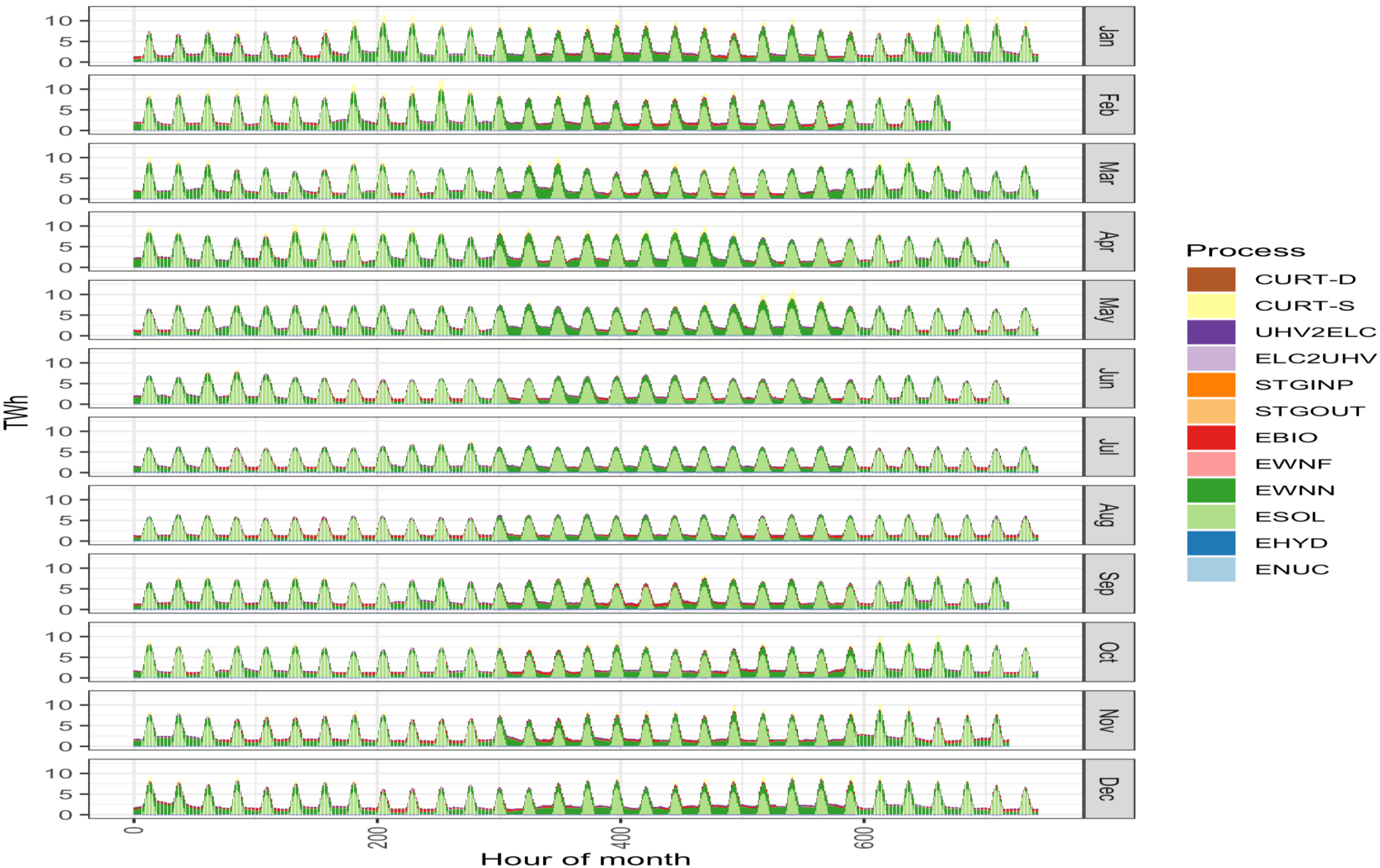
Power sector capacity structure



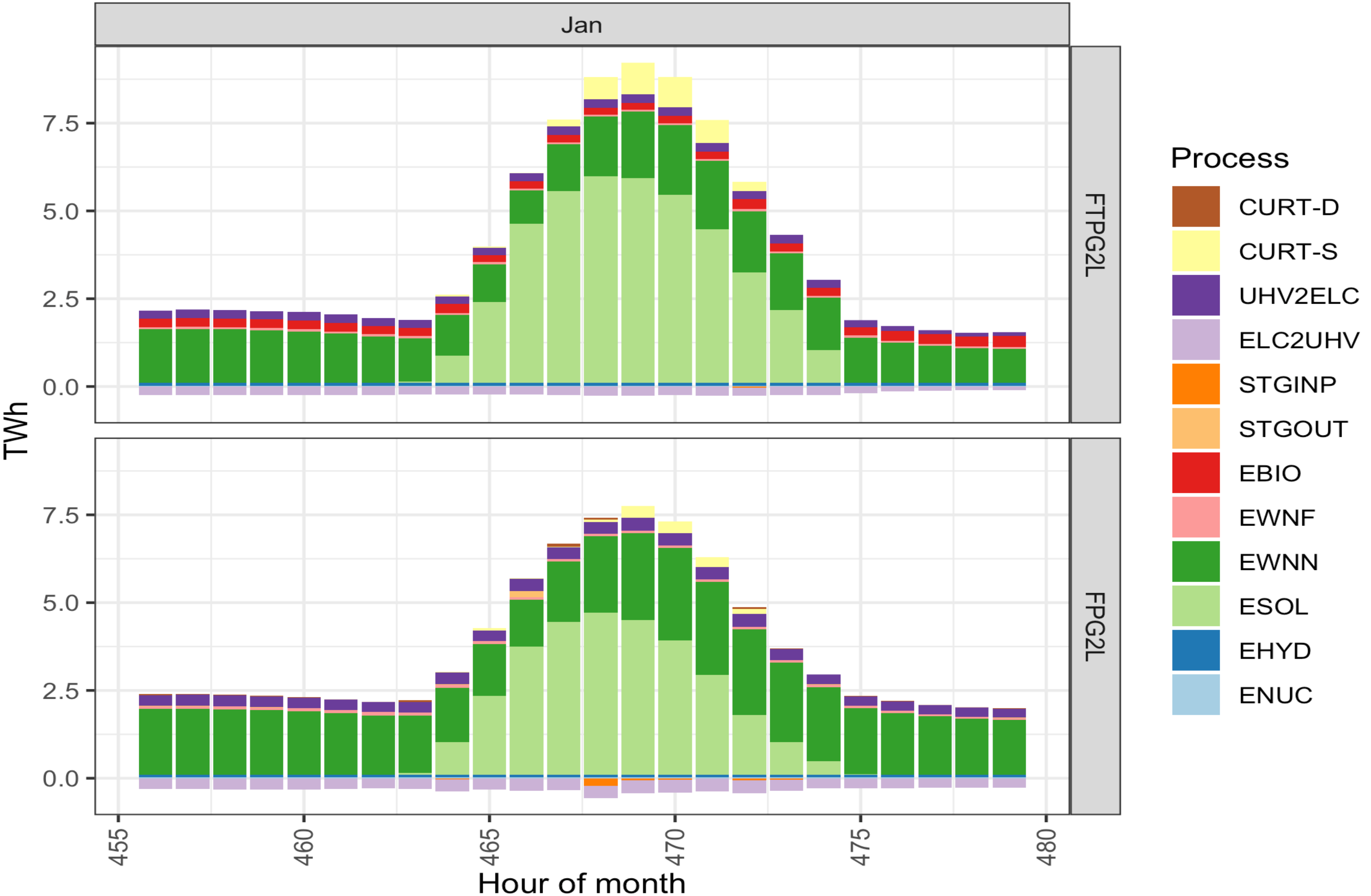
