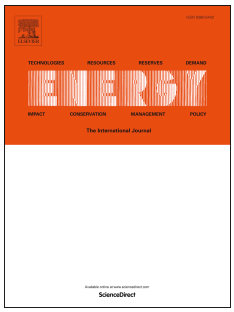
Journal Pre-proof



Regional emission pathways, energy transition paths and cost analysis under various effort-sharing approaches for meeting Paris Agreement goals

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Regional emission pathways, energy transition paths and cost analysis under various effort-sharing approaches for meeting Paris Agreement goals

Supplement Information

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1. Rough estimation of emission budget for NAM under the capacity principle

We take the NPi_V4 scenario as the BAU scenario. In the BAU scenario, the global GHGs emissions from 2020 to 2100 are around 6150 $GtCO_{2e}$, and GHGs emission from NAM are around 660 $GtCO_{2e}$. Global GHGs emissions in the 2℃ scenario over 2020-2100 are 1320 $GtCO_{2e}$, so the global reduced GHG emissions are 4830 $GtCO_{2e}$. For the capacity principle, regional emission reductions are proportional to its GDP share. NAM includes USA, Canada and Mexico, only USA takes global GDP share of 24% in 2018. If the GDP share of NAM is estimated to be 20% over 2020-2100, NAM has to reduce GHGs emissions of about 966 $GtCO_{2e}$. That means NAM has a negative emission budget of 306 $GtCO_{2e}$, which is impractical.

2. IAM framework

Fig.S1 illustrates the framework of MESSAGE model linked with other modules. The energy systems model MESSAGE is soft-linked with the MACRO model to assess the impact of energy prices on macro-economic development and energy demand. It is also coupled with the GLOBIOM model to assess the impact of energy systems on land use, forests and water resources; with the GAINS model to assess the impact of energy use on air pollution and health; with the MAGICC model to assess the impacts of greenhouse gas emissions on the global climate and sea level; and with the ACCESS model to assess increasing modern energies use for clean cooking and access to electricity. When energy optimization reaches converged, technology portfolio and energy investment can also be given by MESSAGEix-GLOBIOM.

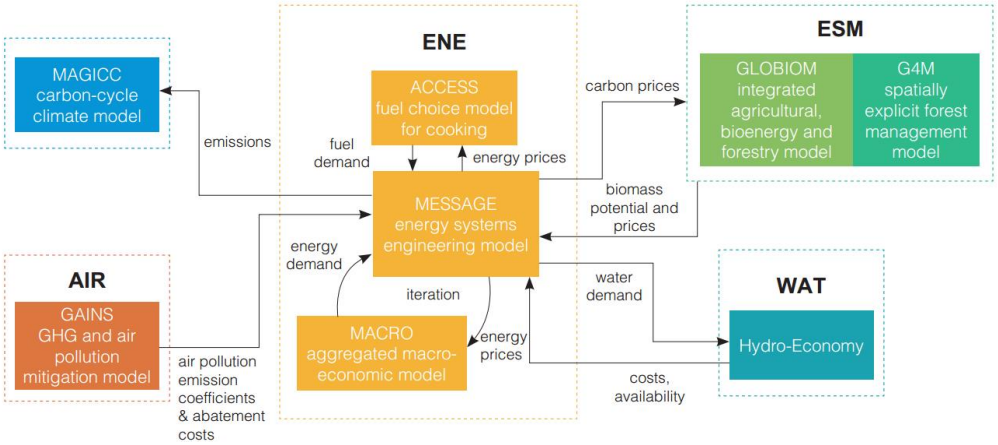
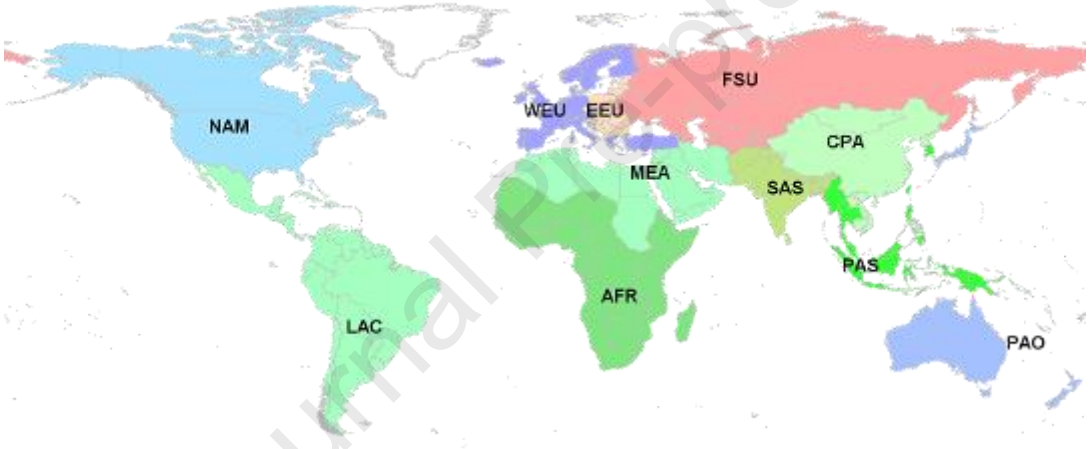


