“Visible and Invisible”- understanding energy transitions through carbon lock-ins

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4

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Potsdam Institute for Climate Impact Research

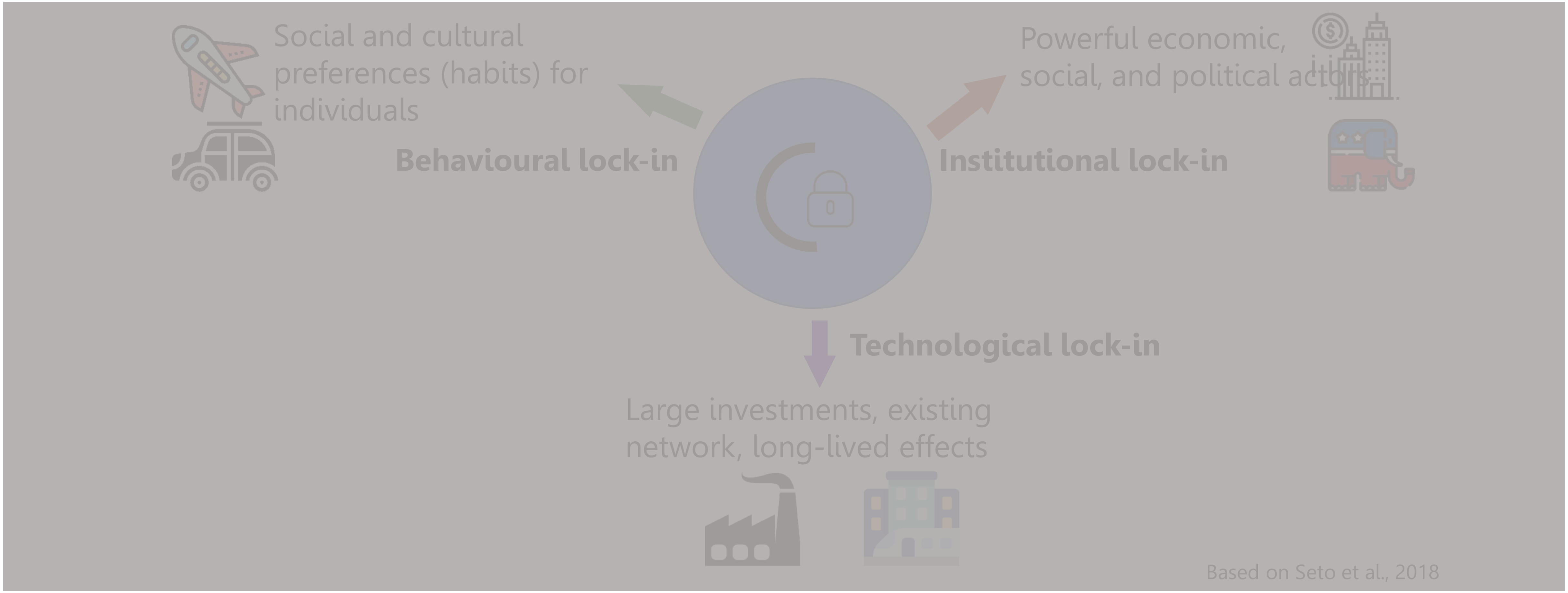
Motivation of my PhD

- We need an energy transition – get rid of fossil and embrace RE.
- This can be achieved through policies (among other things $_{\text{magic}}$).
- But, policy-making is fickle .
- Our hope is to steer policy.
  - By informing the impacts of current policies,
  - By providing visions of the future and their outcomes
- Through:

  Our understanding of energy, economic and political sciences.

Carbon lock-ins

the tendency of carbon-intensive technological systems to **persist over time (inertia)**, *locking -out* lower-carbon alternatives



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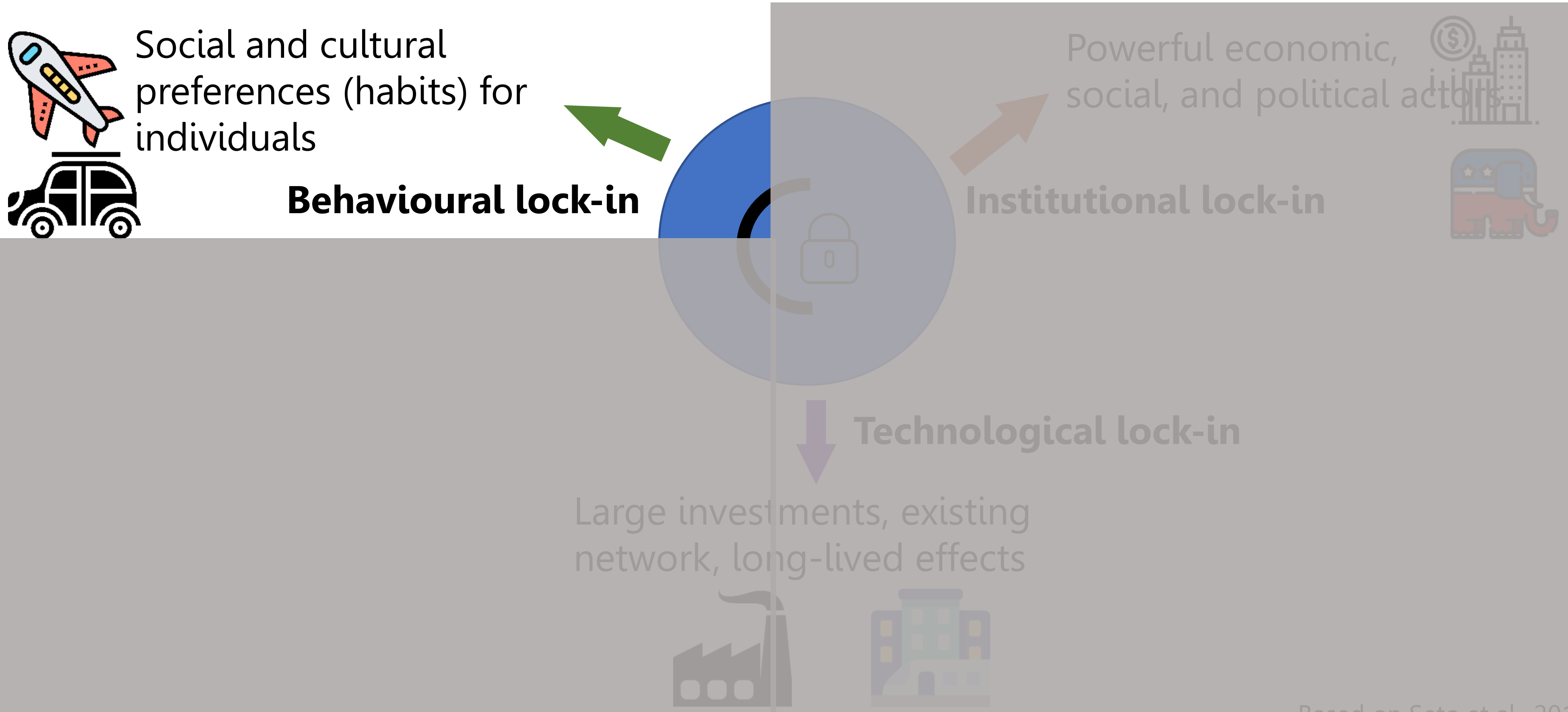

Based on Seto et al., 2018

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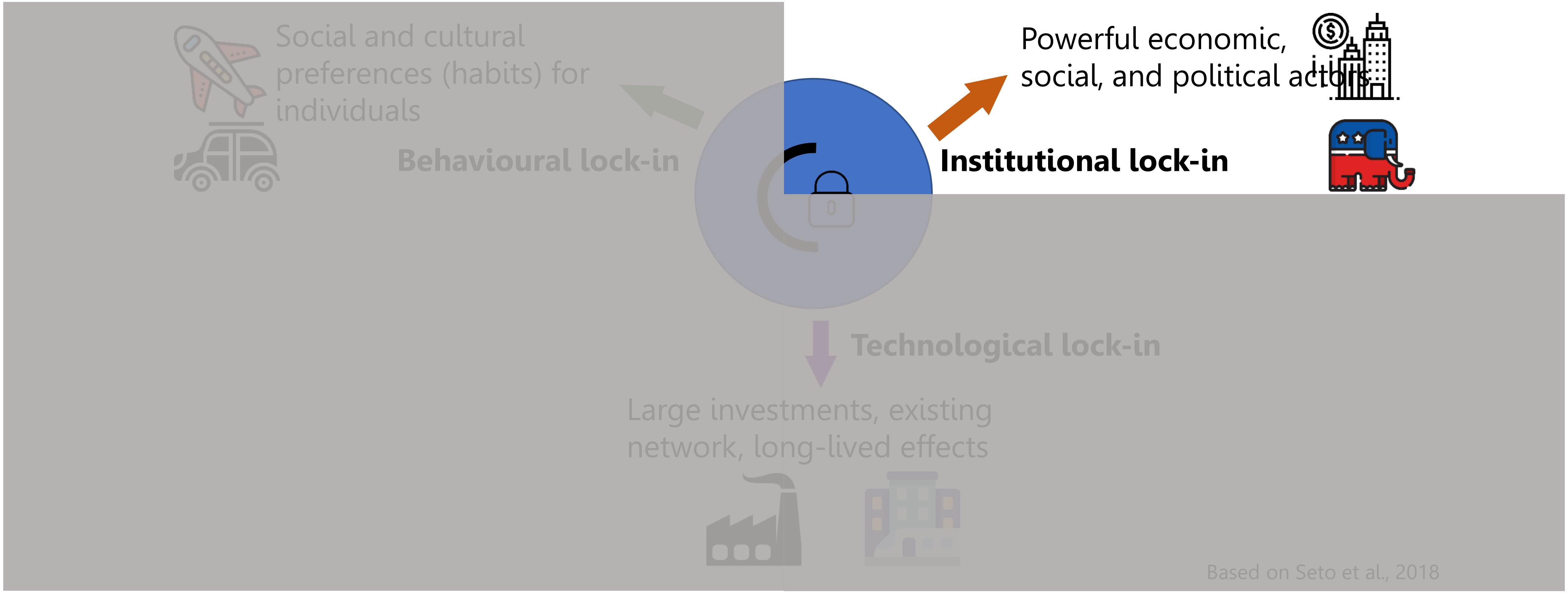


Carbon lock-ins

the tendency of carbon-intensive technological systems to **persist over time (inertia)**, *locking -out* lower-carbon alternatives

Social and cultural preferences (habits) for individuals

Behavioural lock-in

Powerful economic, social, and political actors

Institutional lock-in

Technological lock-in

Large investments, existing network, long-lived effects

Based on Seto et al., 2018

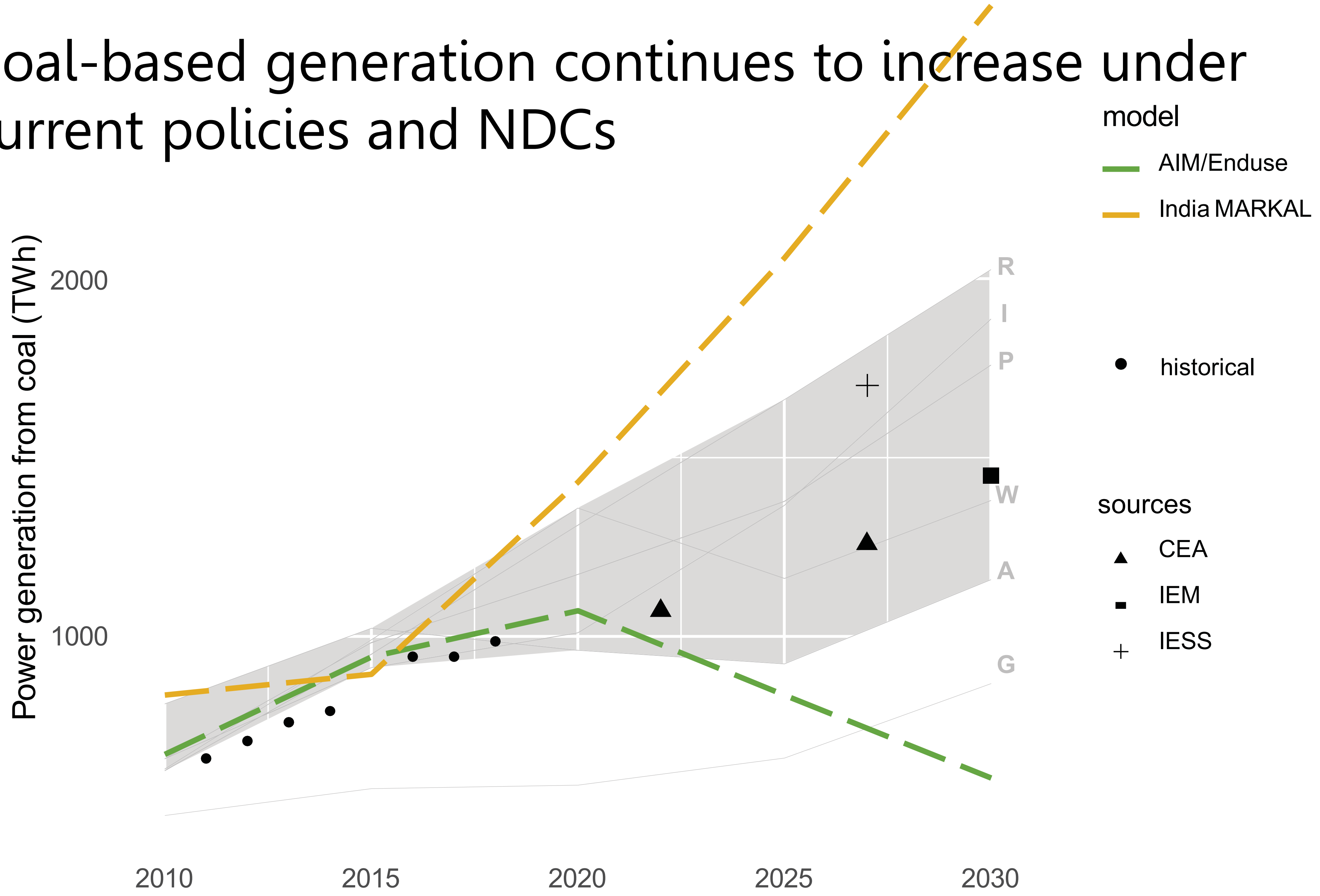
Reducing stranded assets through early action in the Indian power sector

Aman Malik, Christoph Bertram, Jacques Despres, Johannes Emmerling, Shinichiro Fujimori, Amit Garg , Elmar Kriegler, Gunnar Luderer, Ritu Mathur, Mark Roelfsema, Swapnil Shekhar, Saritha Vishwanathan , Zoi Vrontisi