Power production by technologies



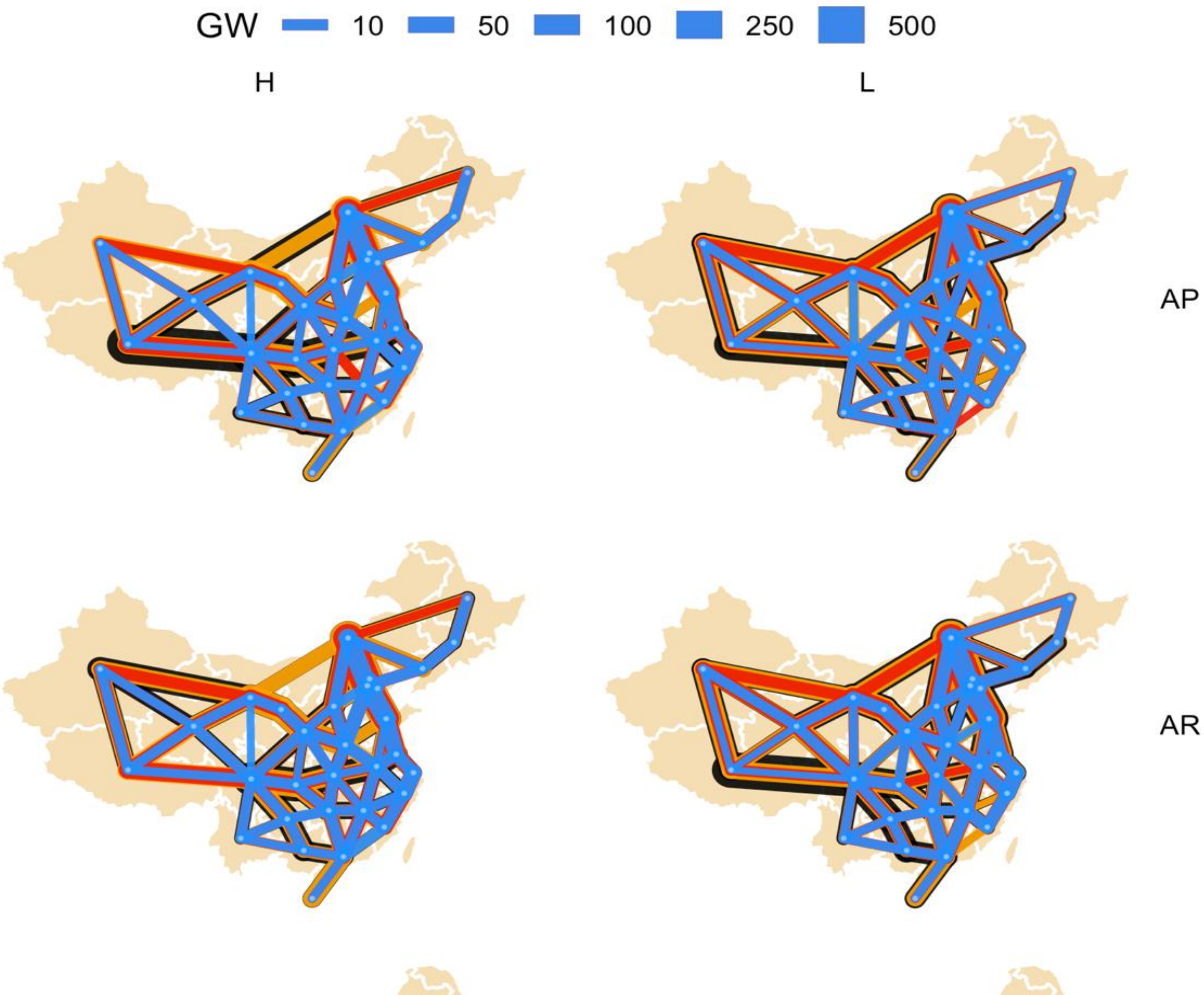
Generation profile in 2050 (base on 2018 weather data)