Figure S1. MESSAGEix-GLOBIOM Integrated Assessment Model Framework

3. **Regions**



AFR:	Sub-Saharan Africa	LAM:	Latin America & The Caribbean	PAS:	Other Pacific Asia
CPA:	Centrally Planned Asia & China	MEA:	Middle East & North Africa	SAS:	South Asia
EEU:	Central & Eastern Europe	NAM:	North America	WEU:	Western Europe
FSU:	Former Soviet Union	PAO:	Pacific OECD		

Figure S2 Map of 11 MESSAGEix-GLOBIOM regions including their aggregation to the four regions used in the Representative Concentration Pathways (RCPs) (From: https://iiasa.ac.at/web/home/research/researchPrograms/Energy/MESSAGE-model-regions.en.html).

4. Key assumptions

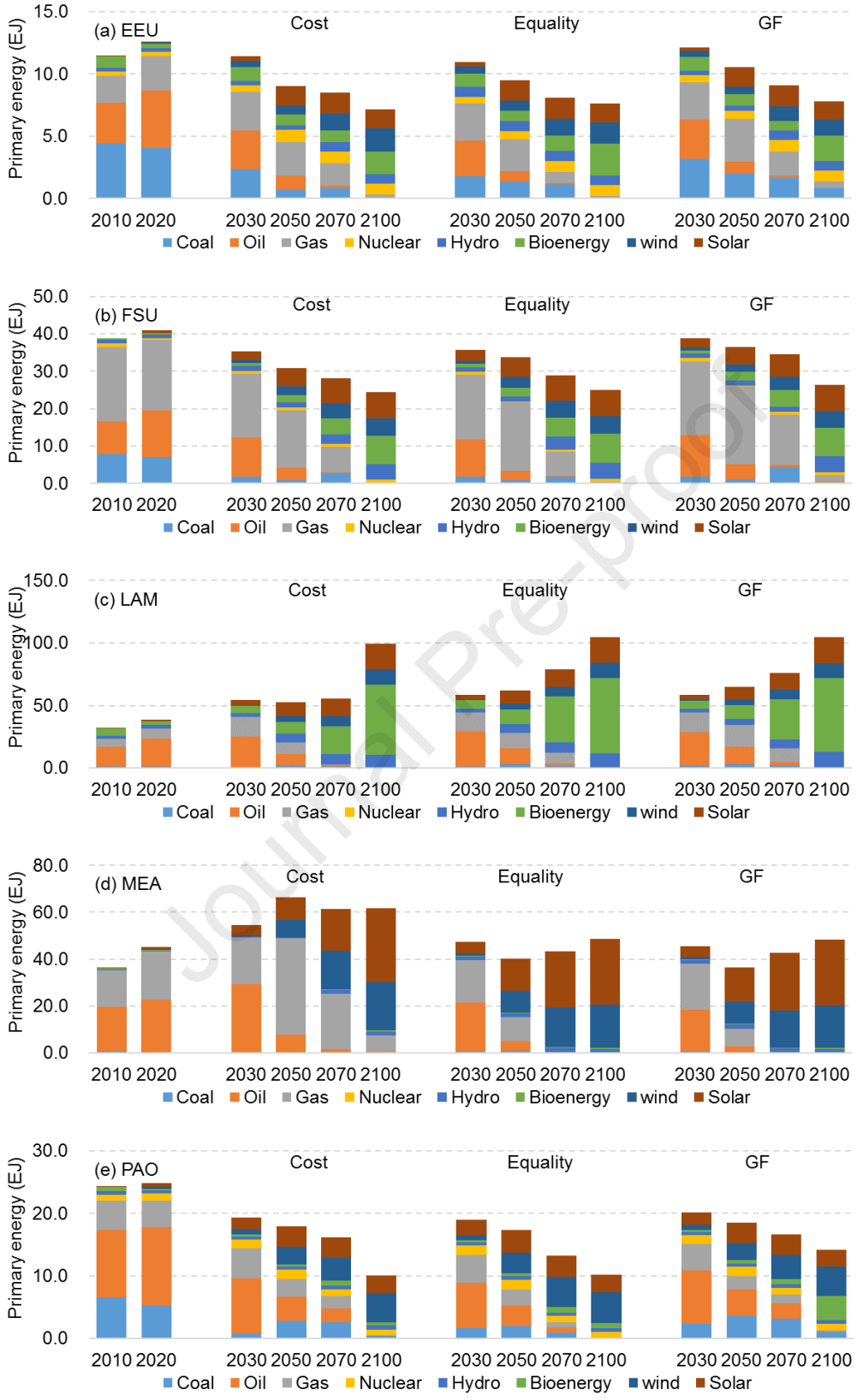
Table S1 Expected population in different regions over 2020-2100 (Unit: million)