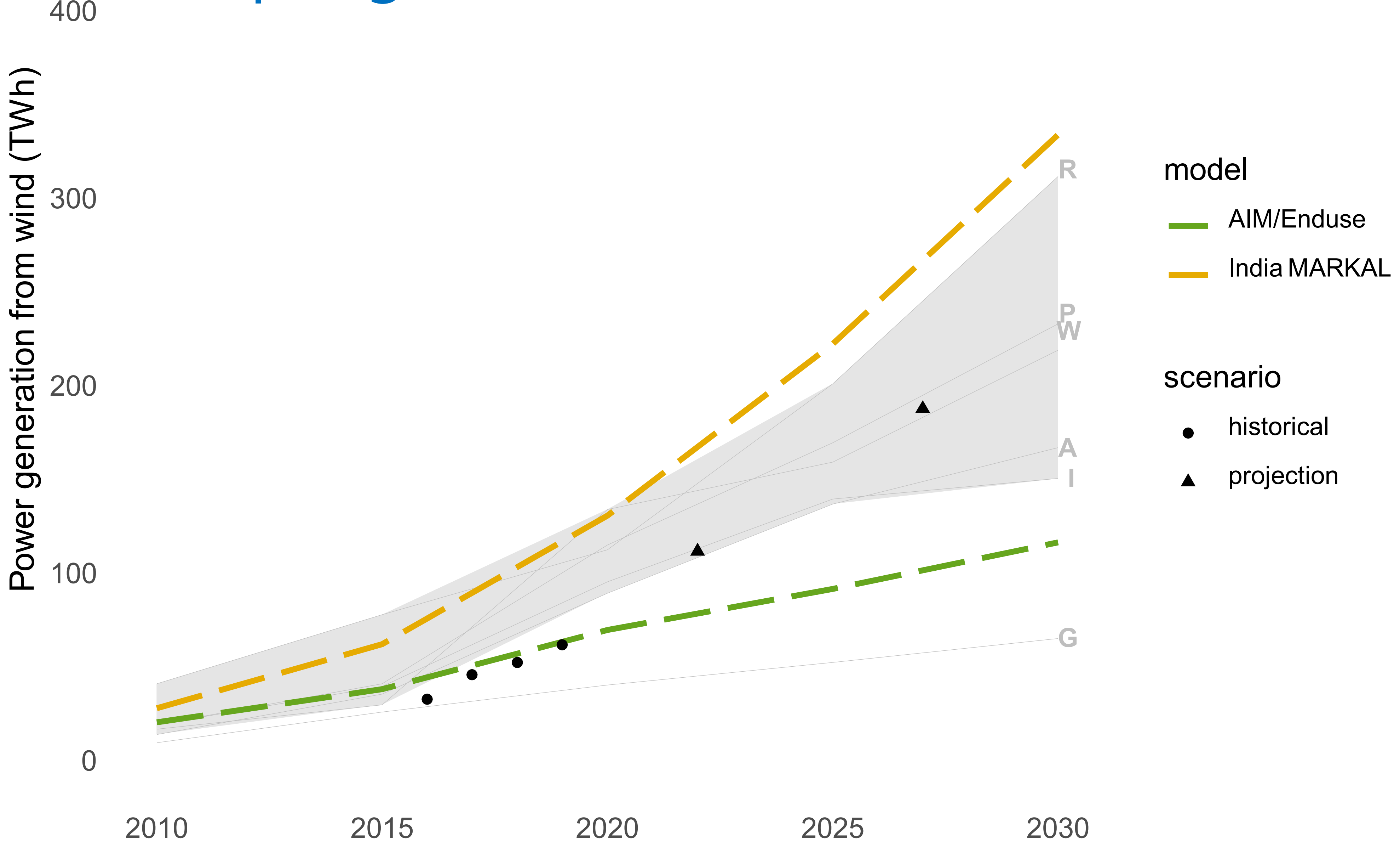
Multi-model scenario comparison

Scenario name	Definition
Early action	Currently implemented policies till 2020 followed by a carbon budget constraint till 2100, corresponding to well-below 2 C.
Delayed action	Currently implemented policies and NDC till 2030 followed by carbon budget constraint till 2100, corresponding to well-below 2 C

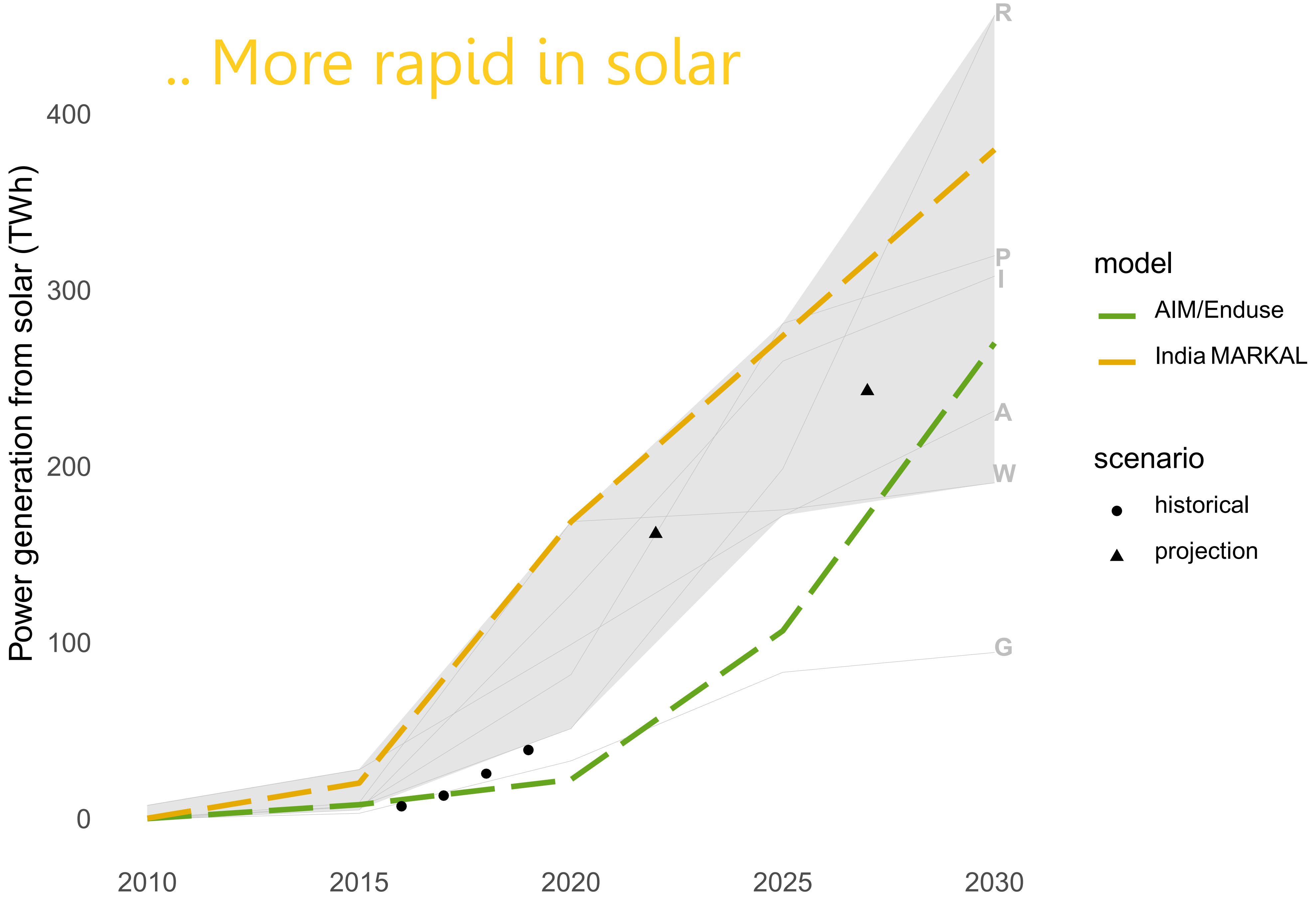
Coal-based generation continues to increase under current policies and NDCs



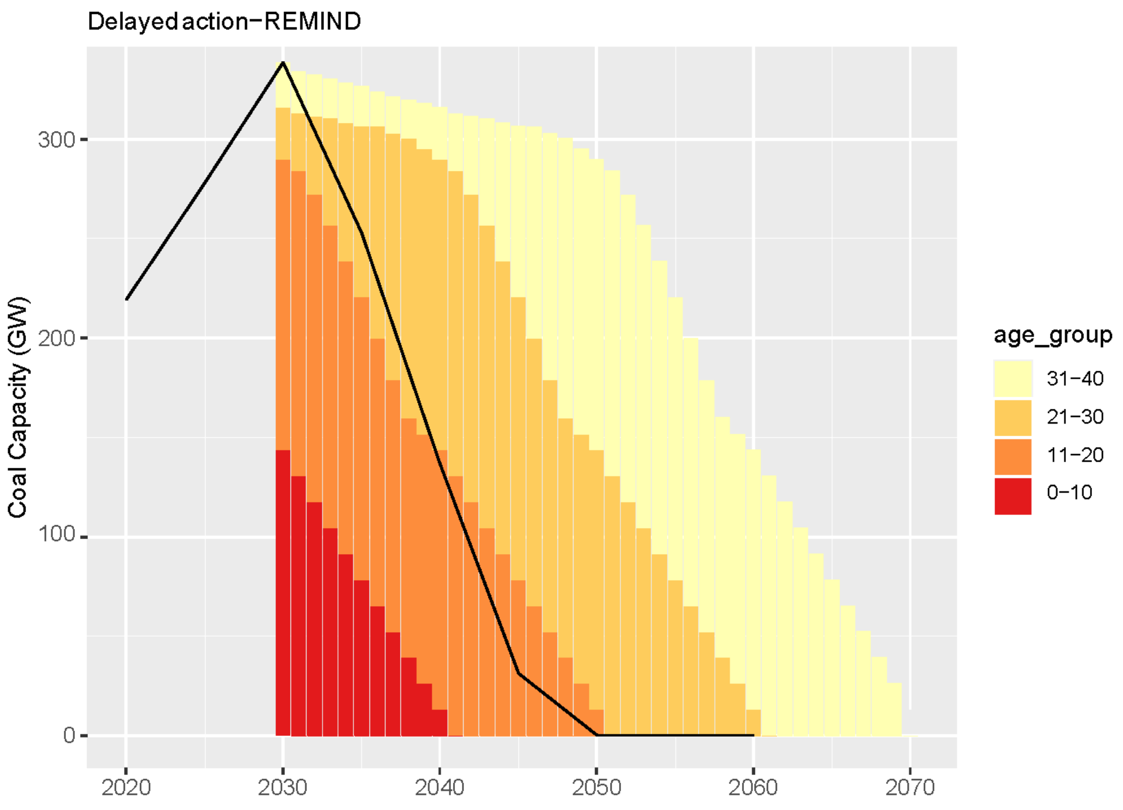
Rapid growth in wind



.. More rapid in solar



Delayed mitigation causes more stranding from plants yet to be built, compared to early action



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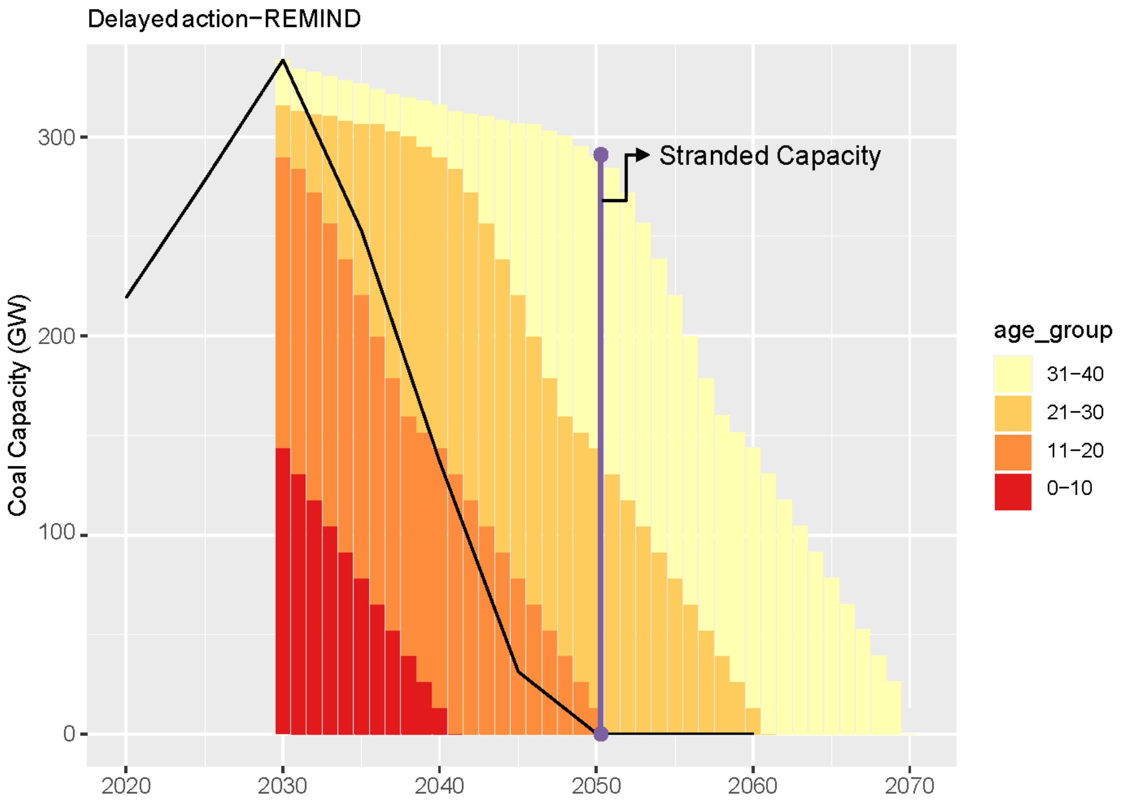