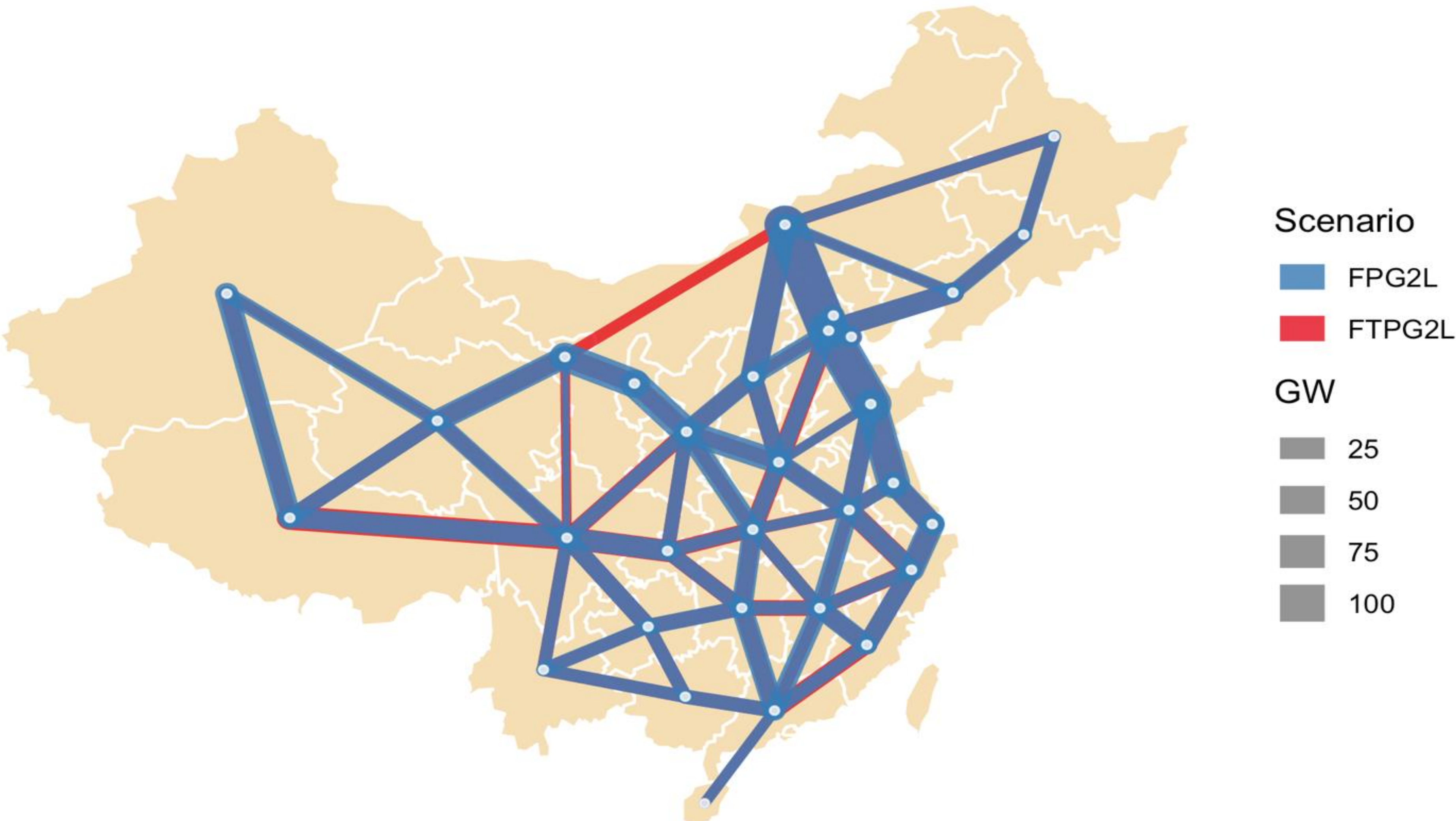
Generation profile (Jan 20, 2050)