Regions	2020	2030	2050	2070	2100
AFR	1021.42	1247.97	1694.07	2039.54	2307.93
CPA	1509.71	1519.41	1407.57	1193.85	882.24
EEU	124.47	122.63	115.91	106.12	88.88
FSU	281.41	280.77	277.28	267.55	241.57
LAM	642.88	690.44	740.67	733.99	669.25
MEA	507.06	581.24	704.39	772.45	779.64
NAM	377.16	405.89	452.86	492.80	514.79
PAO	155.65	155.25	150.58	143.11	124.03
PAS	618.82	659.96	693.20	673.88	594.85
SAS	1861.68	2067.23	2373.34	2467.56	2285.06
WEU	510.99	531.20	559.24	566.03	544.18

Table S2 Expected GDP (PPP) in different regions over 2020-2100 (Unit: billion US$2010/year)

Regions	2020	2030	2050	2070	2100
AFR	3084.36	5286.15	14536.90	37493.19	112528.61
CPA	23734.46	38890.83	59548.47	68739.97	72813.63
EEU	2730.71	3471.95	4869.19	6188.32	7934.08
FSU	4731.77	6644.26	9934.79	13178.92	17695.04
LAM	9420.27	12927.83	21164.96	31389.07	49523.88
MEA	6351.52	9549.79	17770.34	28801.12	50364.14
NAM	20642.92	25309.04	33187.93	40863.01	51599.90
PAO	6170.84	7053.89	8533.00	10307.75	12958.06
PAS	8074.70	11849.90	20369.13	29812.25	44254.57
SAS	9198.30	15947.82	36380.48	66329.72	120715.50
WEU	18046.99	21243.82	29324.52	39385.68	55982.65