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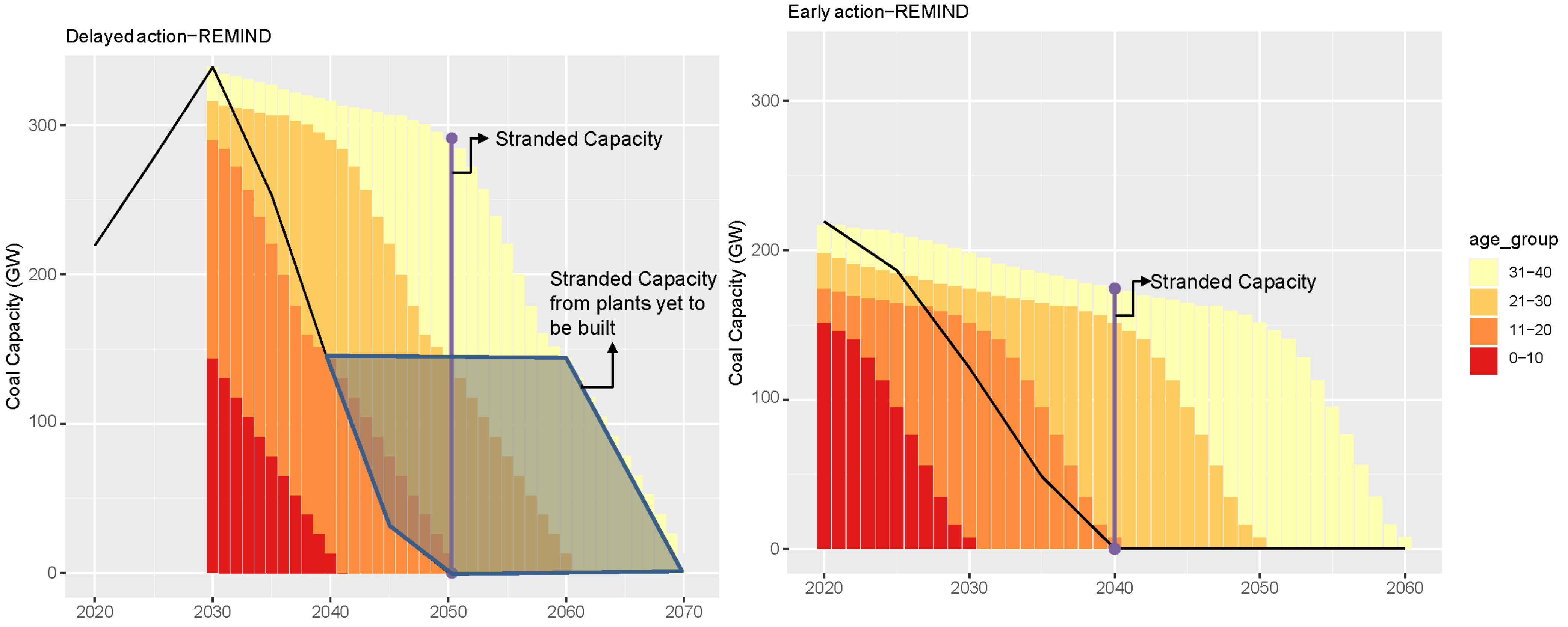
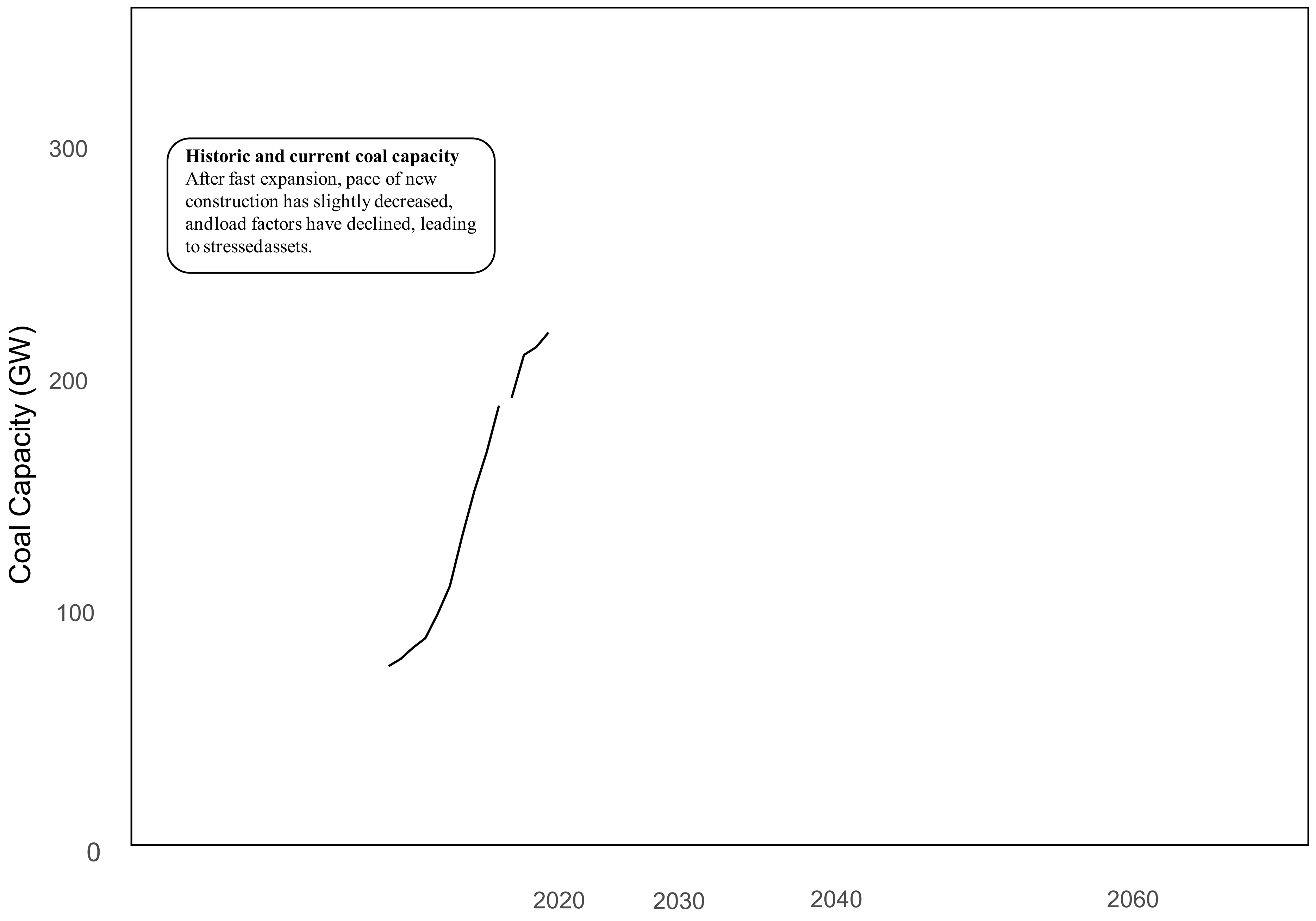
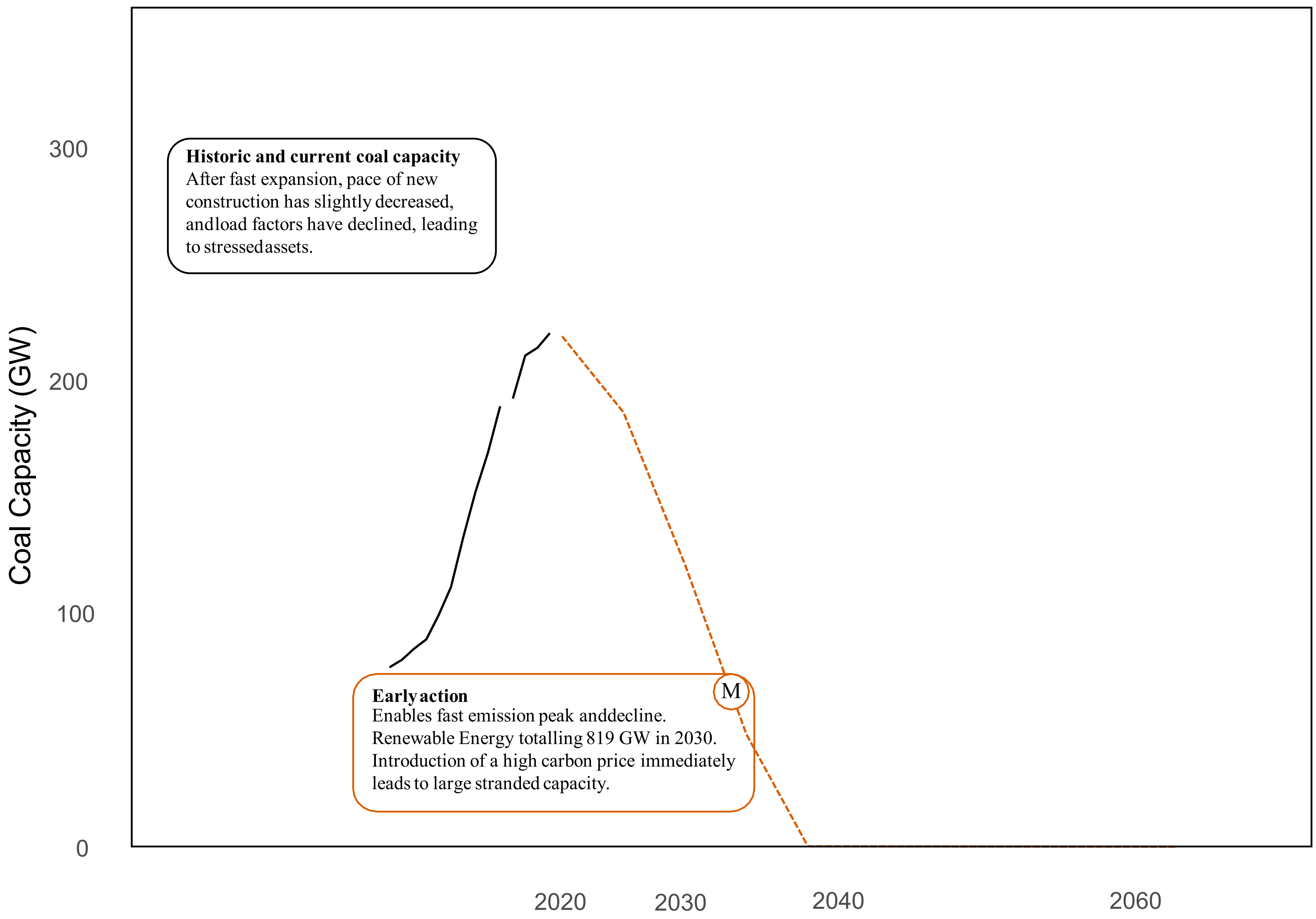




Coal Capacity (GW)
300
200
100
0
2020
2030
2040
2060
Historic and current coal capacity
After fast expansion, pace of new construction has slightly decreased, andload factors have declined, leading to stressedassets.



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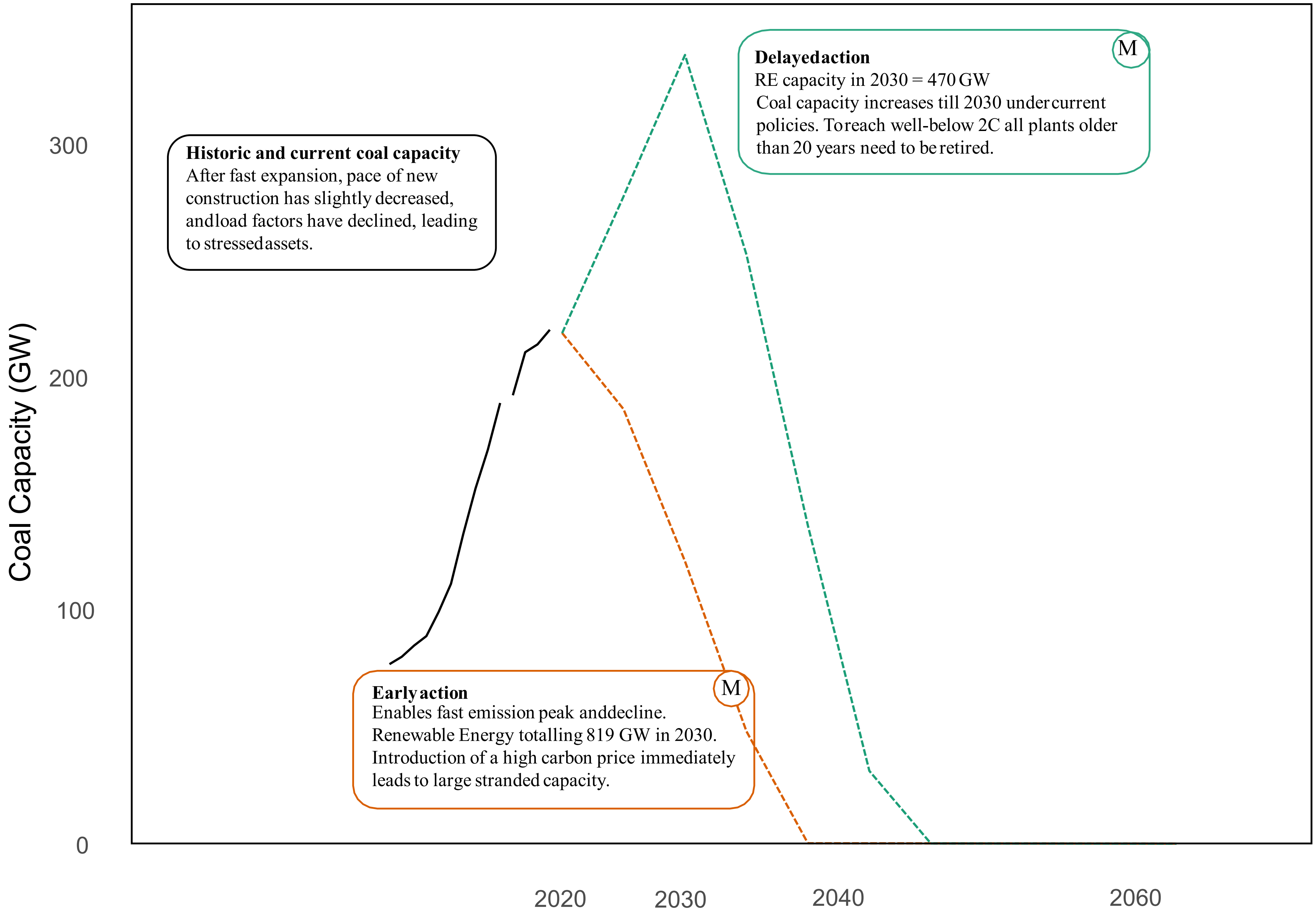
After fast expansion, pace of new construction has slightly decreased, and load factors have declined, leading to stressed assets.
Early action
Enables fast emission peak and decline.
Renewable Energy totalling 819 GW in 2030.
Introduction of a high carbon price immediately leads to large stranded capacity.
M



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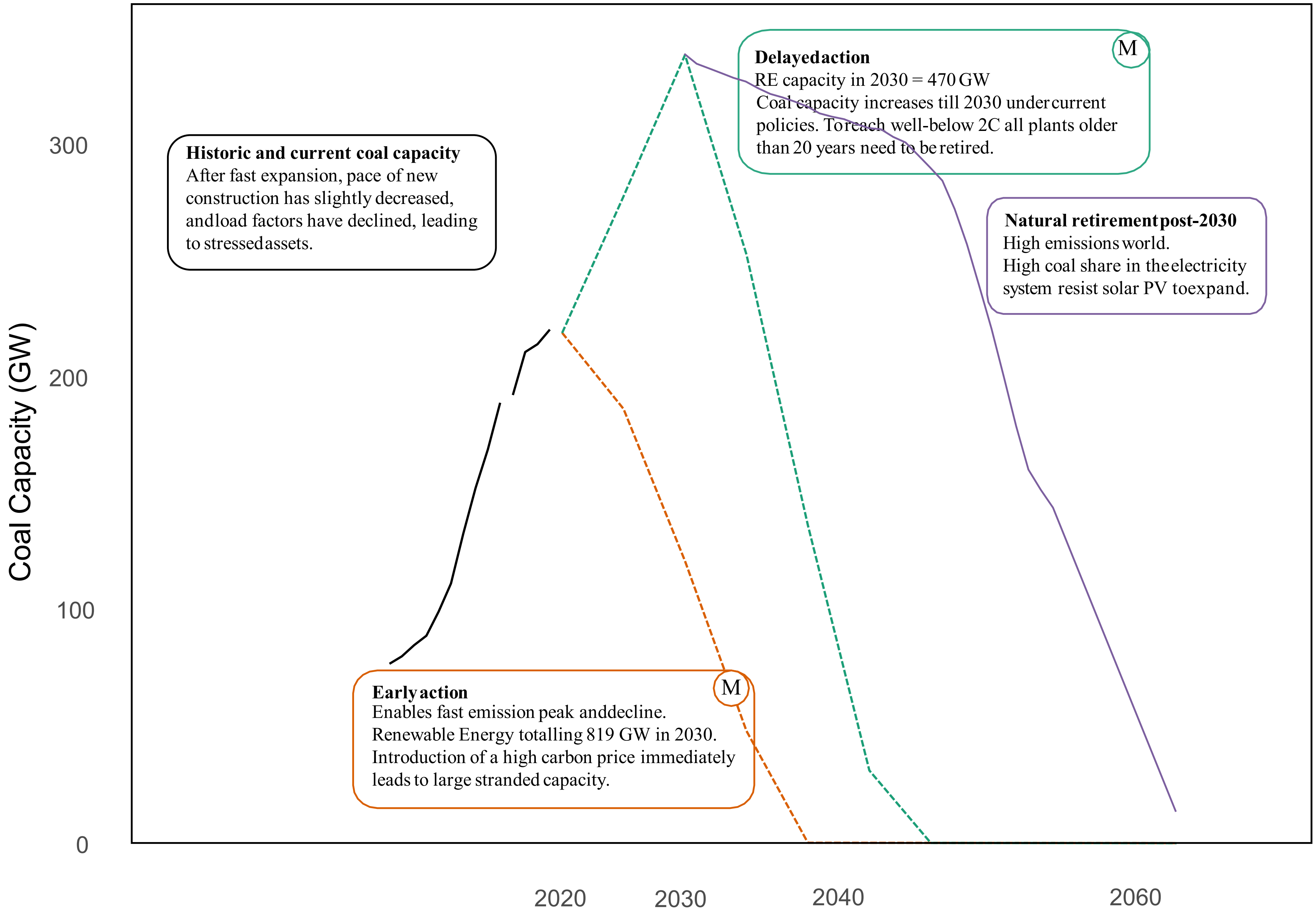

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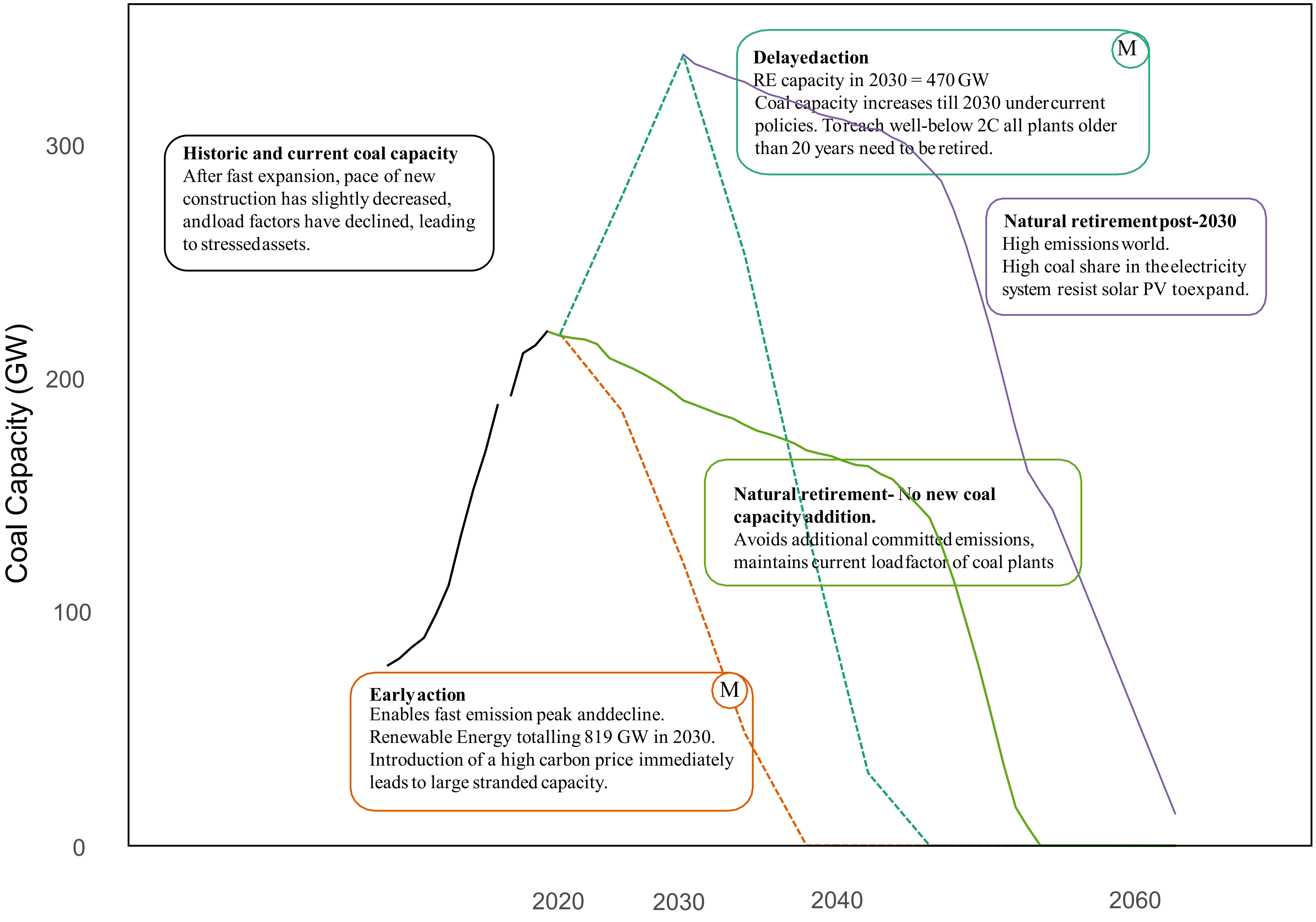
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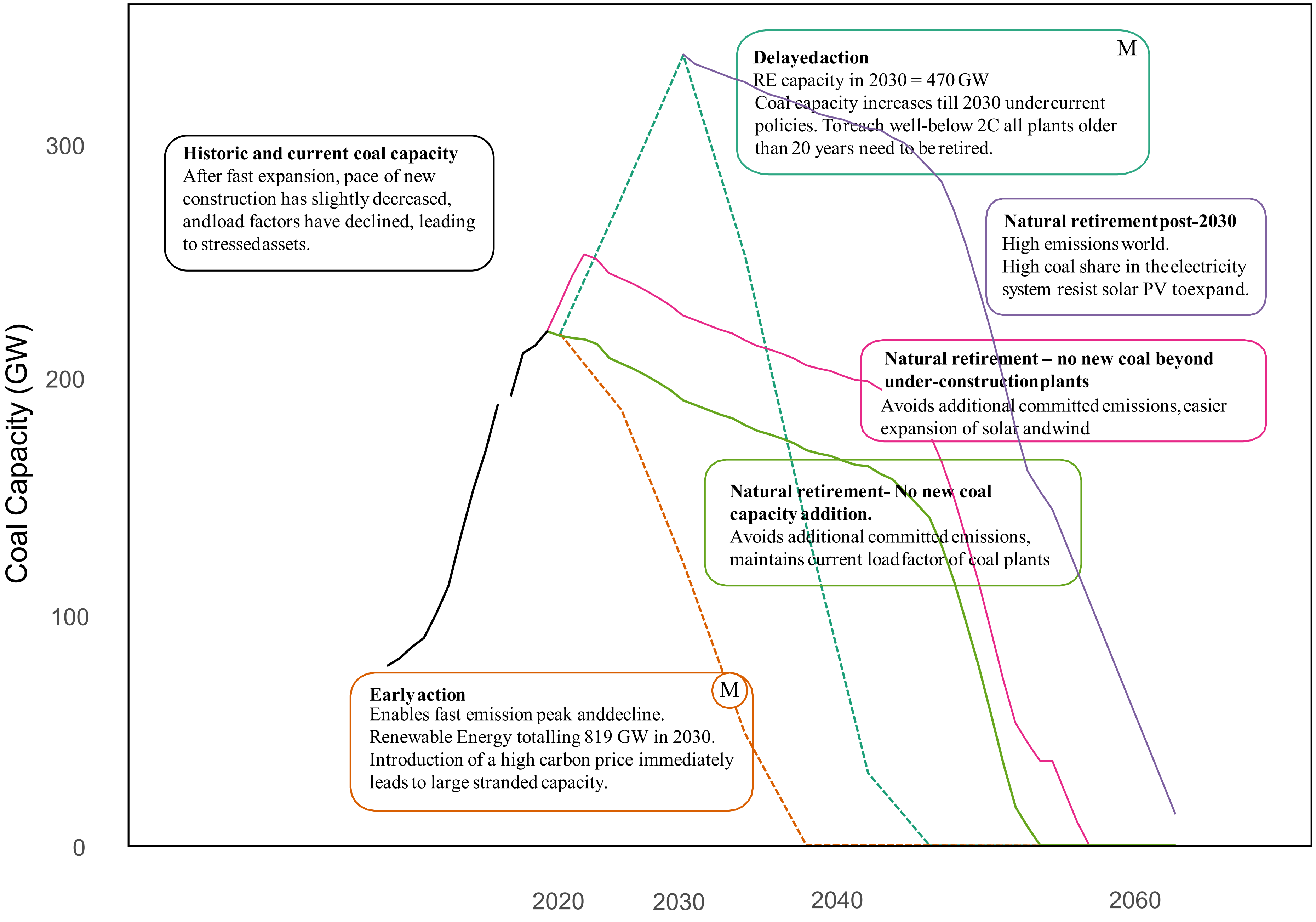

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High emissions world.
High coal share in the electricity system resist solar PV to expand.
Natural retirement – no new coal beyond under-construction plants
Avoids additional committed emissions, easier expansion of solar and wind
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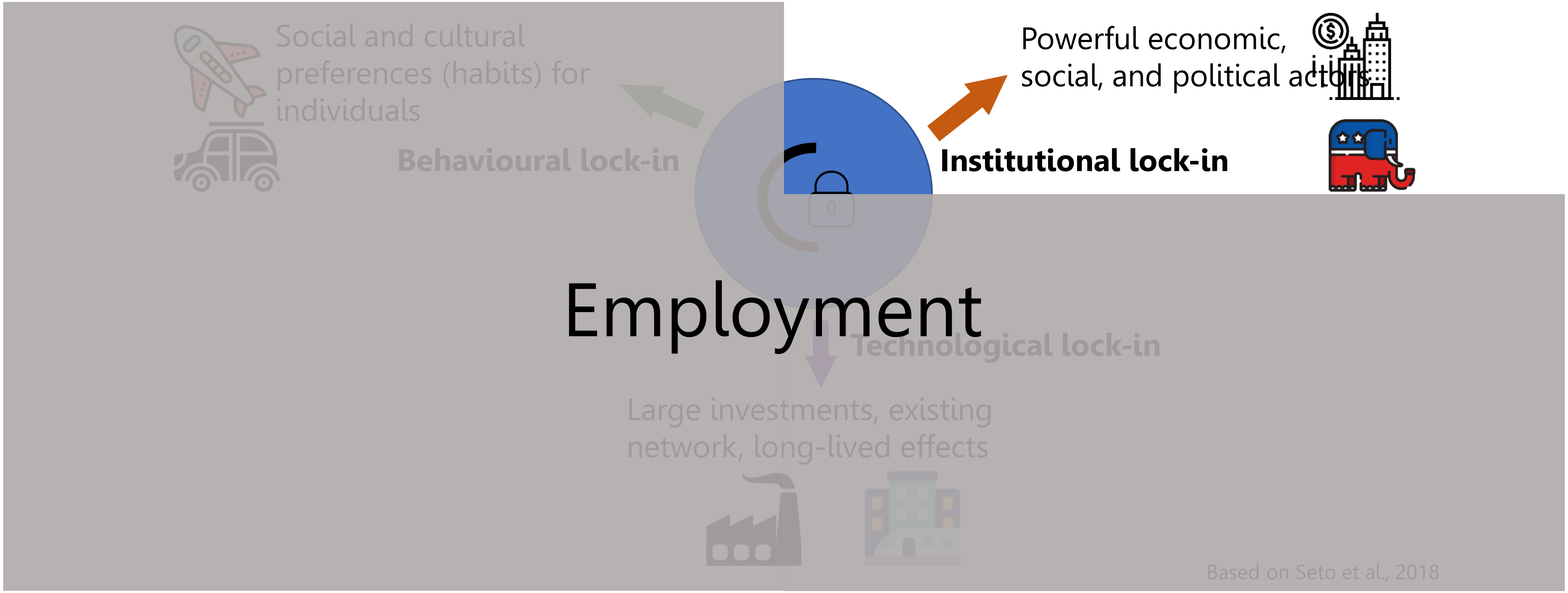
Main insights

- Under current policies and pledges of the Indian NDC (nationally determined contribution), coal-based power generation continues to increase.
- Solar and Wind grow rapidly through ambitious policy targets and decreasing costs.
- Delays in stringent climate mitigation require more stranding, as it allows more coal plants to be built in the near-term (132-233 GW).
- A policy limiting coal plants to those under construction combined with higher solar targets could prevent significant stranded capacity and allow higher mitigation ambition now and in the future.

However, remember policy-making is fickle!

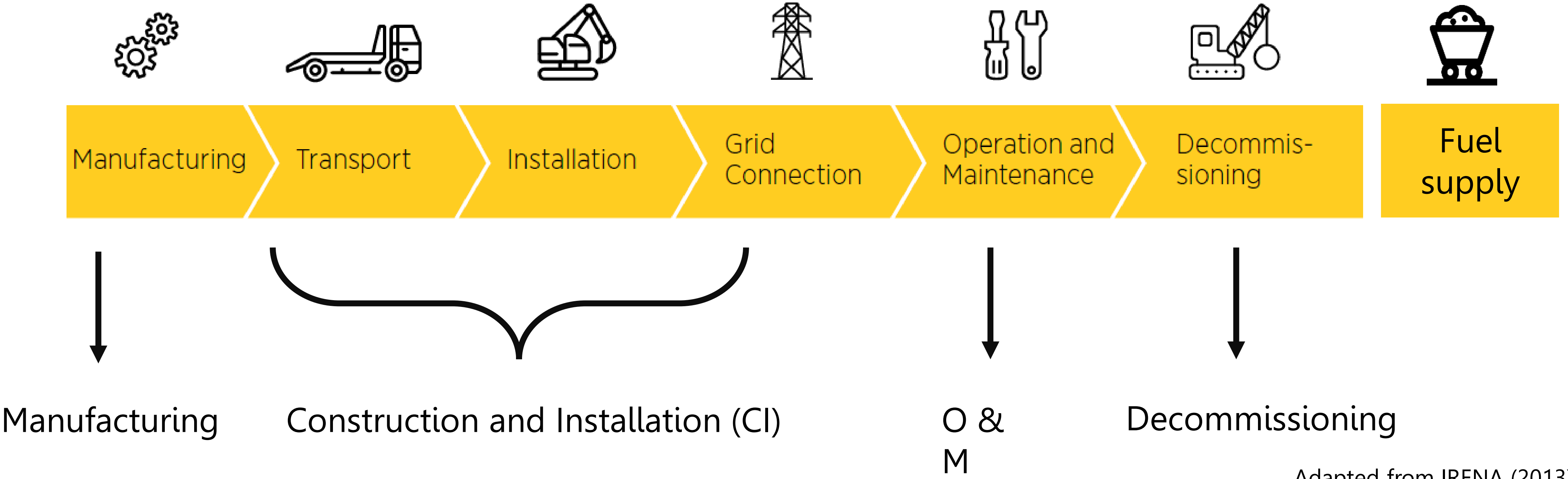


Employment analysis in REMIND

Ex-post analysis

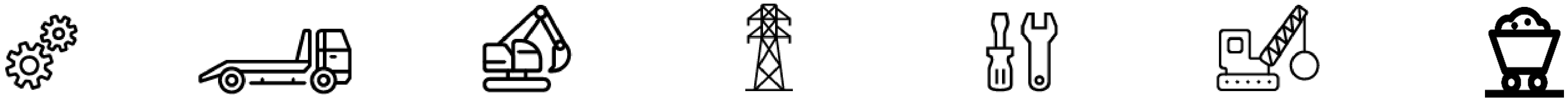
To be able to find direct jobs created and lost in different power producing sectors for different scenarios in REMIND.

Technology value chain



Adapted from IRENA (2013)

Difference across space and time

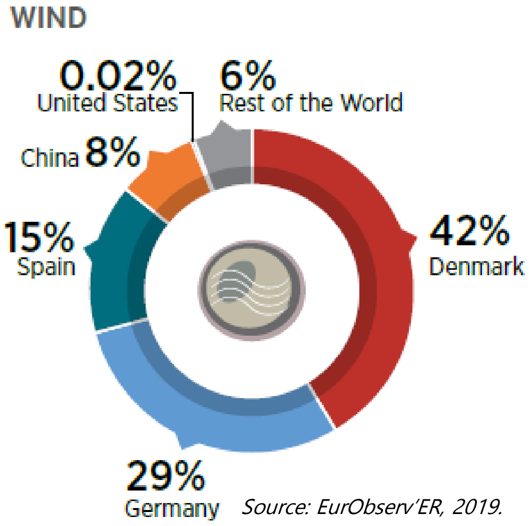


Manufacturing → Transport → Installation → Grid Connection → Operation and Maintenance → Decommis-sioning

Fuel supply

Domestic

International



Source: EurObserv'ER, 2019.

Short-term

Long-term

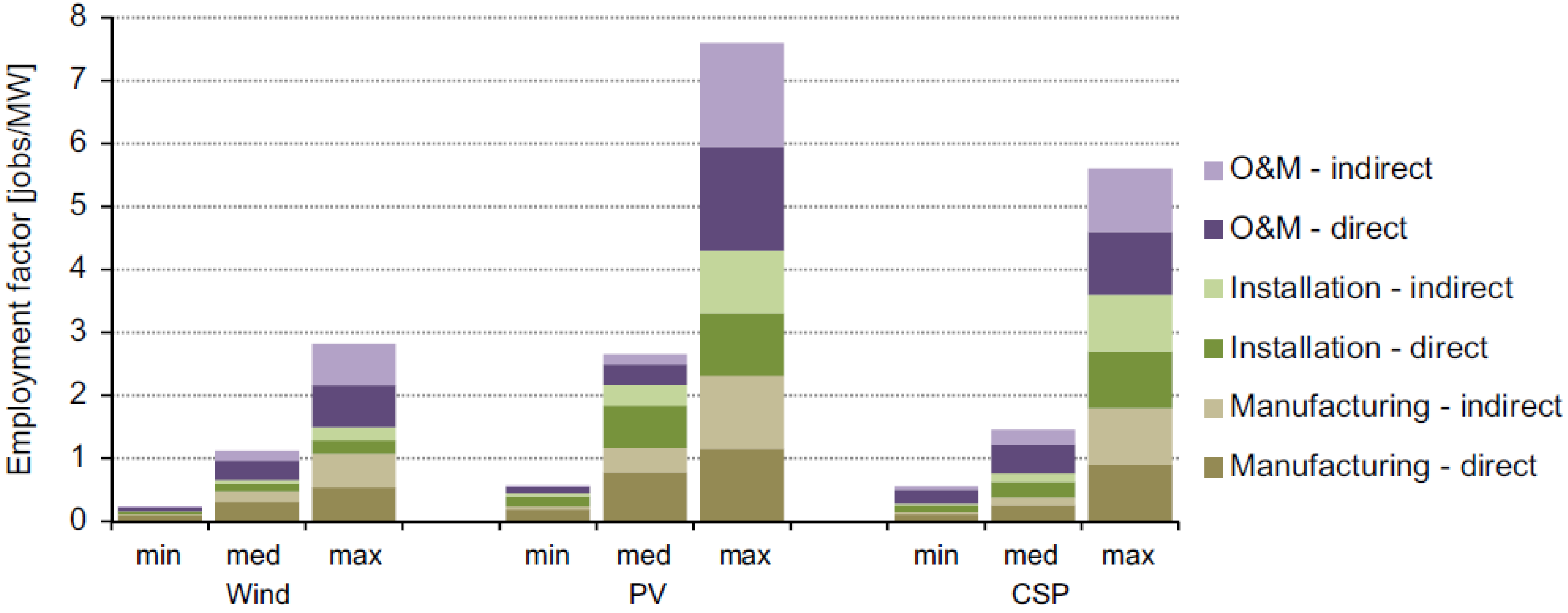
Types of employment

Direct	Indirect	Induced
Jobs related to core activities. E.g., specialty contractors, construction workers, clean-up crews, truck drivers	Extraction and processing of raw materials. E.g., copper and steel, marketing and selling, consultancy, R & D.	Jobs arising from the economic activities of direct and indirect employees.

Measuring Direct Employment - Employment factors

- Employment factors indicate the number of full-time equivalent (FTE) jobs created per physical unit of choice. (e.g., Jobs/MW or Jobs/MWh or Jobs/PJ)
- Different employment factors for different phases of the life cycle
- Measures only direct jobs - does not account for economic interactions and other dynamic effects
- The quickest, most methodologically simple, and least expensive approach

Employment factors range widely for the same technology



Based on ~ 30 studies (Cameron et al. 2015)

As well as within a country

Project	Project size MW	Installation Jobs/MW	O/M jobs/MW
Wind farm 1	4100	1.57	0.31
Wind farm 2	3700	5.8	0.2
Wind farm 3	3640	7.4	0.6
Wind farm 4	1800	0.7	0.14
Wind farm 5	1700	5.12	0.35
Wind farm 6	390	0.48	0.15
Wind farm 7	107	0.07	0.3
Wind farm 8	50	0.51	0.45
Wind farm 9	30	0.87	0.36
Wind farm 10	25	0.16	0.24

Source: NREL (2004), data for USA

Employment factor approach

Jobs in region = Manufacturing + Construction + Operation and maintenance (O&M) + Fuel + Heat

Construction = MW installed per year x Construction employment factor x Regional job multiplier for year

Manufacturing (for local use) = MW installed per year in region x Manufacturing employment factor x Regional job multiplier for year x % local manufacturing

Heat supply = MW installed per year x Employment factor for heat x Regional job multiplier for year

Fuel supply (coal, gas and biomass) = Primary energy demand plus exports x Fuel employment factor (always regional for coal) x Regional job multiplier for year x % of local production

Employment factors – CMI, O & M

	Construction/installation	Manufacturing	Operations & maintenance	Fuel – PRIMARY energy demand
	Job years/ MW	Job years/ MW	Jobs/MW	
Coal	11.4	5.1	0.14	Regional
Gas	1.8	2.9	0.14	Regional
Nuclear	11.8	1.3	0.6	0.001 jobs per GWh final energy demand
Biomass	14.0	2.9	1.5	29.9 jobs/PJ
Hydro-large	7.5	3.9	0.2	
Hydro-small	15.8	11.1	4.9	
Wind onshore	3.0	3.4	0.3	
Wind offshore	6.5	13.6	0.15	
PV	13.0	6.7	0.7	
Geothermal	6.8	3.9	0.4	
Solar thermal	8.9	4.0	0.7	
Ocean	10.3	10.3	0.6	
Geothermal – heat	6.9 jobs/ MW (construction and manufacturing)			
Solar – heat	8.4 jobs/ MW (construction and manufacturing)			
Nuclear decommissioning	0.95 jobs per MW decommissioned			
Combined heat and power	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc., increased by a factor of 1.5 for O&M only.			

Dominish et al. (2019)

Employment factors – fuel supply

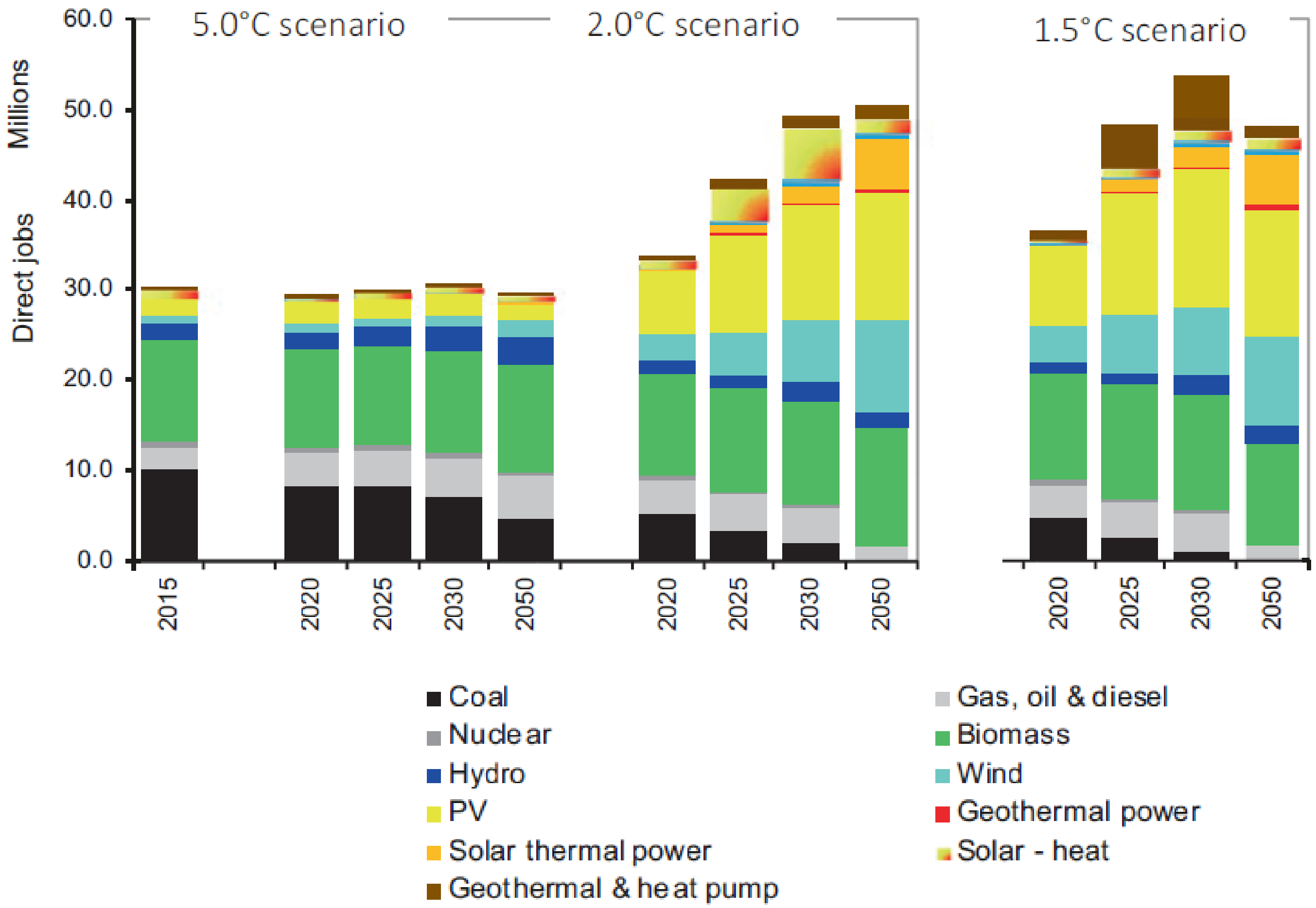
	Employment factor Jobs per PJ	Tonnes per person per year (coal equivalent)
World average	36.2	943
OECD North America	3.5	9613
OECD Europe	36.2	942
OECD Asia-Oceania	3.6	9455
India	33.6	1016
China	52.9	645
Africa	13.7	2482
Eastern Europe/Eurasia	36.0	948
Developing Asia	6.5	5273
Latin America	12.5	2725
Middle East	Used world average because no employment data were available	

Regional multipliers

	2015	2020	2030	2040	2050
OECD (North America, Europe, Pacific)	1.0	1.0	1.0	1.0	1.0
Latin America	3.4	3.4	3.4	3.1	2.9
Africa	5.7	5.7	5.6	5.2	4.9
Middle East	1.4	1.5	1.5	1.4	1.3
Eastern Europe/Eurasia	2.4	2.4	2.2	2.0	1.8
India	7.0	5.6	3.7	2.7	2.0
Developing Asia	6.1	5.3	4.2	3.5	2.9
China	2.6	2.2	1.6	1.3	1.1

Dominish et al. (2019)

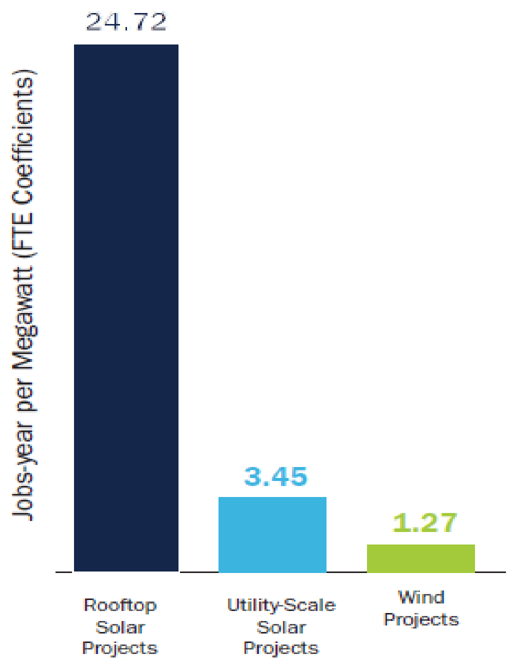
World employment in the energy sector



Teske et al. (2015), Dominish et al. (2019)

Limitations of Employment factor approach

- Using regional factors for developing or emerging countries.
- No sensitivity analysis on employment factors (EFs) or decline factors
- Distinction between technologies. E.g., solar PV and rooftop
- Old data on employment factors, share of trade
- Contribution of learning effects and regional differences of EFs not disintagled.



Kuldeep et al. (2019)

Further outlook and Ideas

- Addressing the limitations of previous studies while analysing with REMIND.

- Starting with India and Europe

- Downscaling jobs –
- Loses and gains don’t coincide geographically

Thank you!

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Questions and Comments?

Backup

Proposed methodology ex-post analysis

Data Input

Employment factors (Jobs/MW)

Trade flows - manufacturing (import and export)

REMIND

Per country
Per technology
Per activity

Between countries
Per technology

Added capacity (AC) (MW) per region.
Existing capacity (EC) (MW) per region

$$
\begin{aligned}
Jobs_{t,R,T} = {} & EC_{t,R,T} \text{ X } EF^{T}_{Inst,OM,Heatsupply} + \\
& EC_{t,R,T} \text{ X } EF^{T}_{localExtract} \text{ X share local}_{R,T} + \\
& (\text{World } EC_{T} - EC_{R}) \text{ X share of export in world extraction}_{R,T} \text{ x } EF^{T}_{localExtract} + \\
& AC_{t,R,T} \text{ X } EF^{T}_{localmanu} \text{ X share local}_{R,T} + \\
& (\text{World } AC_{T} - AC_{R}) \text{ X share of export in world manufacturing}_{R,T} \text{ x } EF^{T}_{localmanu}
\end{aligned}
$$

Proposed methodology downscaling

Objective:

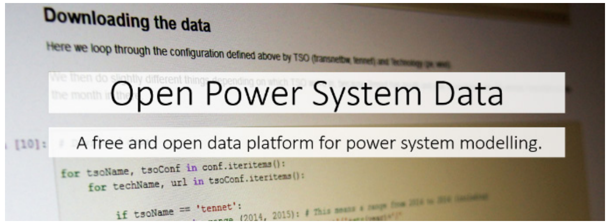
Use current configuration of power plants and mines to downscale jobs from country to sub-regional scale. Extrapolate setup into the future.

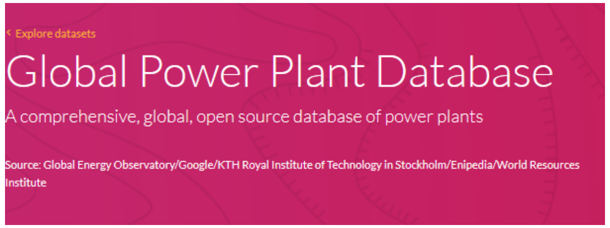
Needed:

1. Bottom-up data on power plants and mines

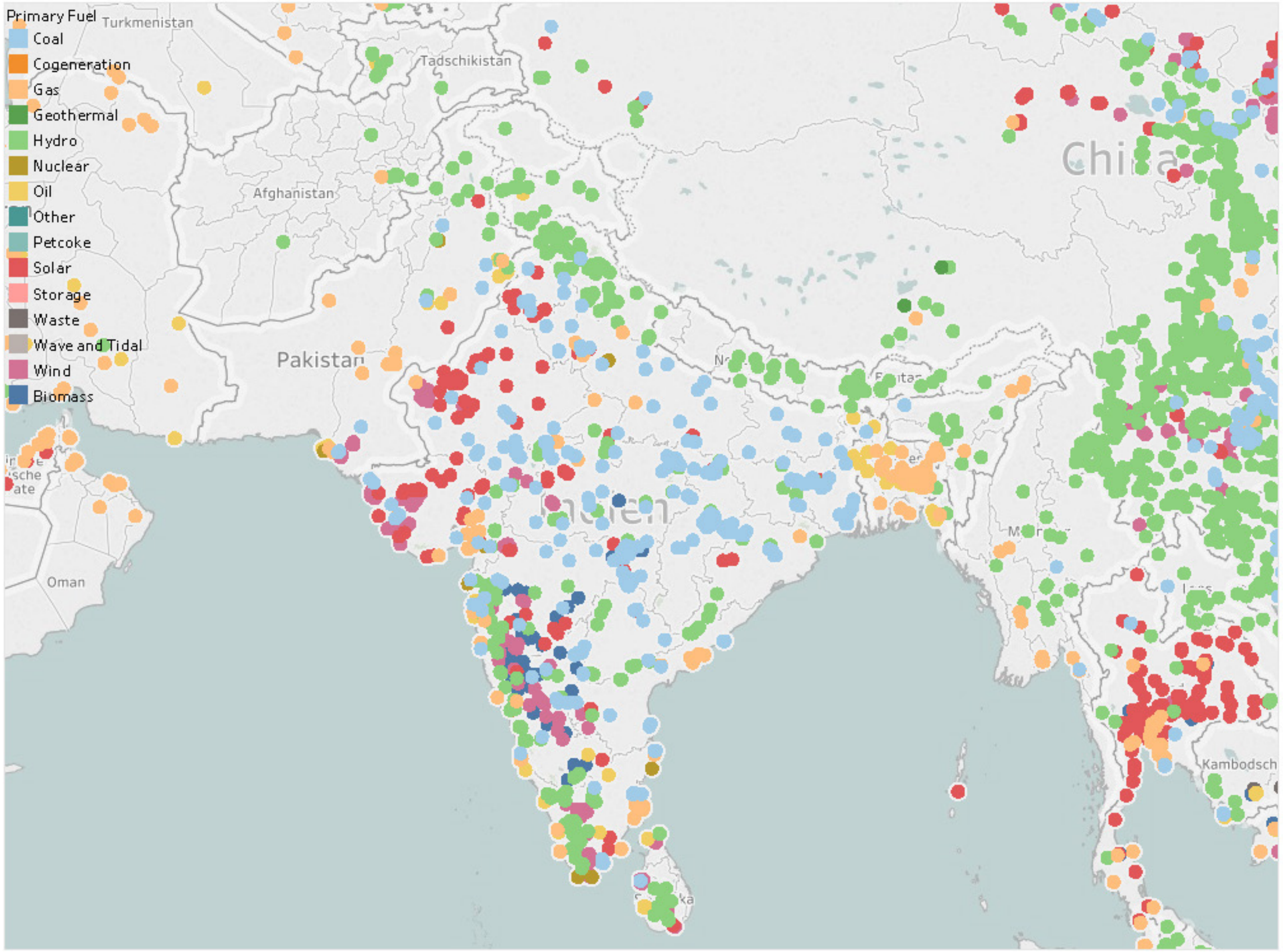
2. Bottom-up data on total employment per technology per country

1. Power plants searching for open-access plant-level data



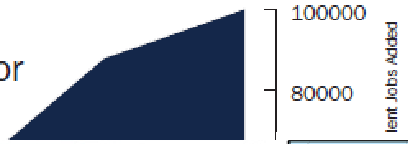


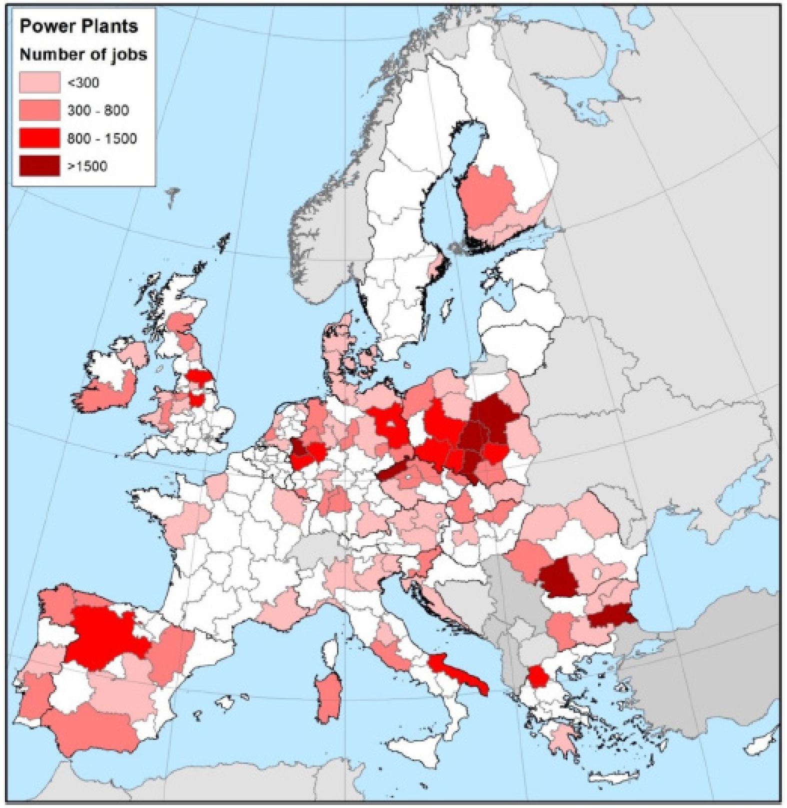
Other sources?

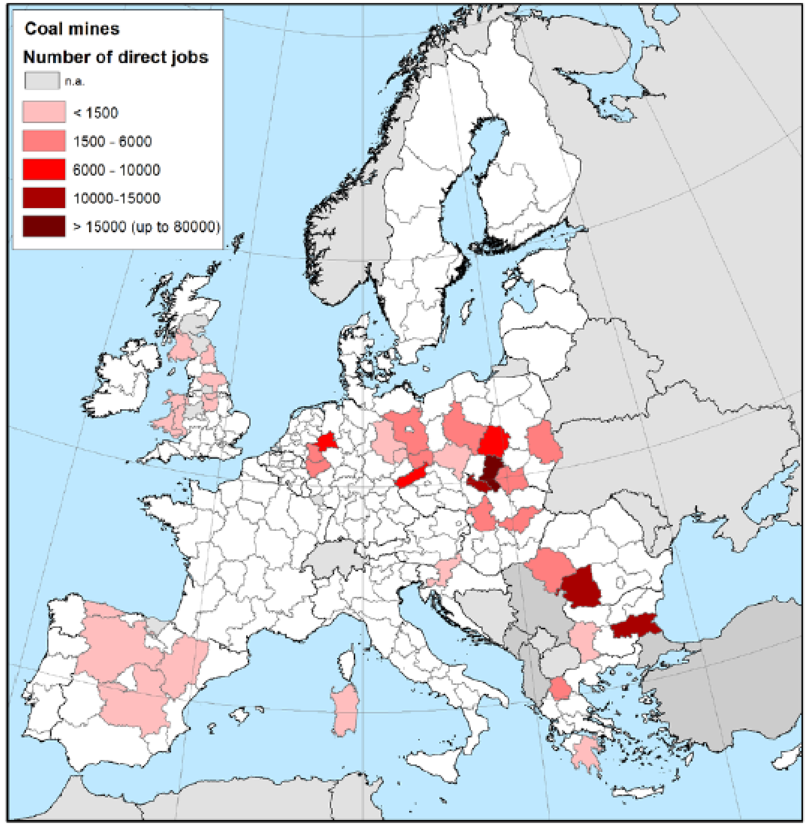


2. Employment data

5-fold increase in the workforce employed in the Indian renewable energy sector between FY14 and FY19.







INDIA 2018

719 000 jobs

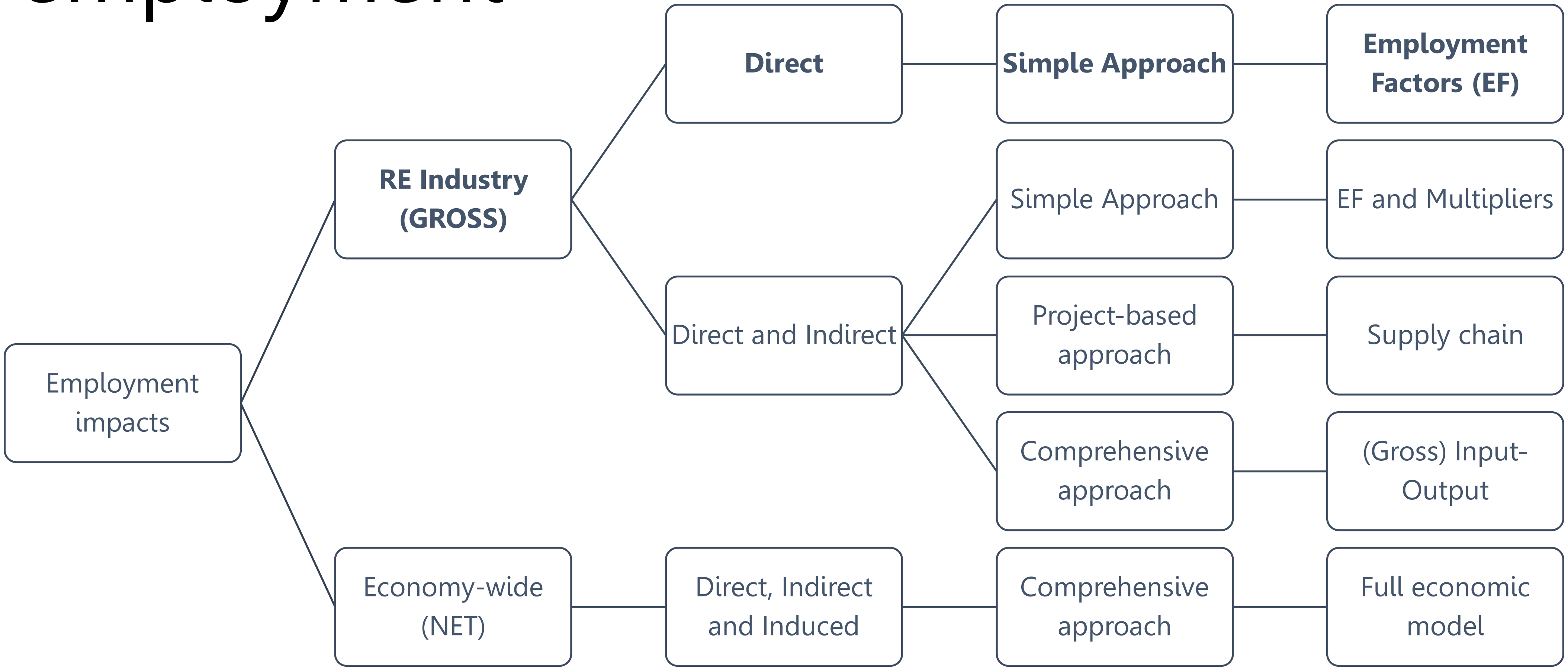
- Hydropower: **347 000** jobs
- Solar PV: **115 000** jobs (Grid-connected)
- Wind: **58 000** jobs

EUROPEAN UNION

1.2 million jobs

- Solid biomass: **387 000** jobs
- Wind: **314 000** jobs
- Solar PV: **96 000** jobs

Other methods of measuring employment



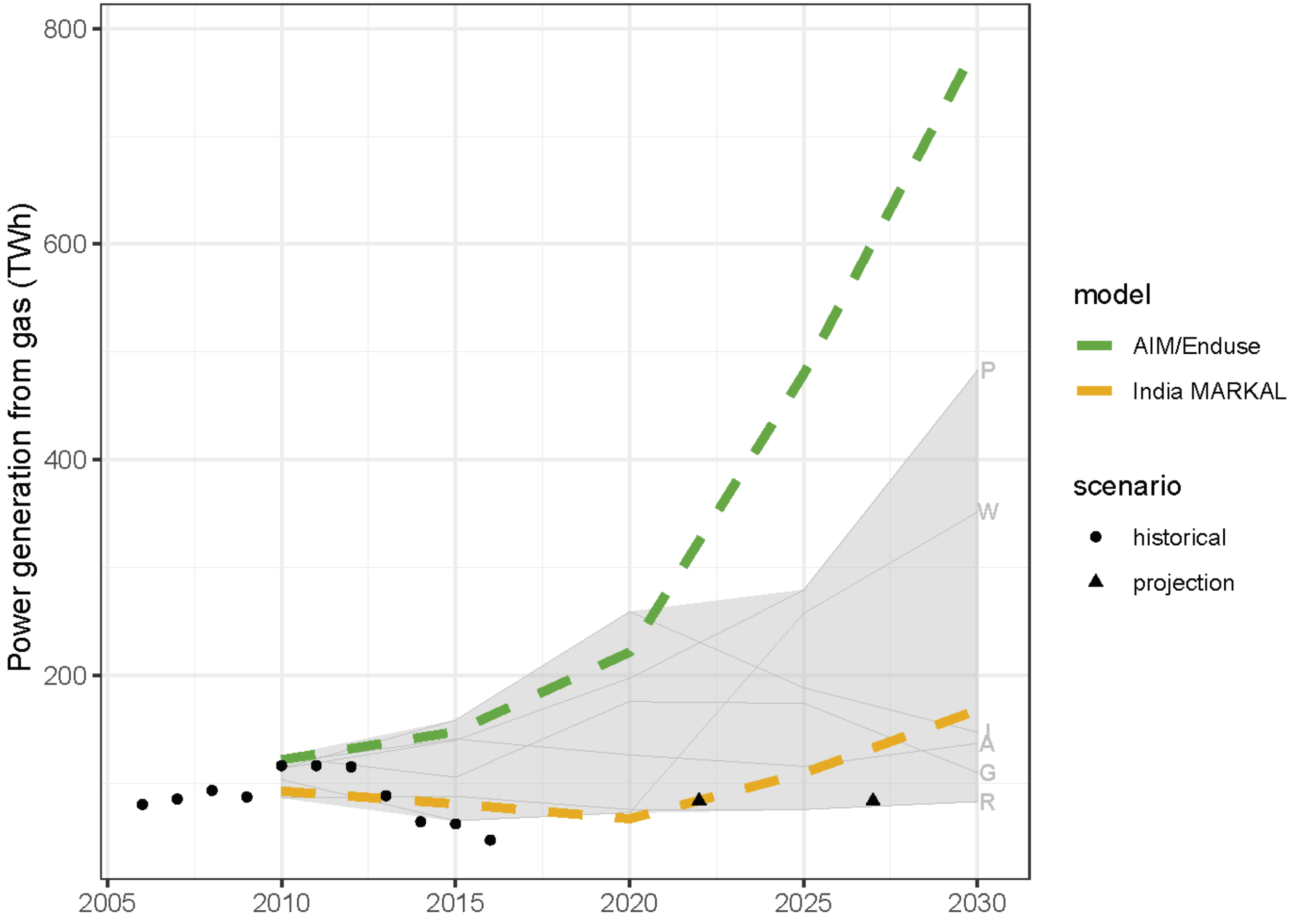
Source: IRENA elaboration, adapted from Breitschopf, Nathani, and Resch (2012)

Carbon budgets

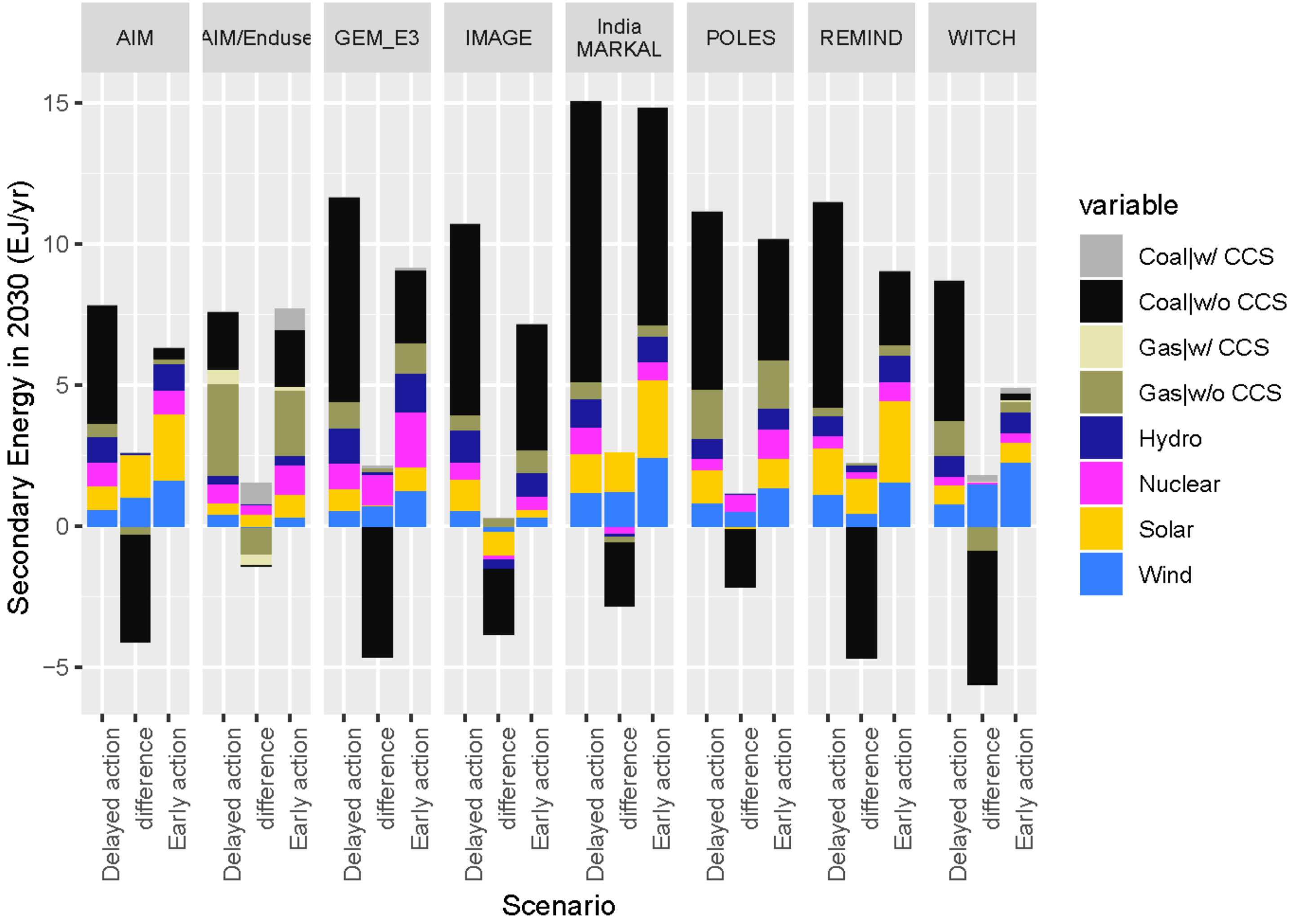
	Carbon budget for India (Gt CO2)	
	Early action	Delayed action
Global models	25-86	32-91
IIM-AIM	~ 115	~140
India-Markal*	187	191

Table S3 Budget ranges from preliminary global least-cost pathways with strengthening after 2020 that were used to inform the choice of national budgets, although some adjustment was made after initial scenario tests.

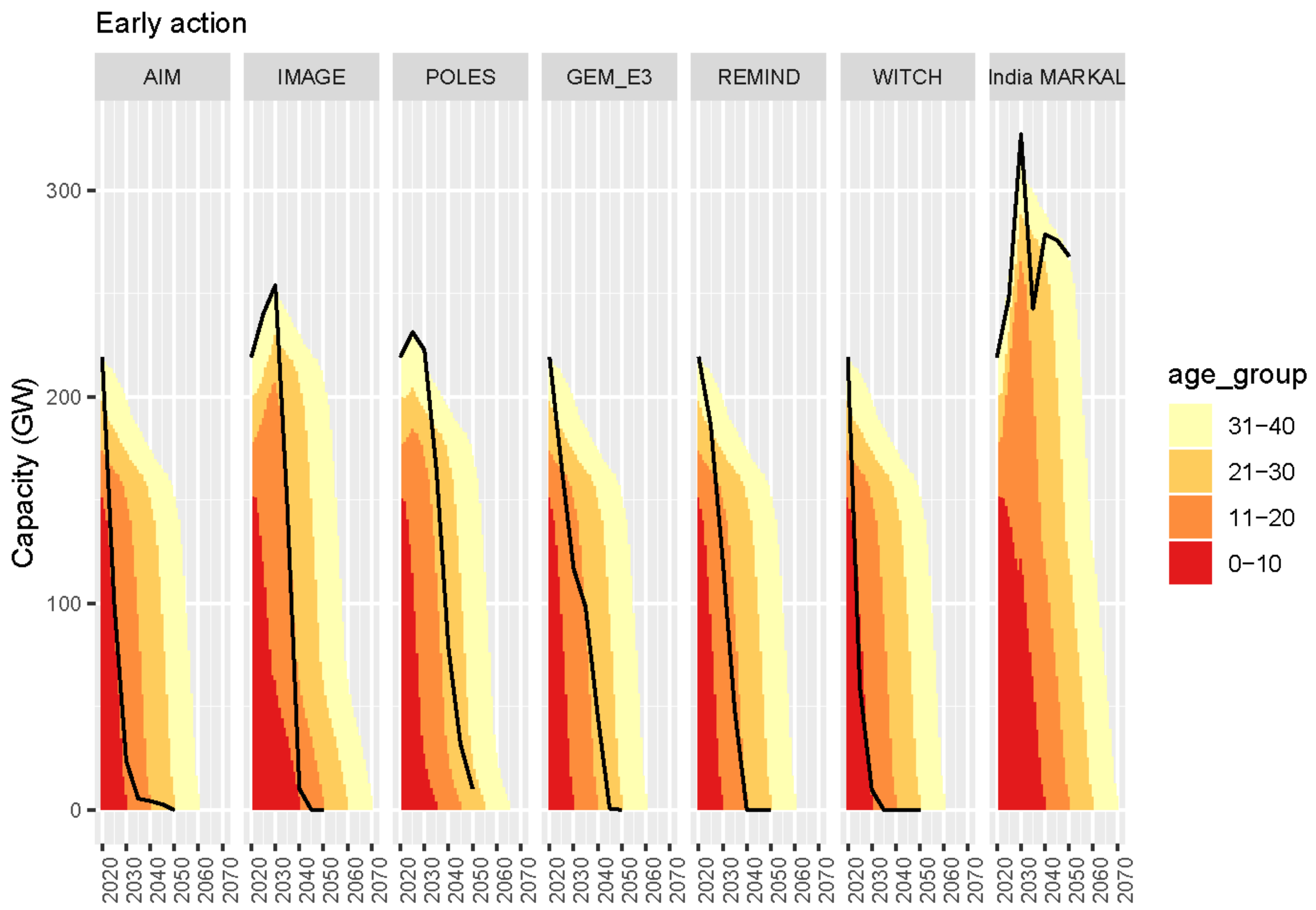
Power generation from gas



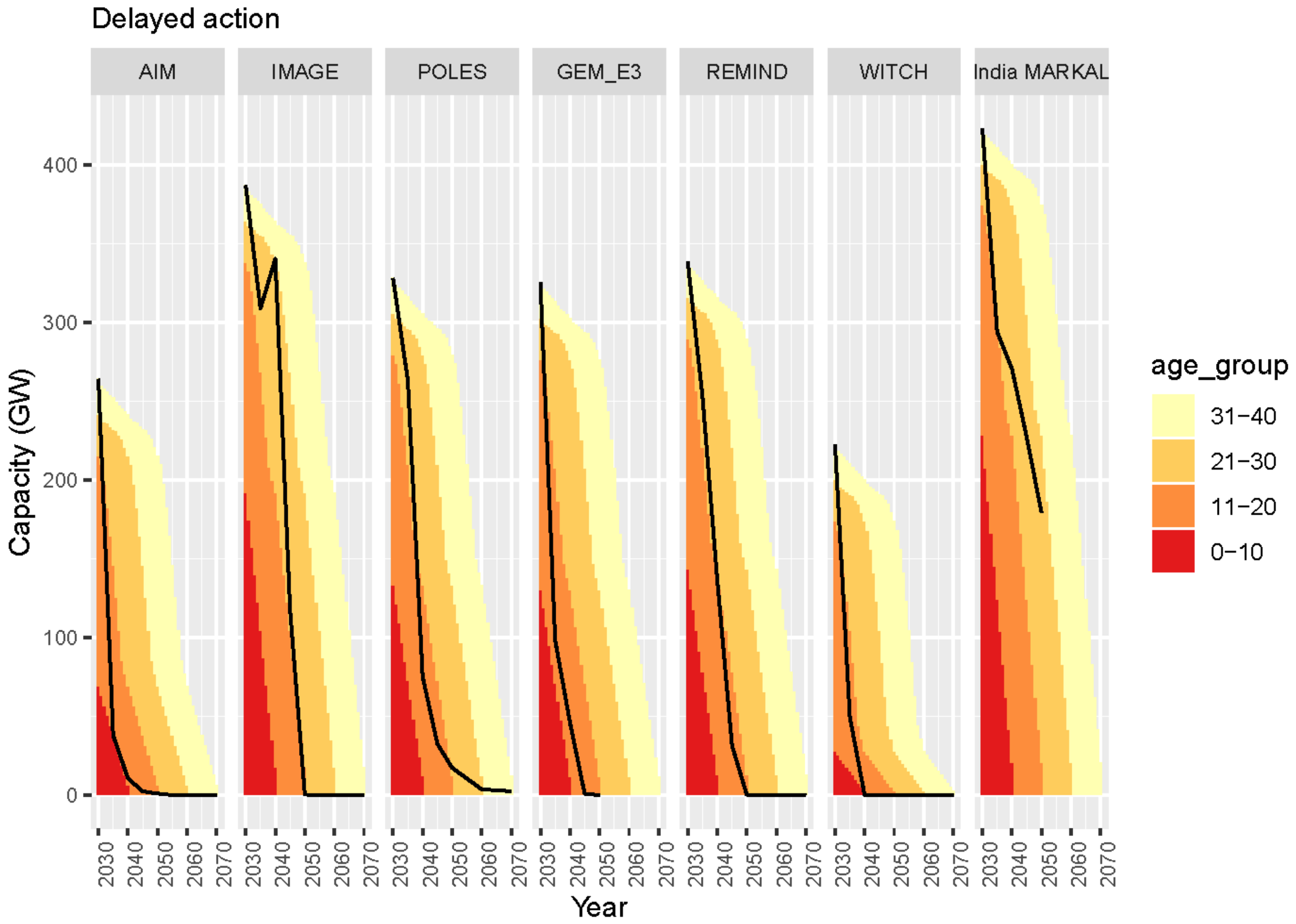
Secondary Energy –all



Stranded capacity- early action



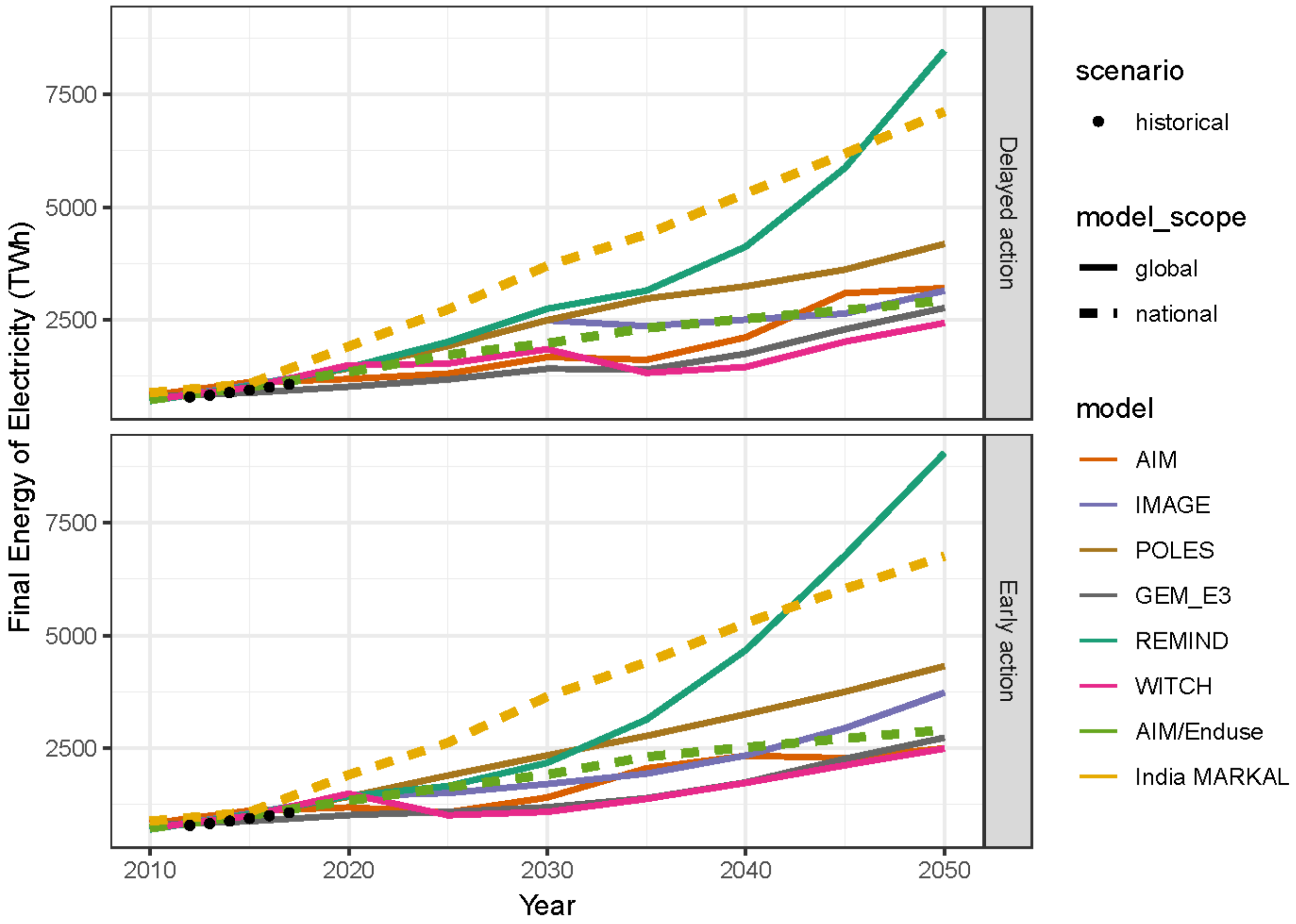
Stranded capacity- Delayed action



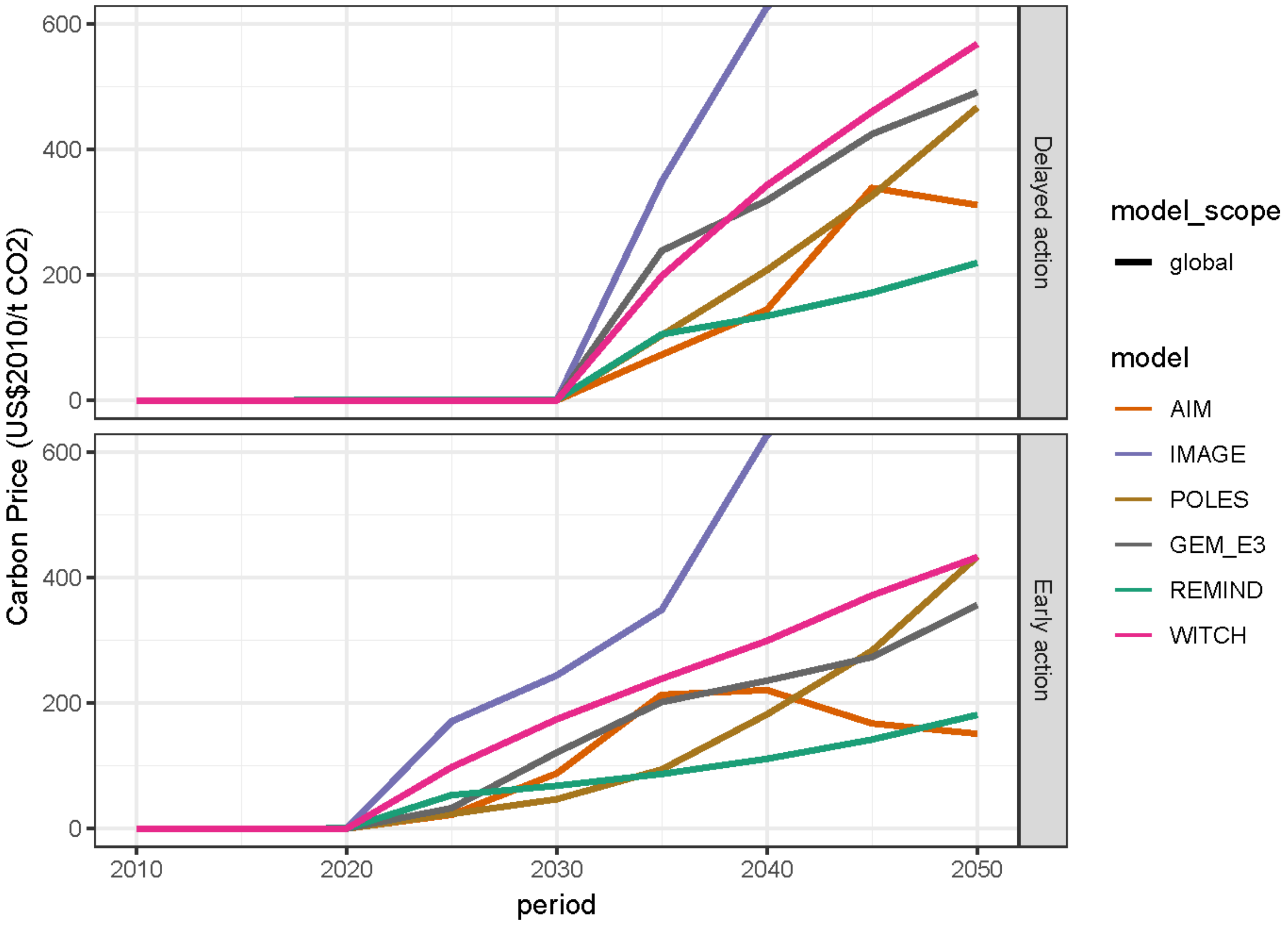
Average stranded capacity

Model	Average stranded capacity (GW)			
	Early action		Delayed action	
	2021-2050[7]	2021-2060[8]	2031-2050	2031-2070
AIM	148	131	201	143
GEM_E3	100	-	233	-
IMAGE	114	120	133	155
India MARKAL	11	-	132	-
POLES	78	83	176	152
REMIND	111	104	176	159
WITCH	159	140	164	109
Median	111	120	175	151

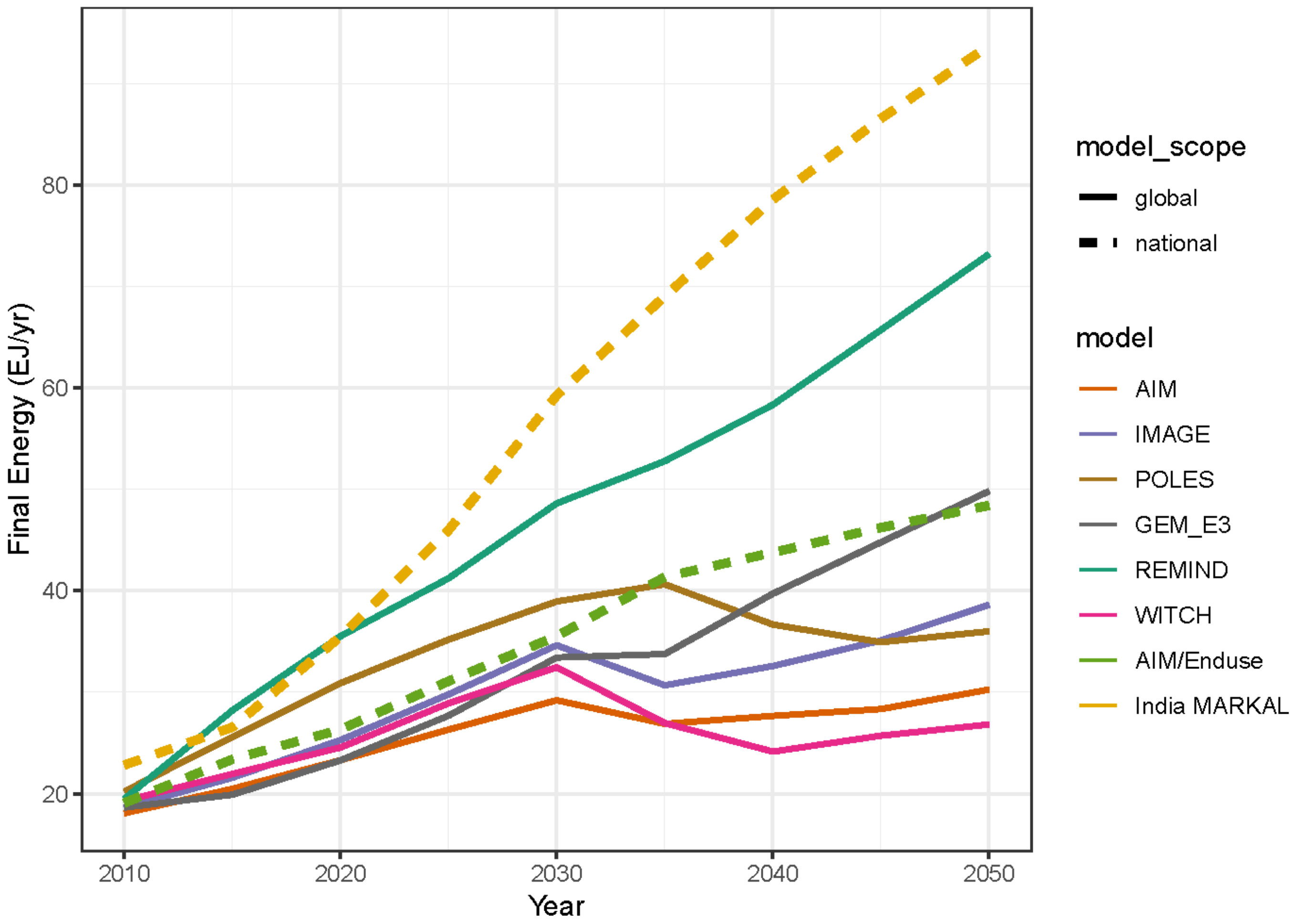
Final Energy of Electricity



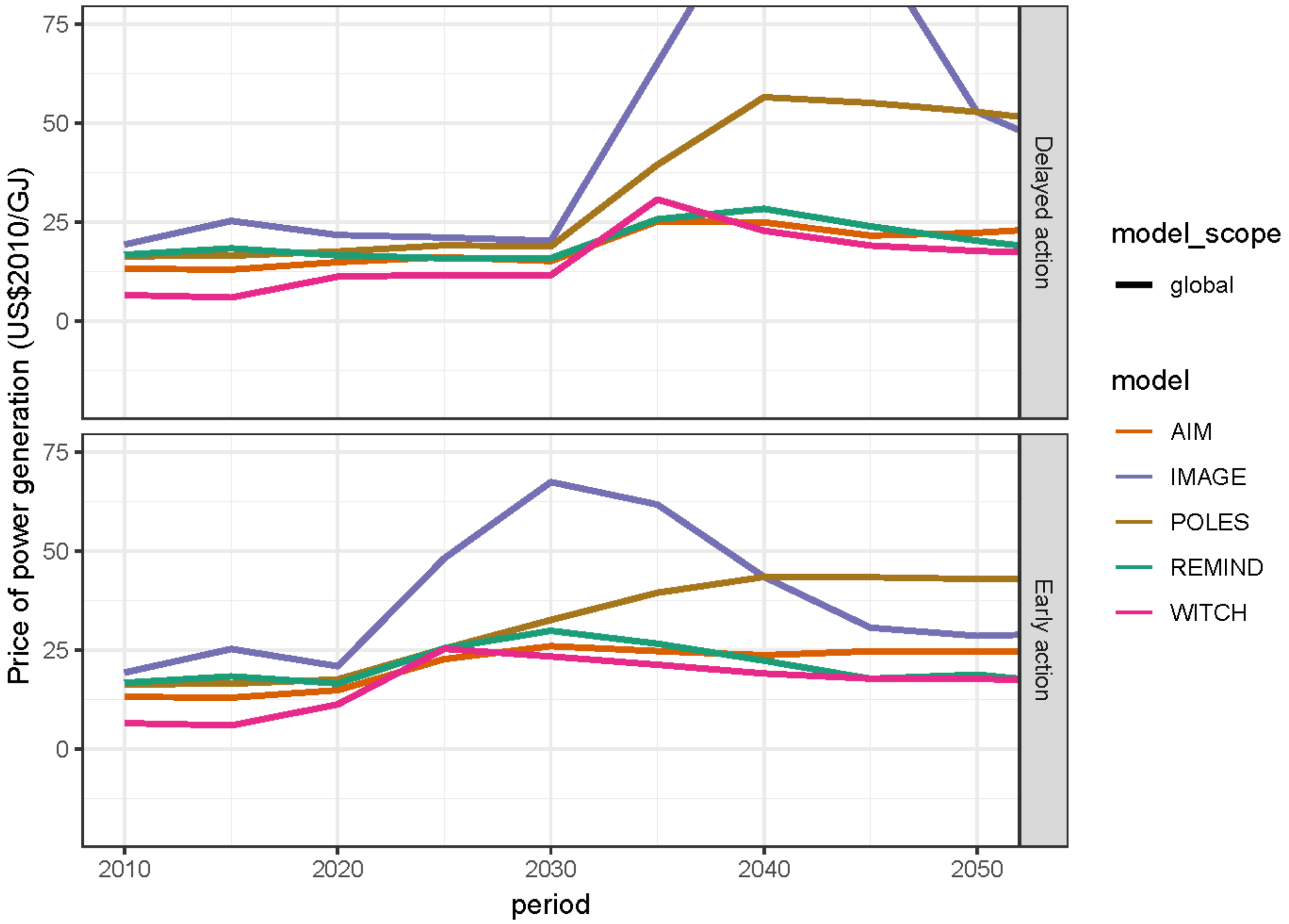
Carbon Price

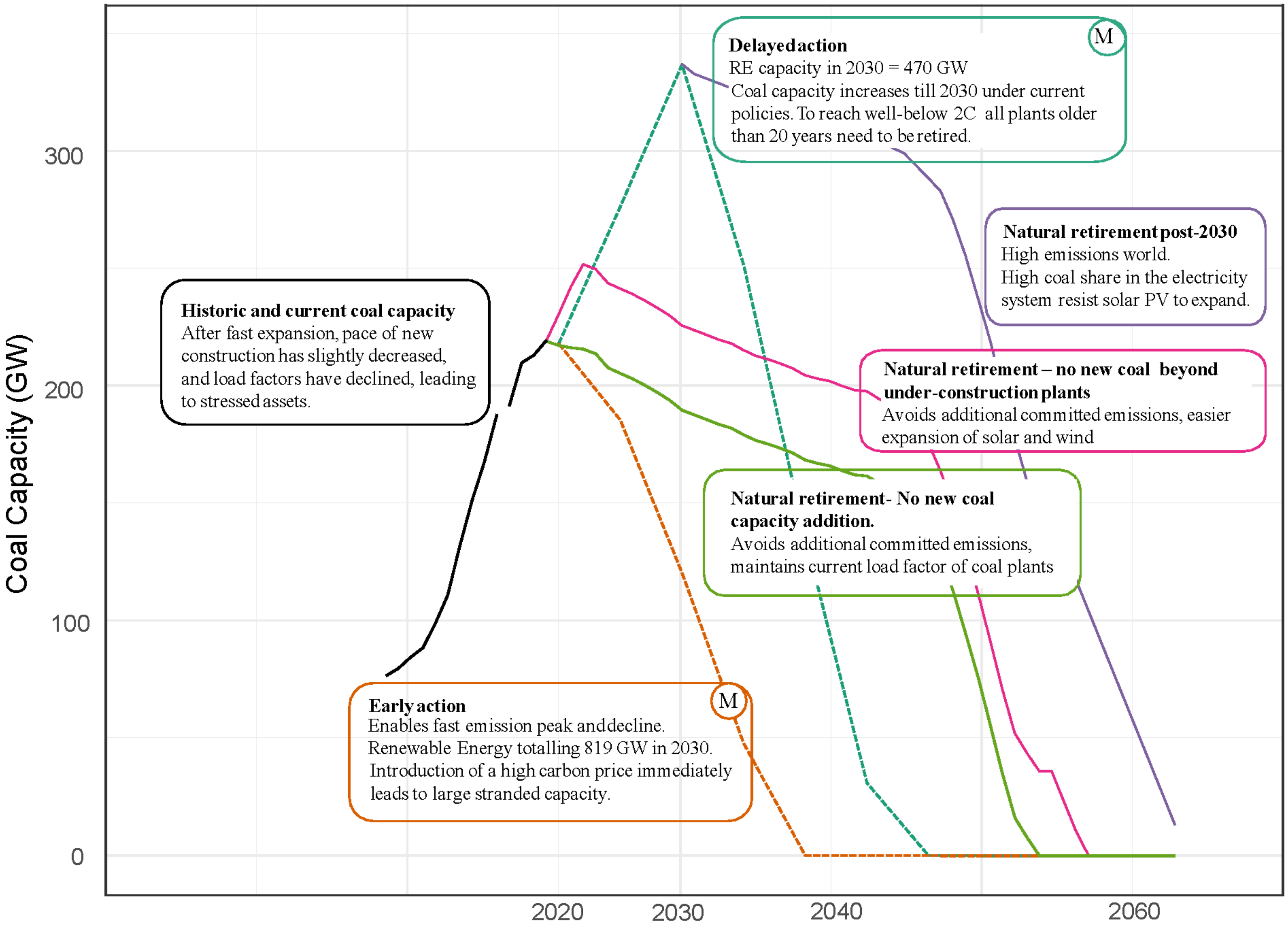


Final Energy



Price of power generation





Coal Capacity (GW)
300
200
100
0
2020
2030
2040
2060
Delayed action
RE capacity in 2030 = 470 GW
Coal capacity increases till 2030 under current policies. To reach well-below 2C all plants older than 20 years need to be retired.
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Natural retirement post-2030
High emissions world.
High coal share in the electricity system resist solar PV to expand.
Historic and current coal capacity
After fast expansion, pace of new construction has slightly decreased, and load factors have declined, leading to stressed assets.
Natural retirement – no new coal beyond under-construction plants
Avoids additional committed emissions, easier expansion of solar and wind
Natural retirement- No new coal capacity addition.
Avoids additional committed emissions, maintains current load factor of coal plants
Early action
Enables fast emission peak and decline.
Renewable Energy totalling 819 GW in 2030.
Introduction of a high carbon price immediately leads to large stranded capacity.
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