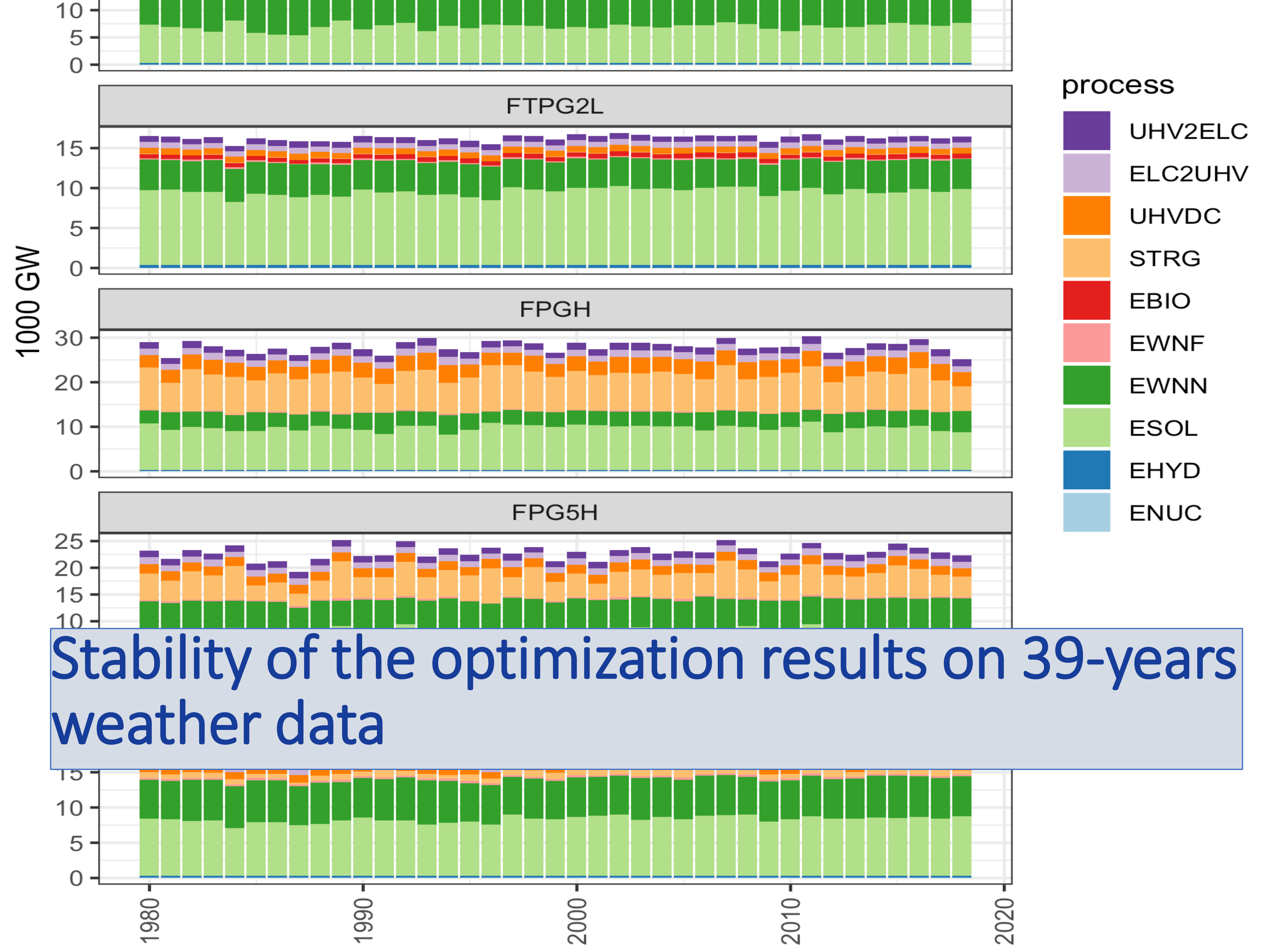
Optimized UHVDC grid by scenarios

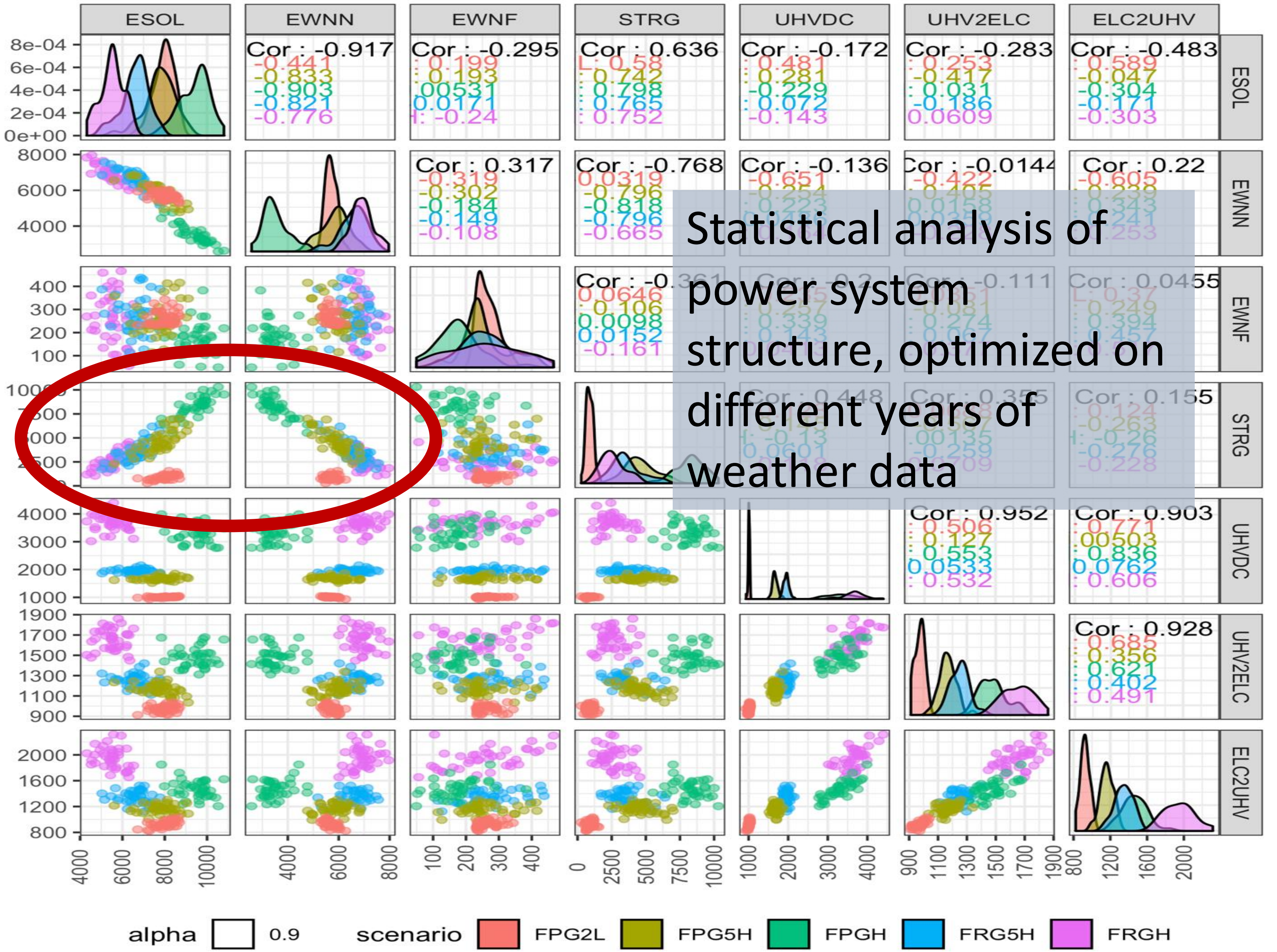


UHVDC grid, two selected scenarios



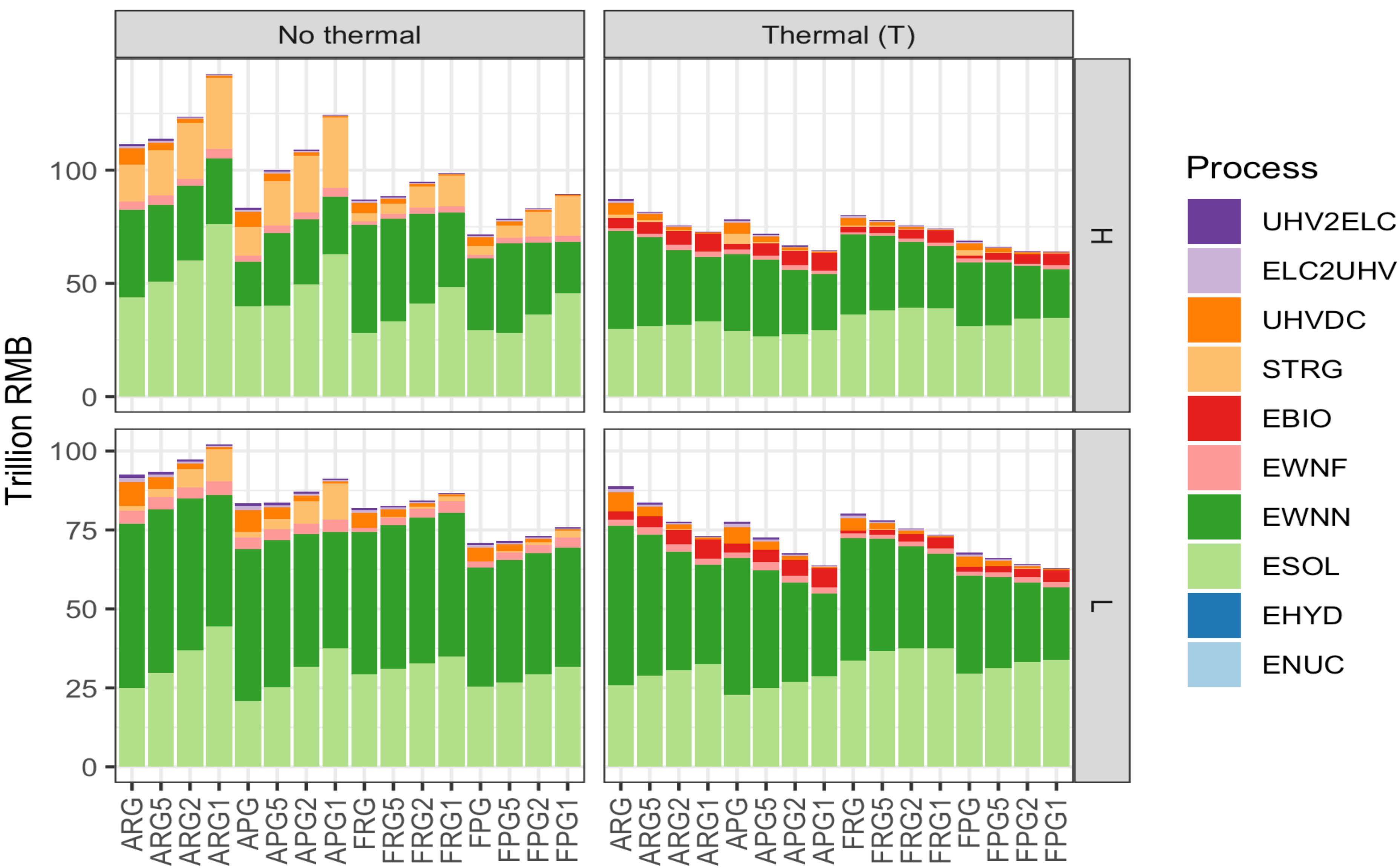
Stability of the optimization results on 39-years weather data



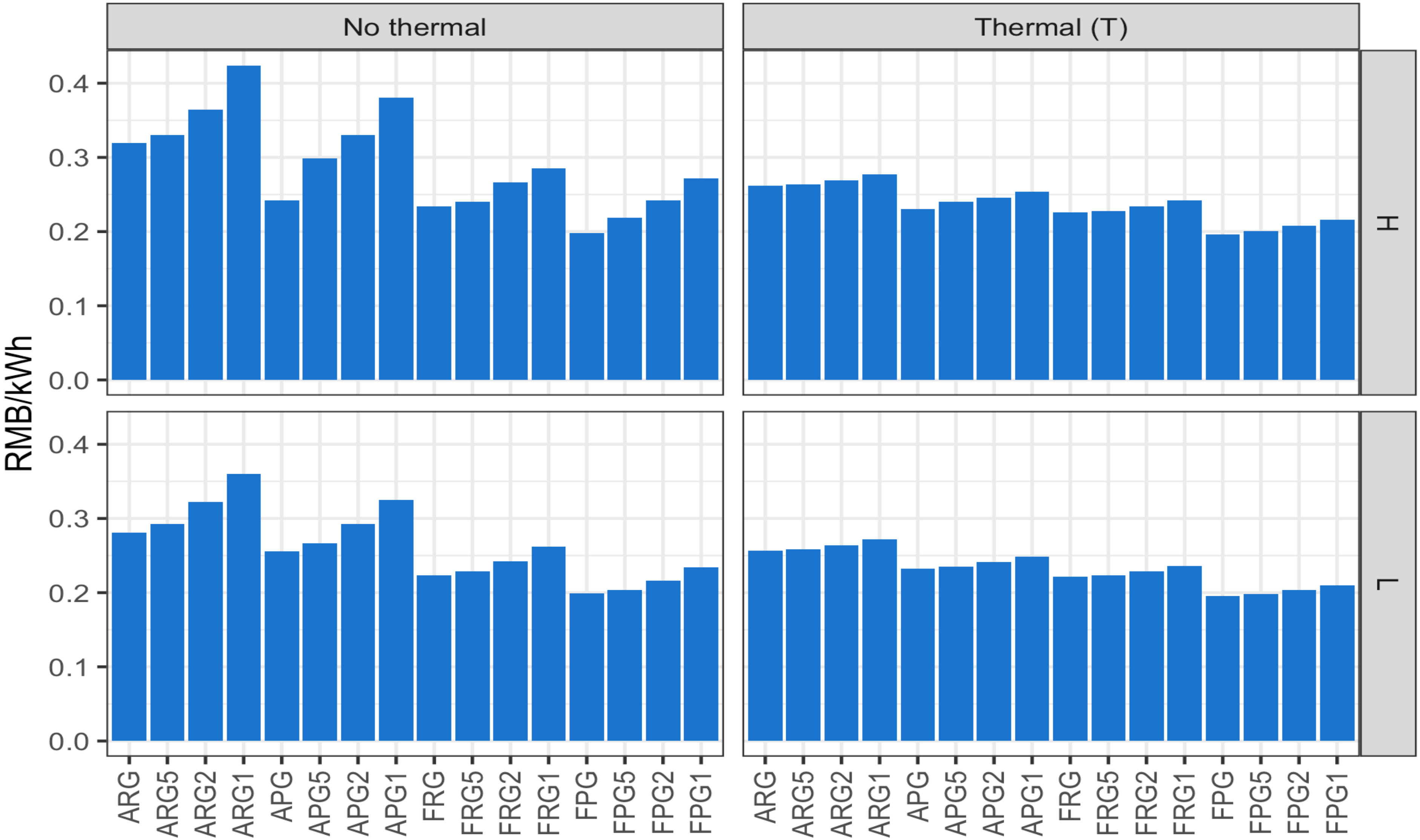


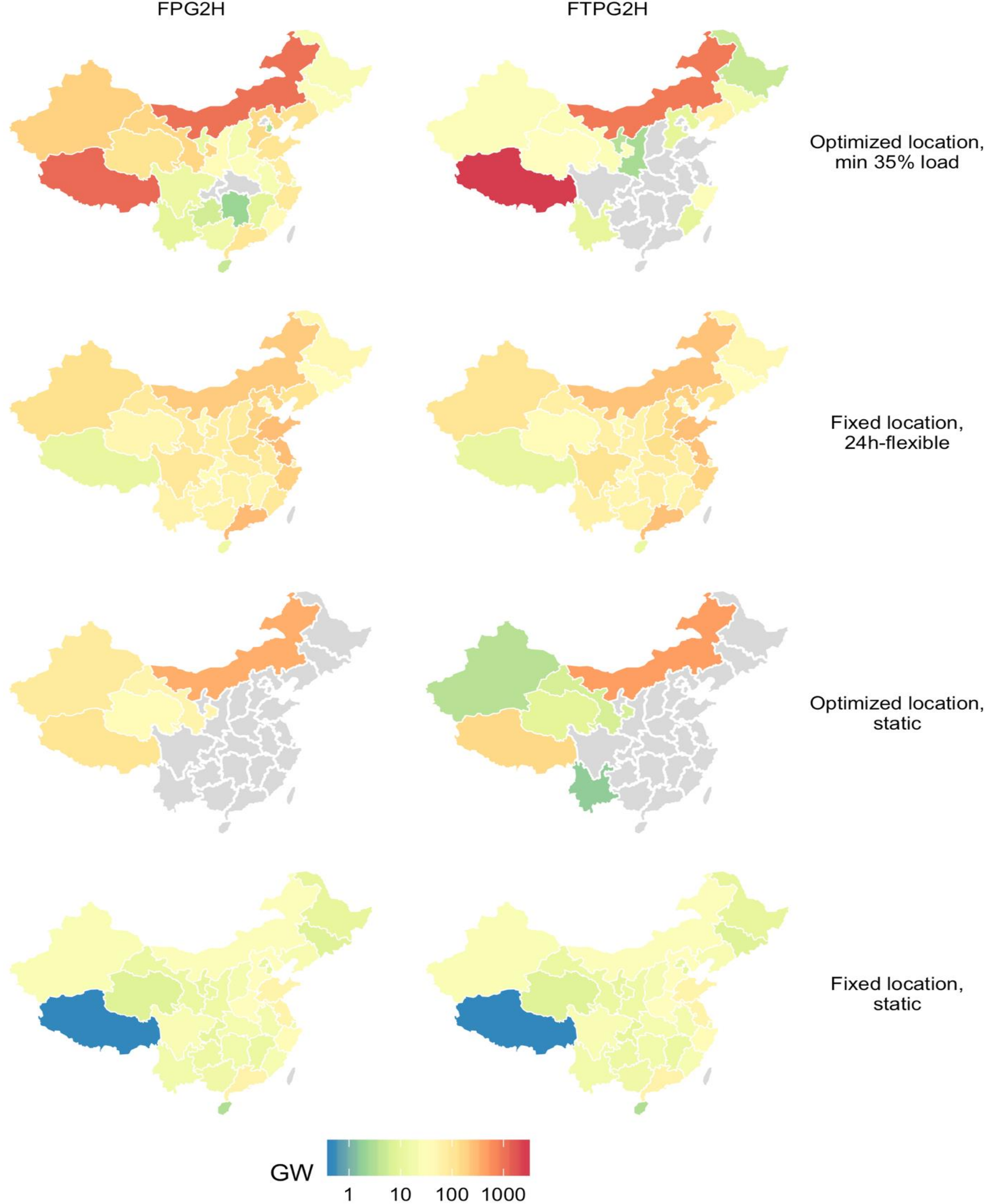
ESOL
EWNN
EWNF
STRG
UHVDC
UHV2ELC
ELC2UHV
Statistical analysis of power system structure, optimized on different years of weather data
alpha
0.9
scenario
FPG2L
FPG5H
FPGH
FRG5H
FRGH

Required investments



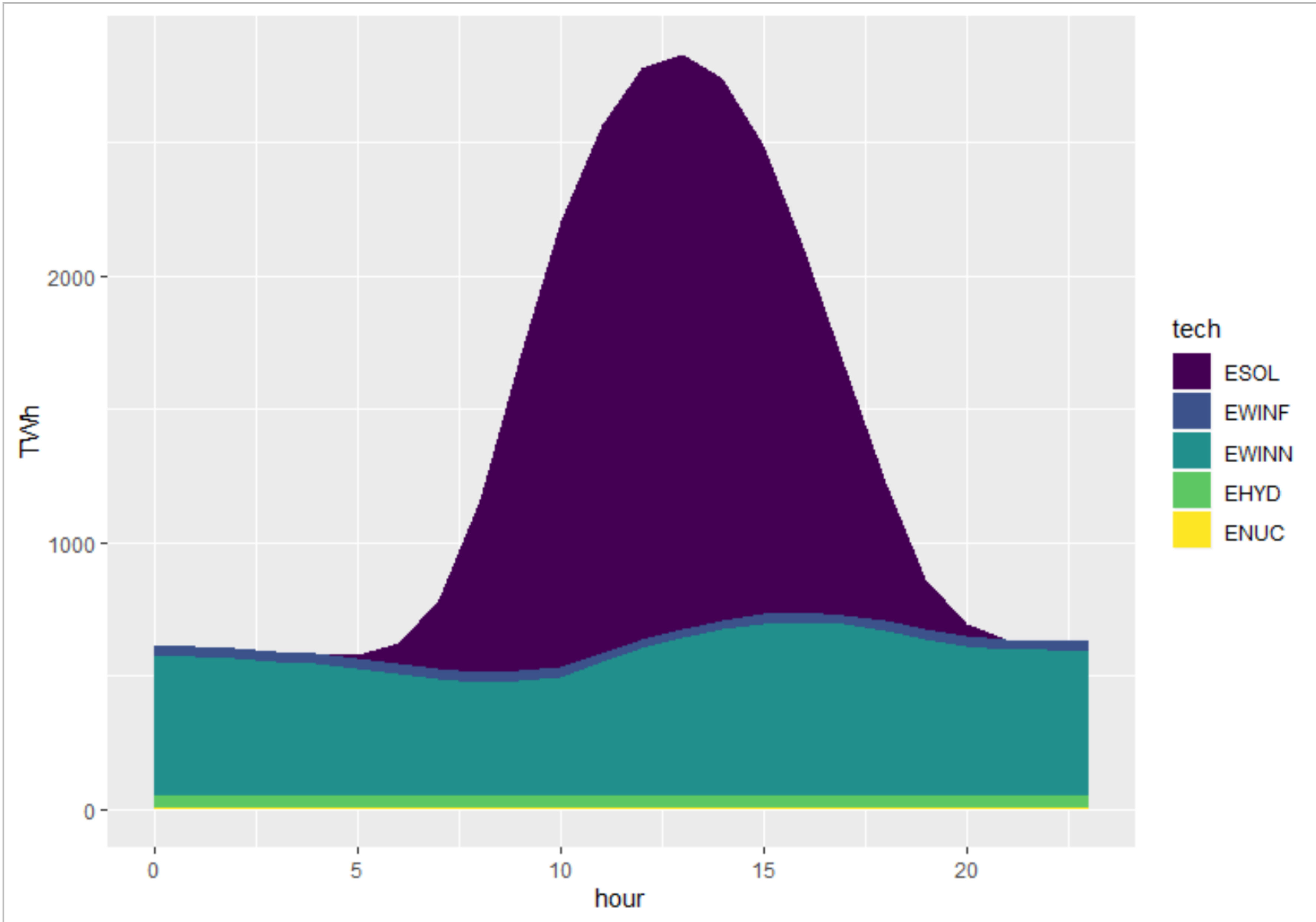
Levelized costs of electricity (3-5 US cents per kWh)



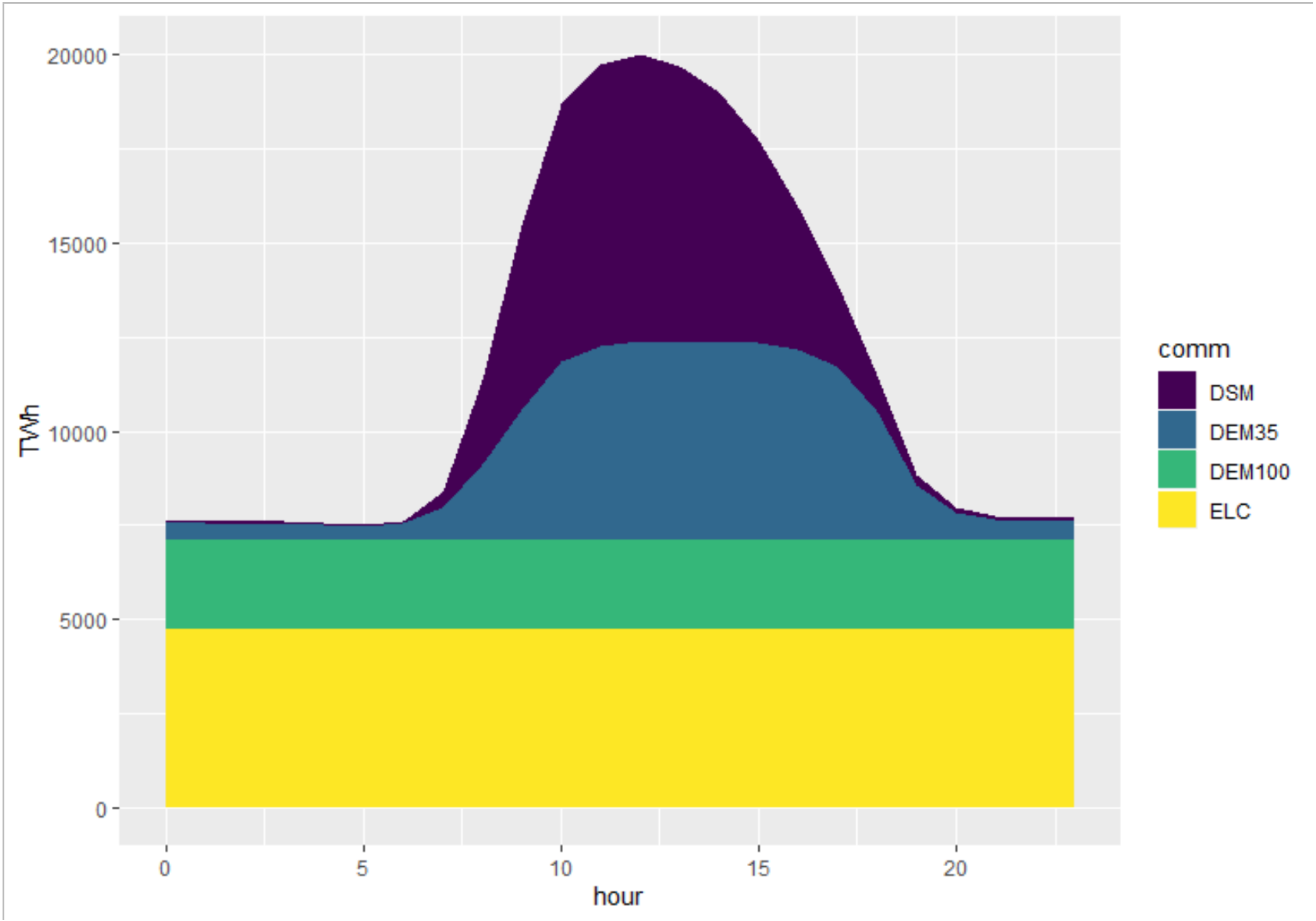


FPG2H
FTPG2H
Optimized location,
min 35% load
Fixed location,
24h-flexible
Optimized location,
static
Fixed location,
static
GW
1
10
100
1000

Annual generation profile



Annual demand profile (”A”)



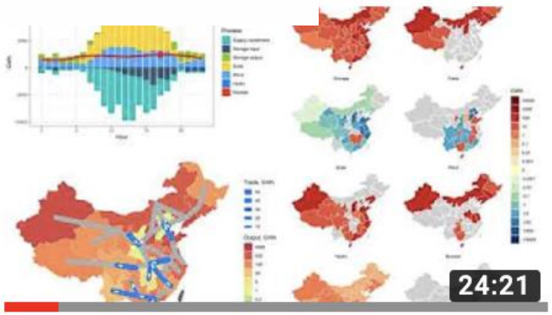
Summary of results

- Solar and wind – reach potential
- Interregional grid may significantly reduce balancing costs
- Demand Side Response (DSR) can significantly reduce requirement for storage
- Systemwide electricity costs: 3-5 US cents per kWh with DSR, even with current costs of technologies (in China)

Summary of results (cont.)

- Zero emissions power sector scenarios for China are:
  - technically feasible
  - economically viable and cost competitive
- Is ~100% renewables BAU?

Channel: “CHN_ELC_PRO” (currently updating)



Simulation of zero emission China's Electric Power Sector in 2050

3 views • 6 hours ago

The visualization of results from China Electric Power sector Province level optimization model CHN_ELC_PRO: - hour-level resolution, 31 regions (provinces). - Weather data is from MERRA-2

Thank you for your attention!

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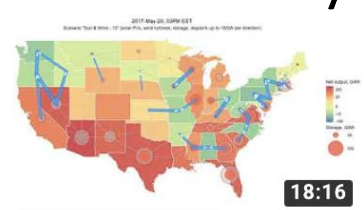
Satellite study for US and India, in work: YouTube channel “energyRt”



Scenario #8: “The Wind and the Sun – 10”

Scenario #7: “The Wind and the Sun – 100”

Scenario #6: “The Wind and the Sun”

Scenario #5: “Windy states – 100”

Scenario #4: “Sharing the Sun – 10”