5. Primary energy structure in other regions



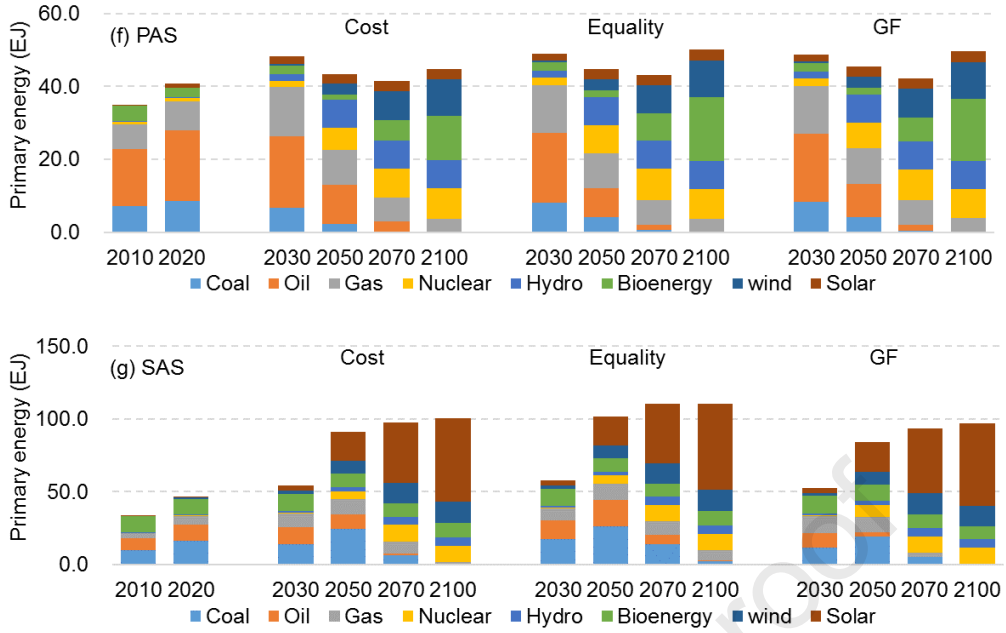
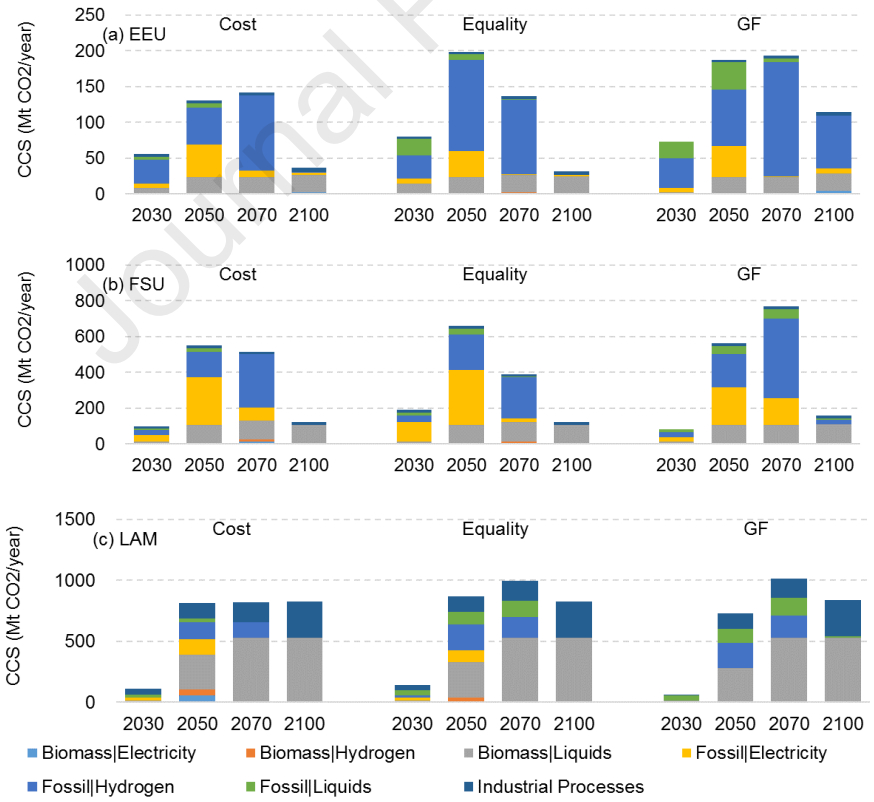


Figure S3 Primary energy structure under cost-effectiveness, equality, and grandfathering (GF) principals in EEU, FSU, LAM, MEA, PAO, PAS and SAS

6. CO_2 mitigation of CCS technologies in other regions



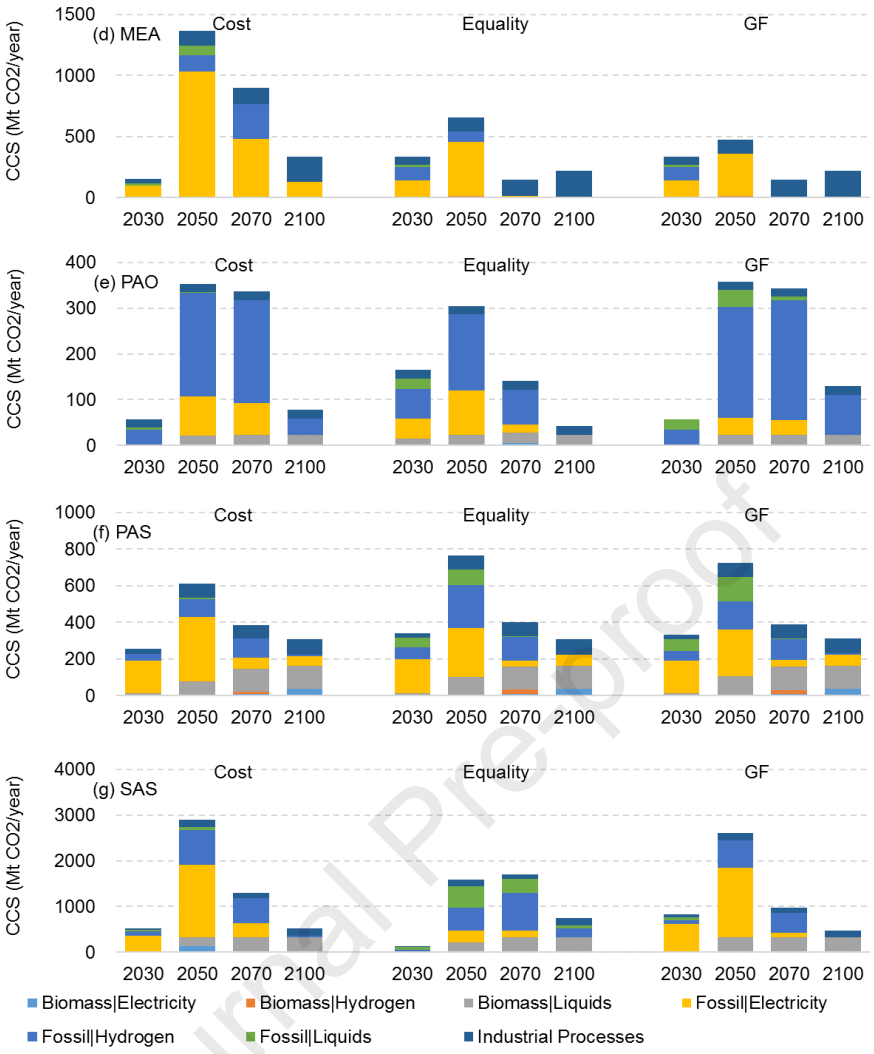


Figure S4 CO_2 Mitigations of CCS technology under cost-effectiveness, equality, and grandfathering (GF) principals in EEU, FSU, LAM, MEA, PAO, PAS and SAS

7. Energy investment in other regions

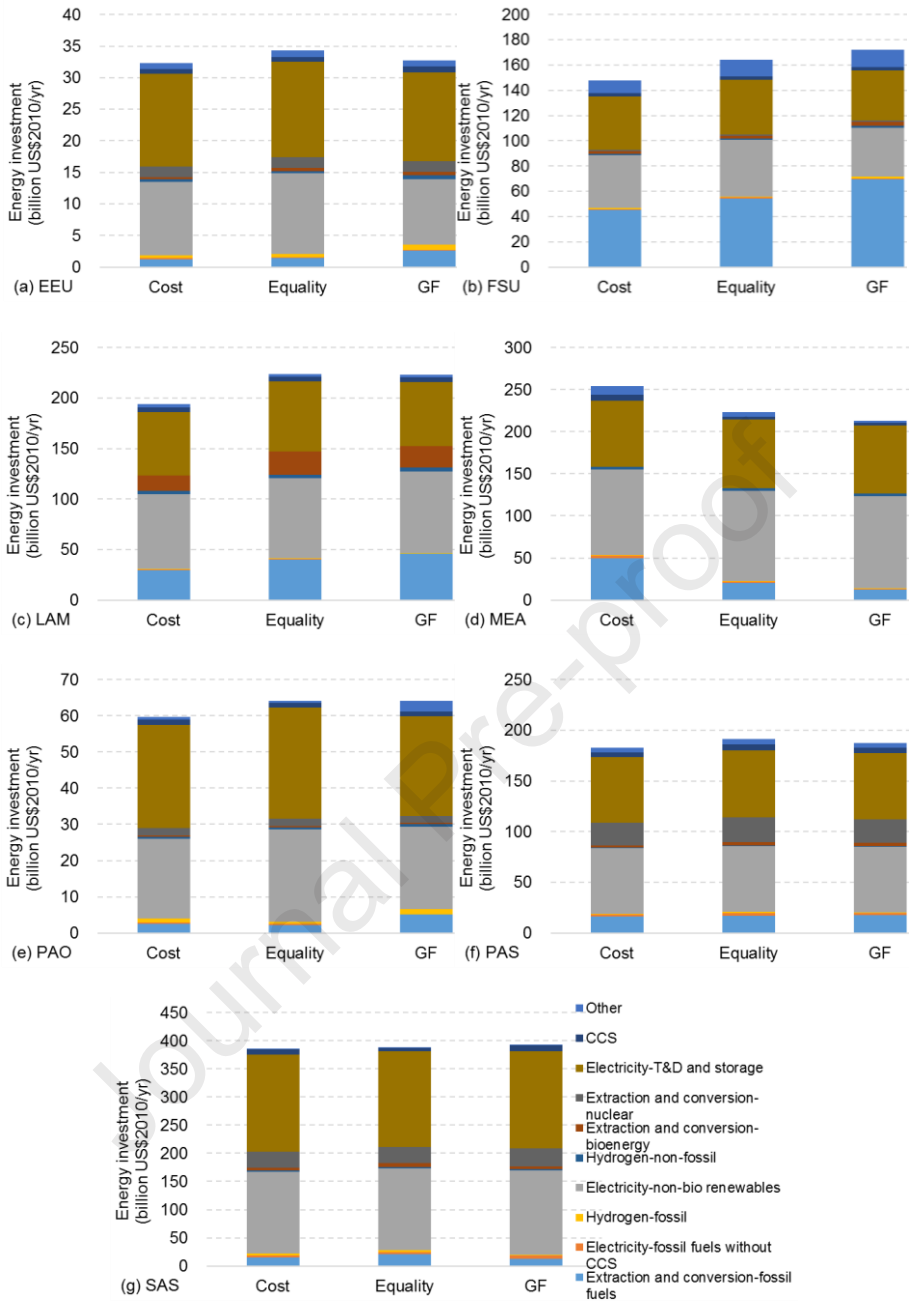


Figure S5 Average annual investment in energy supply over 2030-2100 under cost-effectiveness, equality, and grandfathering (GF) principals in EEU, FSU, LAM, MEA, PAO, PAS and SAS

8. Relationship between the energy investment in the supply side and the carbon quota

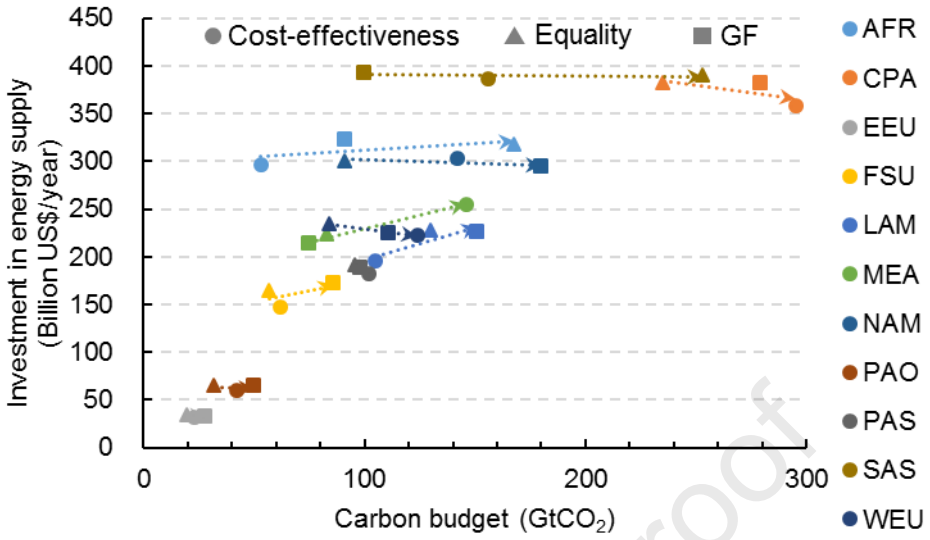


Figure S6 Relationship between the energy investment in the supply side and the carbon quota under cost-effectiveness, equality and grandfathering (GF) principles

- Allocation of carbon budget for 11 world regions is estimated under 3 principles
- Effects of allocation principles on emissions and energy transition are investigated
- The effects of carbon quota on MAC and energy investment are different.
- International cooperation can help achieve climate goals in a cost-effective way

Xiaotong Chen: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing-Original Draft, Visualization. Fang Yang: Conceptualization, Formal analysis, Investigation, Supervision, Funding acquisition. Shining Zhang: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - Review & Editing, Project administration. Behnam Zakeri: Methodology, Investigation, Revision. Xing Chen: Methodology, Investigation. Changyi Liu: Investigation, Writing - Review & Editing. Fangxin Hou: Software.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: