LSE THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Hellenic Observatory Research Centre Launch Event

Clean growth: challenges and opportunities in the renewable energy paradigm

Speaker: **Costas Arkolakis**, Professor of Economics, Yale University

Chair: **Vassilis Monastiriotis**, Hellenic Observatory Centre Director

Hosted by the Hellenic Observatory Centre for Research on Contemporary Greece and Cyprus

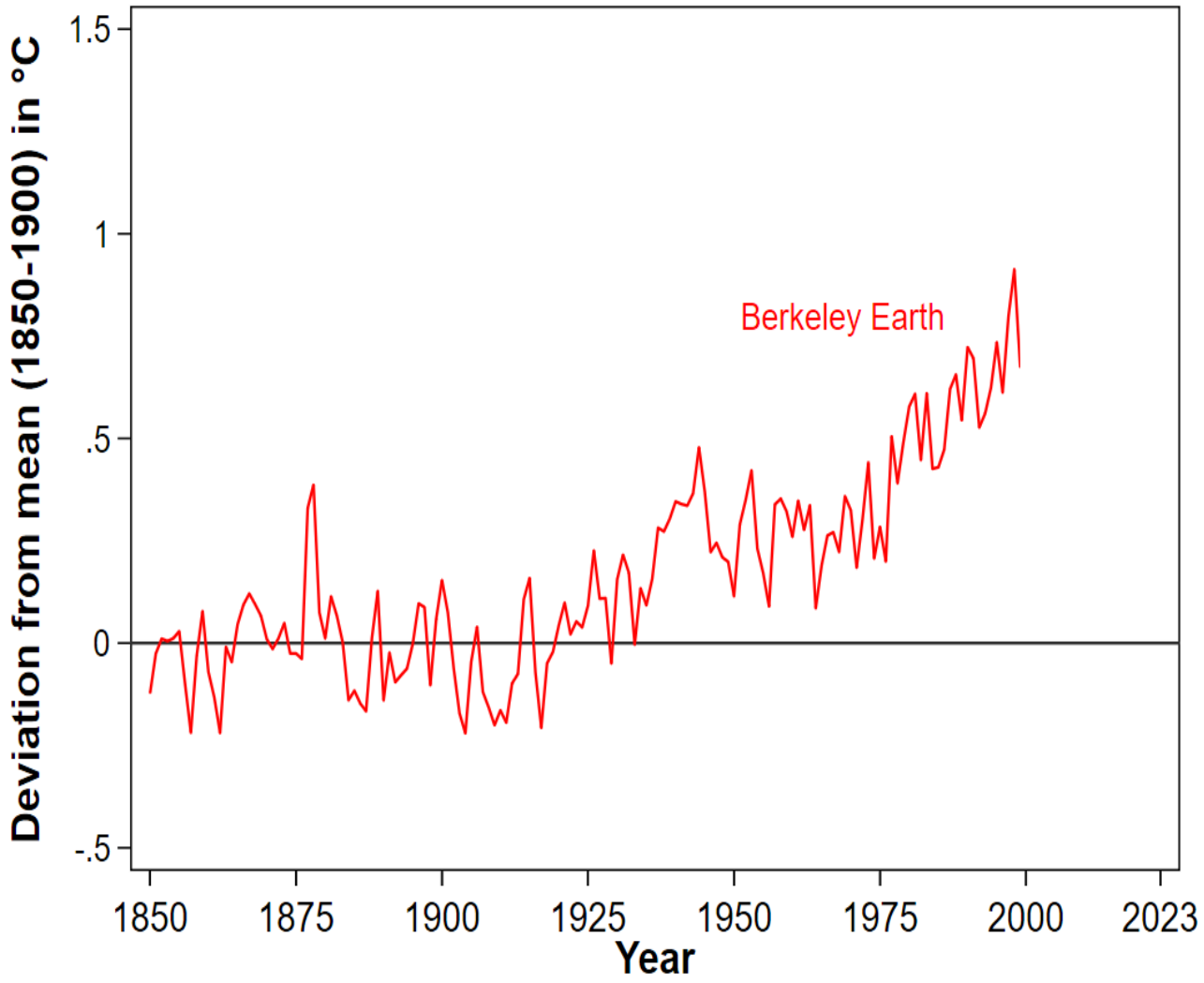
Clean Growth: Challenges & Opportunities in the Renewable Energy Paradigm

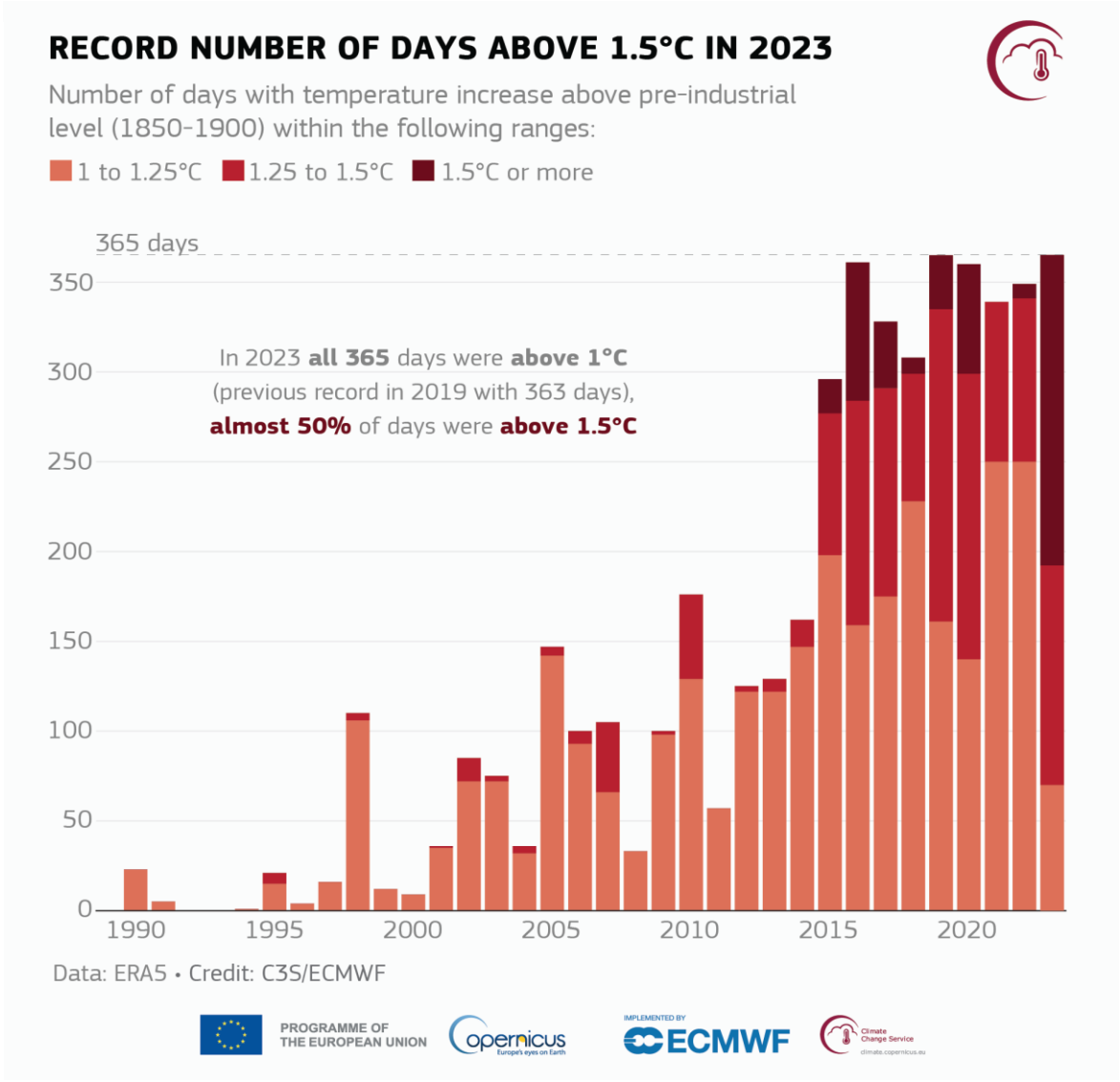
Costas Arkolakis
Yale

Conor Walsh
Columbia

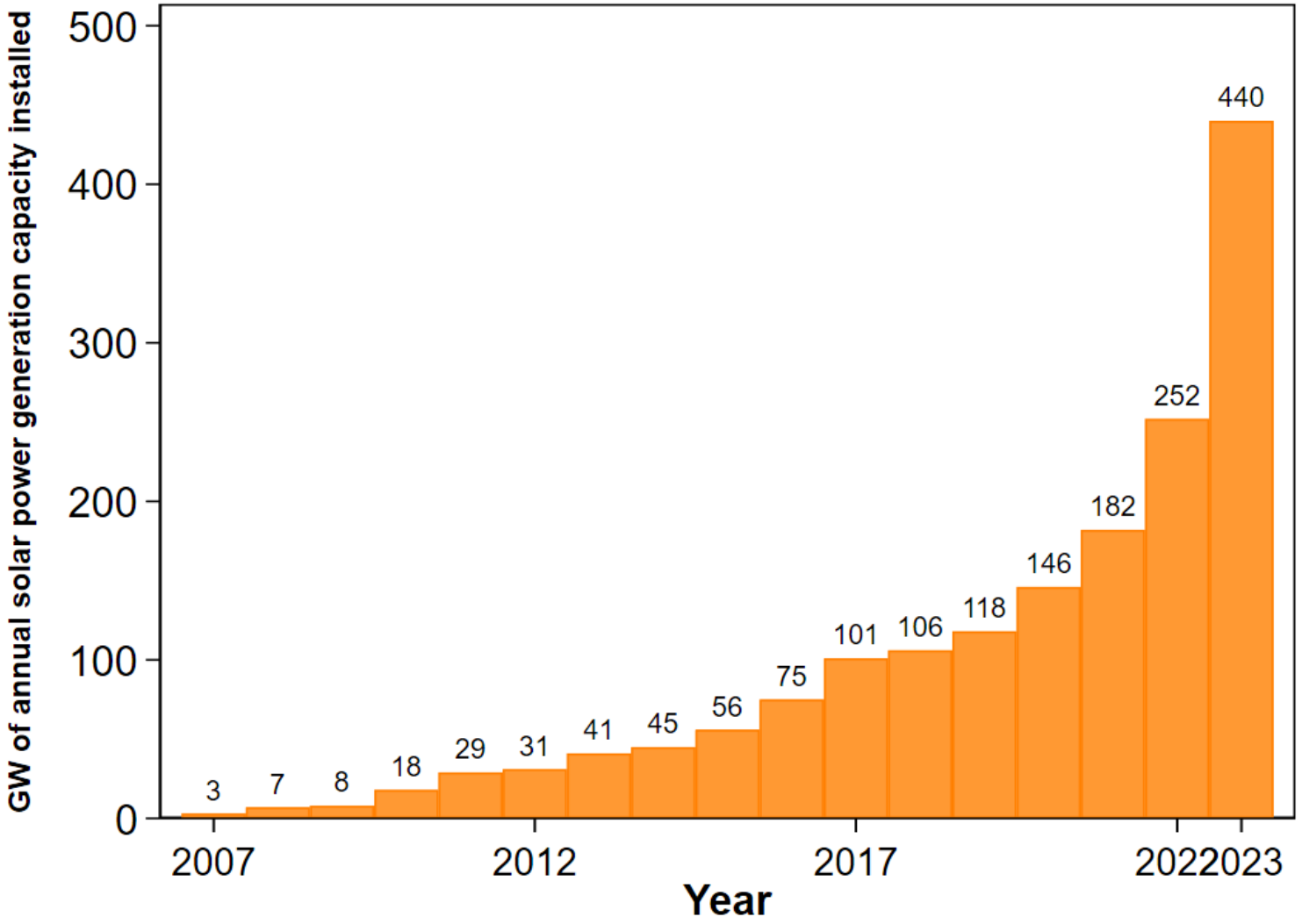
Hellenic Observatory Research Centre Launch Event
London School of Economics, October 2024

Some (Really) Bad News

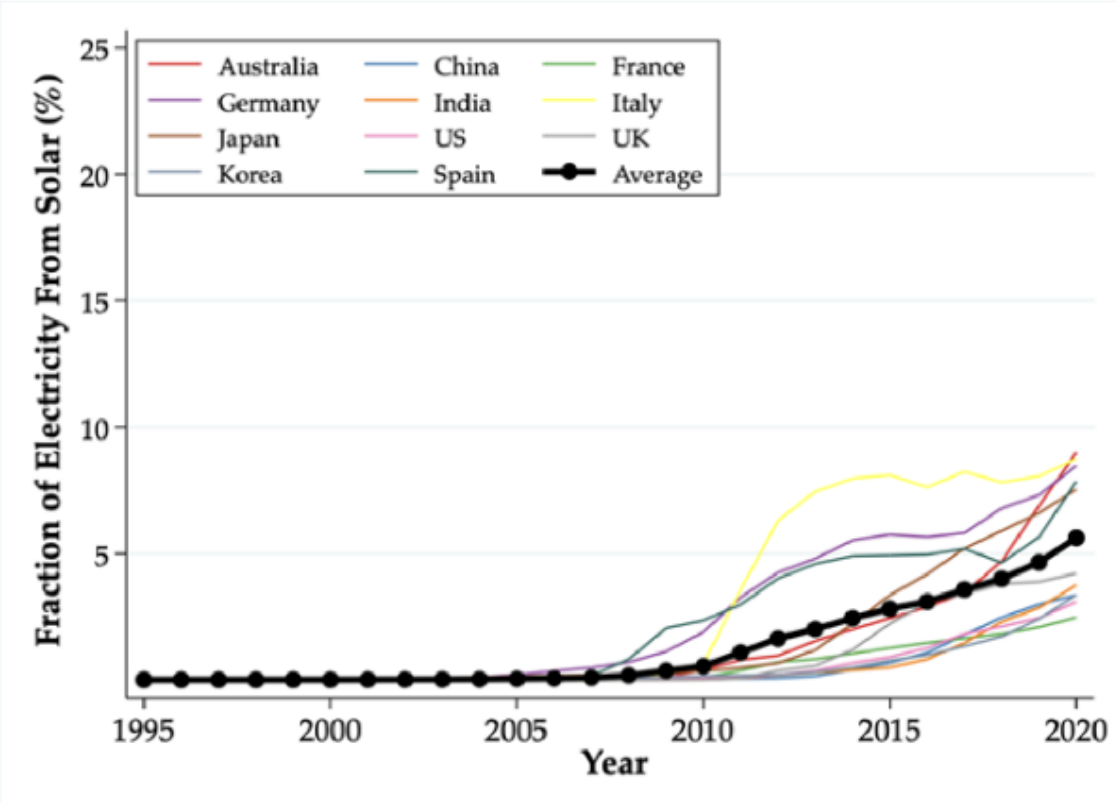


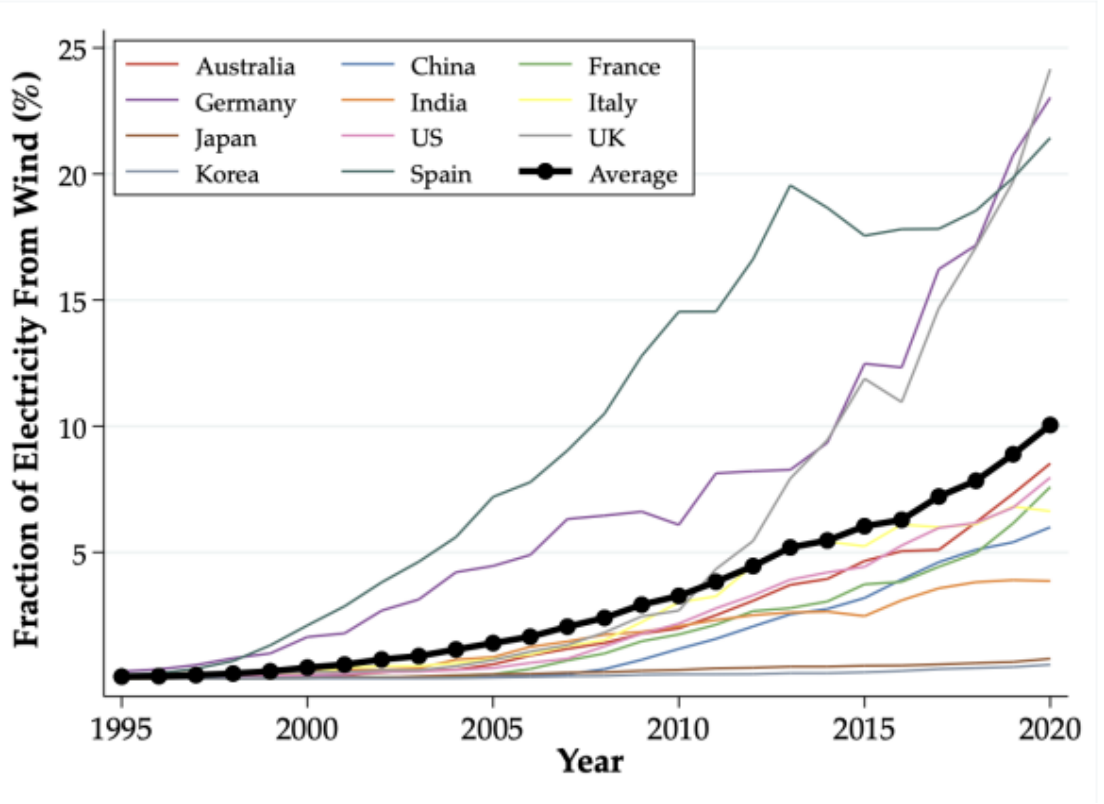


Some Stellar News for Renewable Energy



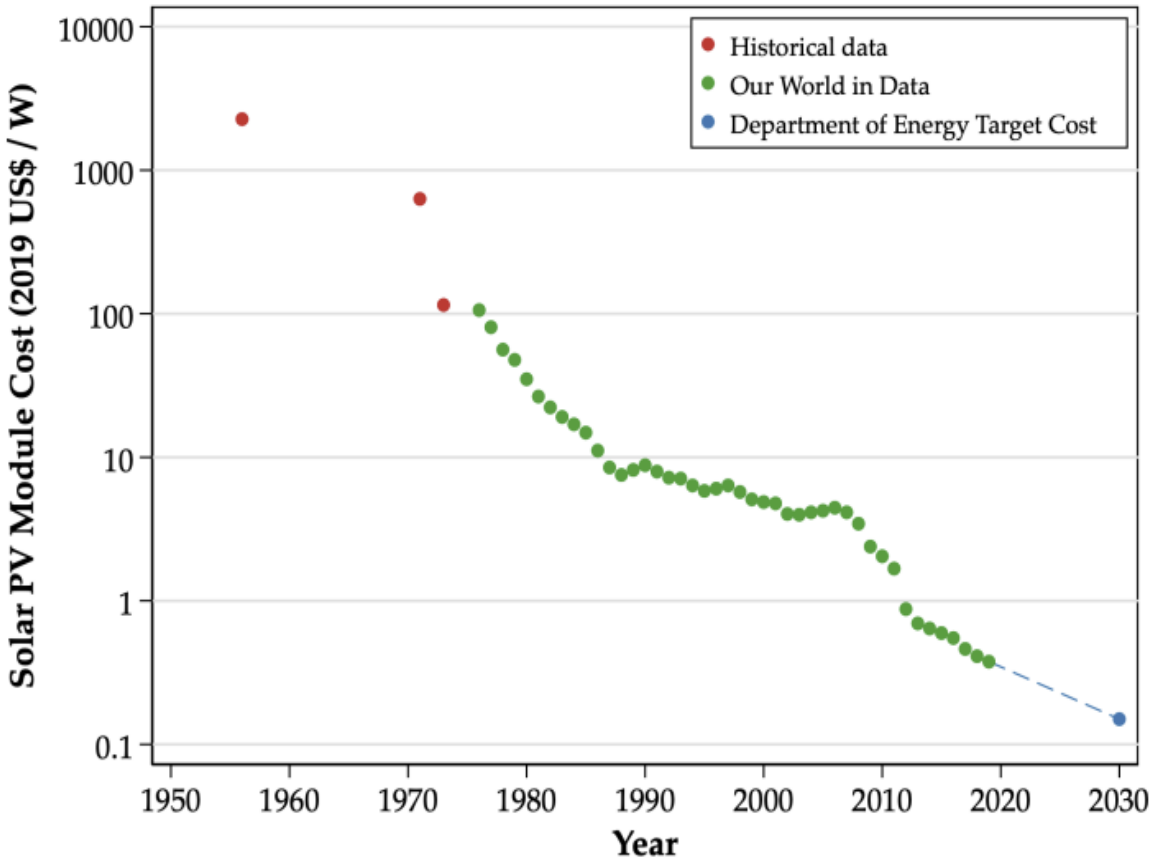
Generation Increasing Fast from Nothing



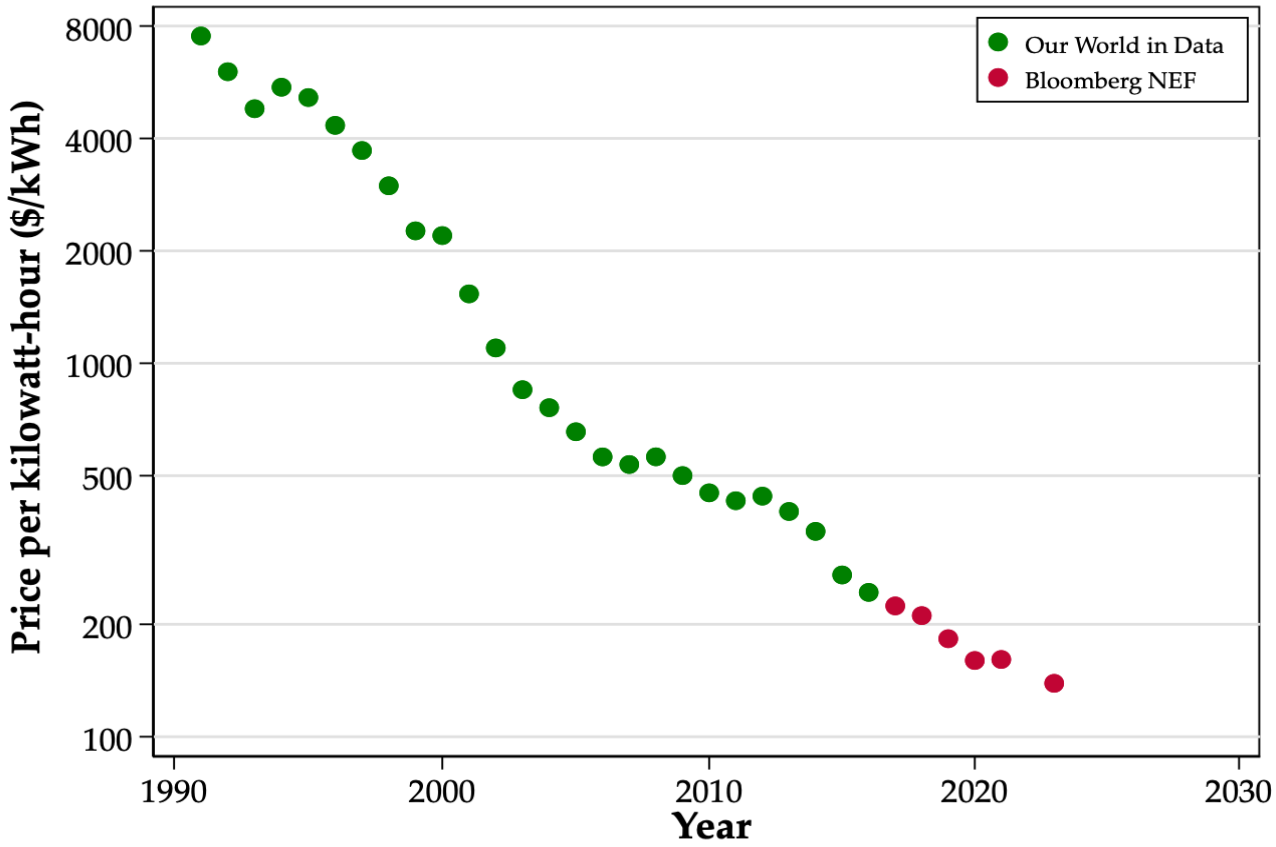


A Technological Revolution Decades in the Making

Solar Costs



(Lithium-ion) Batteries



The Renewable Energy Revolution: Opportunities and Challenges

1. What are the new opportunities that arise
   a. Economic gains from the great technological revolution
   b. Promise of European (and more) energy security
   c. Environmentally friendly (You can have your cake and eat it too!)

2. What are the challenges of the transition
   a. Transmission Grid constraints
   b. Intermittency of renewables
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Clean Growth Research: Two Main Questions

1. Who are the winners and losers of this technological revolution
   a. What is the impact on electricity markets: renewable share, prices etc
   b. Welfare gains: welfare improvement, income effects etc

2. What is the role for policy?
   a. Subsidies to renewables (e.g. Inflation Reduction Act)
   b. Investments in the grid (e.g. Infrastructure Investment and Jobs Act)

Based on

Arkolakis Walsh ’23 “Clean Growth”,

Arkolakis Walsh ’24 “The Economic Impacts of Clean Power”

Clean Growth Research Goal:
An Integrated Assessment Model w/ Energy Markets

- Study implications of energy transition
  - Model energy markets, transmission, renewables
  - Model spatial element -follow Quantitative Spatial Literature-
  - Model investment in energy resources –renewables: modular/fossil: resource extraction-
    - Model interplay of all these forces through integrated modeling in General Equilibrium

- New predictions for
  - Renewable investment and fossil fuel extraction in the long run
  - Electricity prices across countries
  - Welfare implications of energy transition and policies across countries, regions

The Economy:
Energy, Production, Consumption

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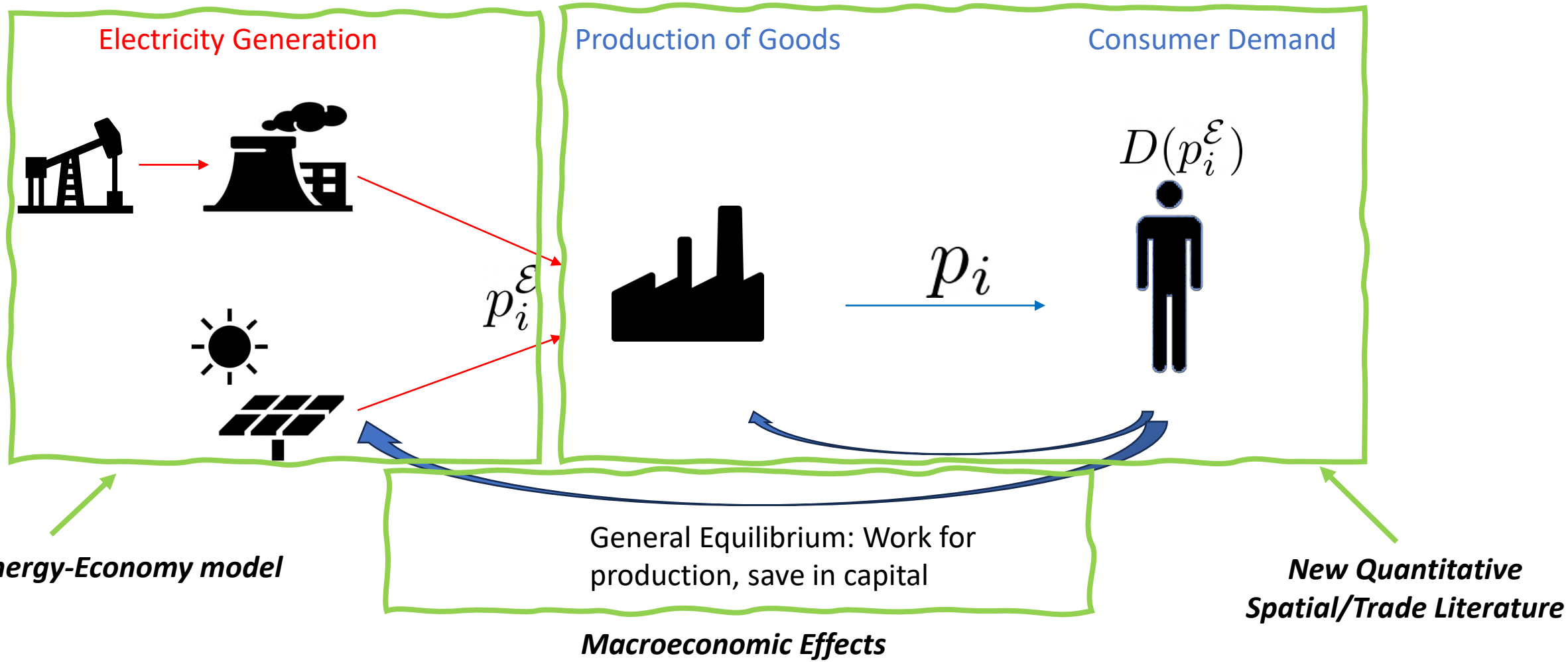
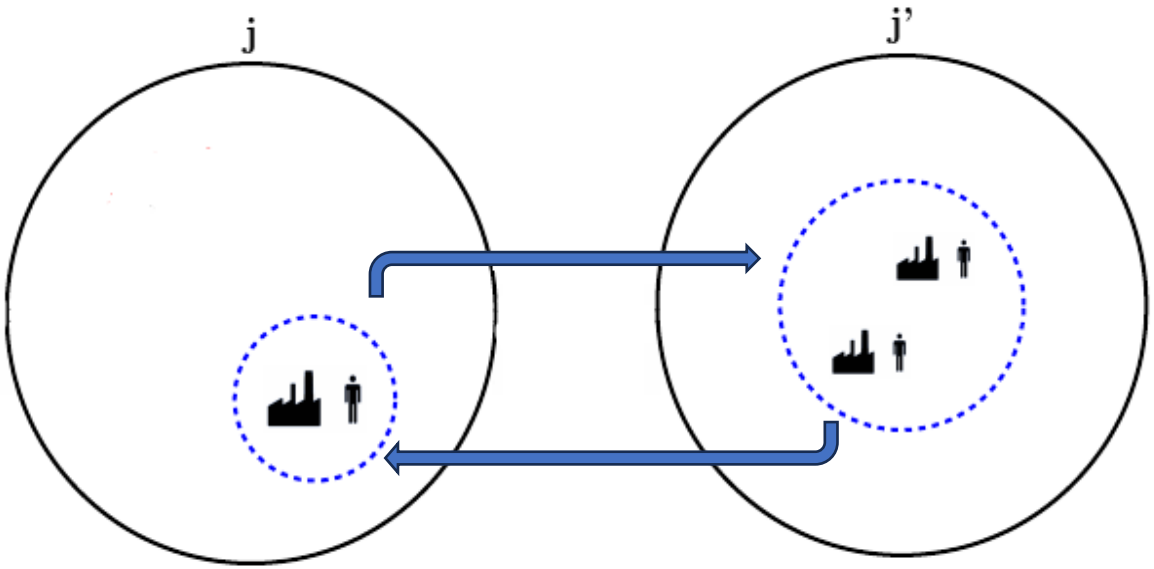
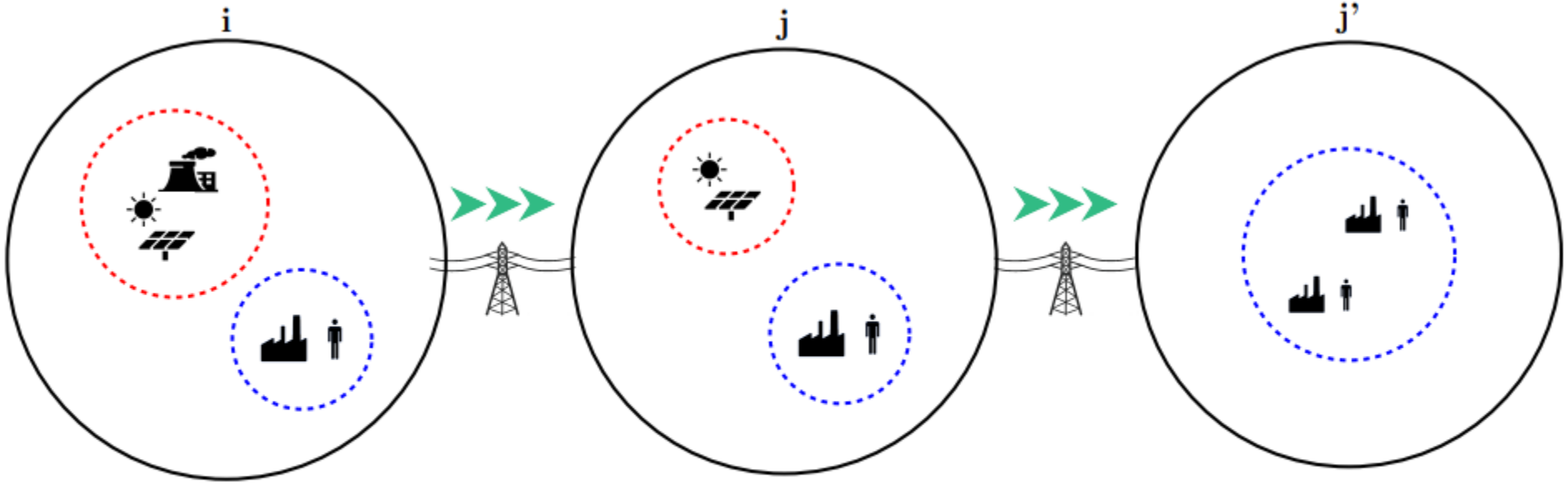


Trade in Goods (Gross)



Trade in Electricity (Net)

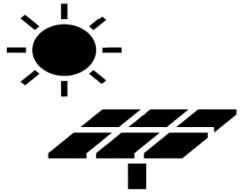


The Economy:
Electricity Generation and Electricity Markets

Electricity Generation Technologies

Traditional Energy Sector

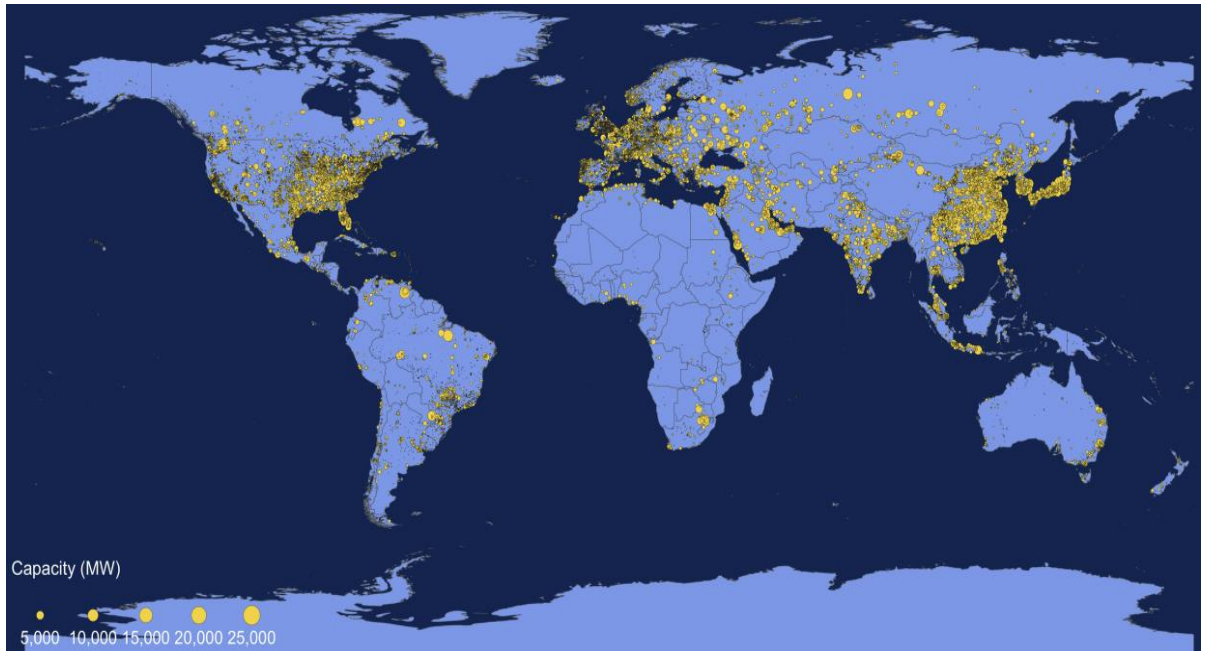
- Install capacity in region *i*, $K_i^{\mathcal{F}}$



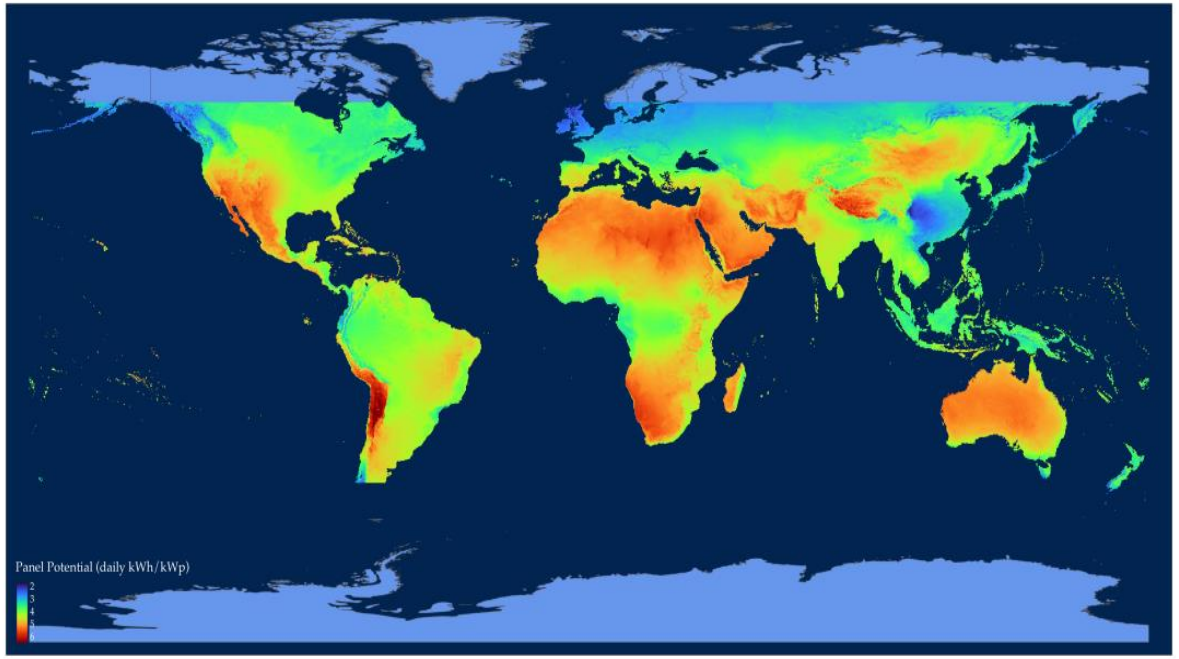
Renewable Energy Sector

- Installed capacity in region i, $K_i^{\mathcal{R}},\ \mathcal{R} = \{\mathcal{S}, \mathcal{W}\}$
- Wind or Solar, Efficiency $\theta_i^{\mathcal{R}}$

Global Installed Traditional Energy Sector Capacity

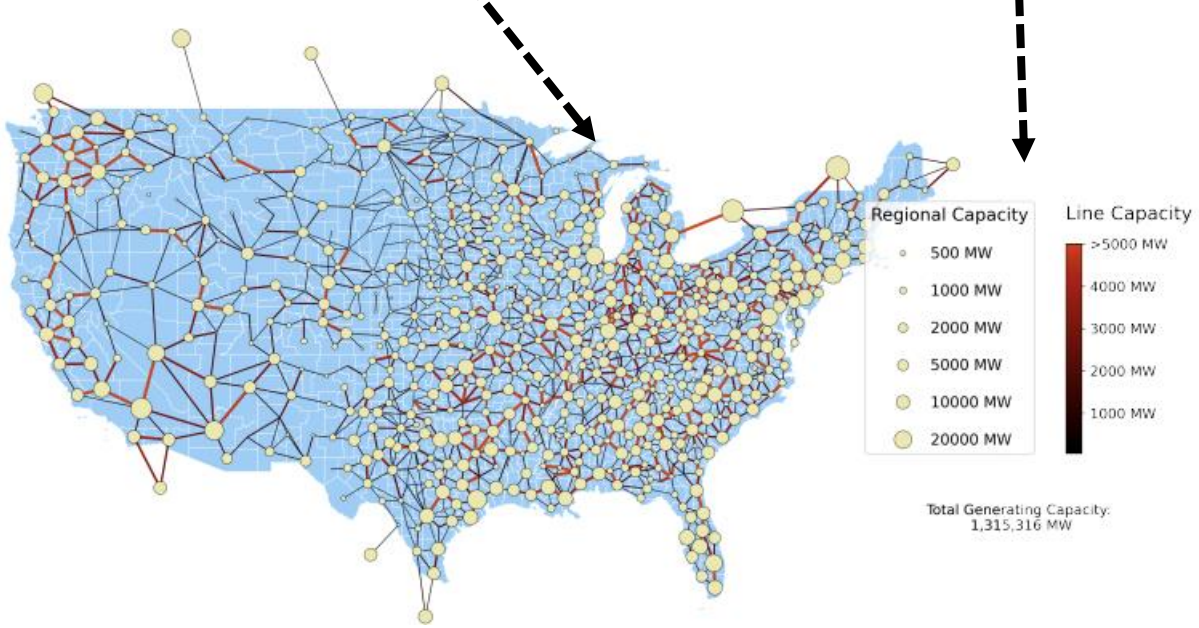


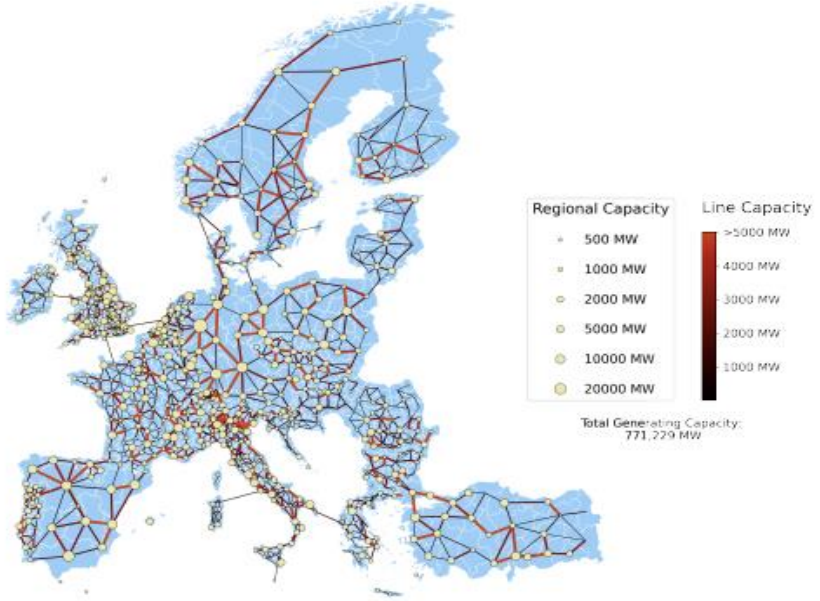
Global Variation in Solar Efficiency



Electricity Transmission Technology

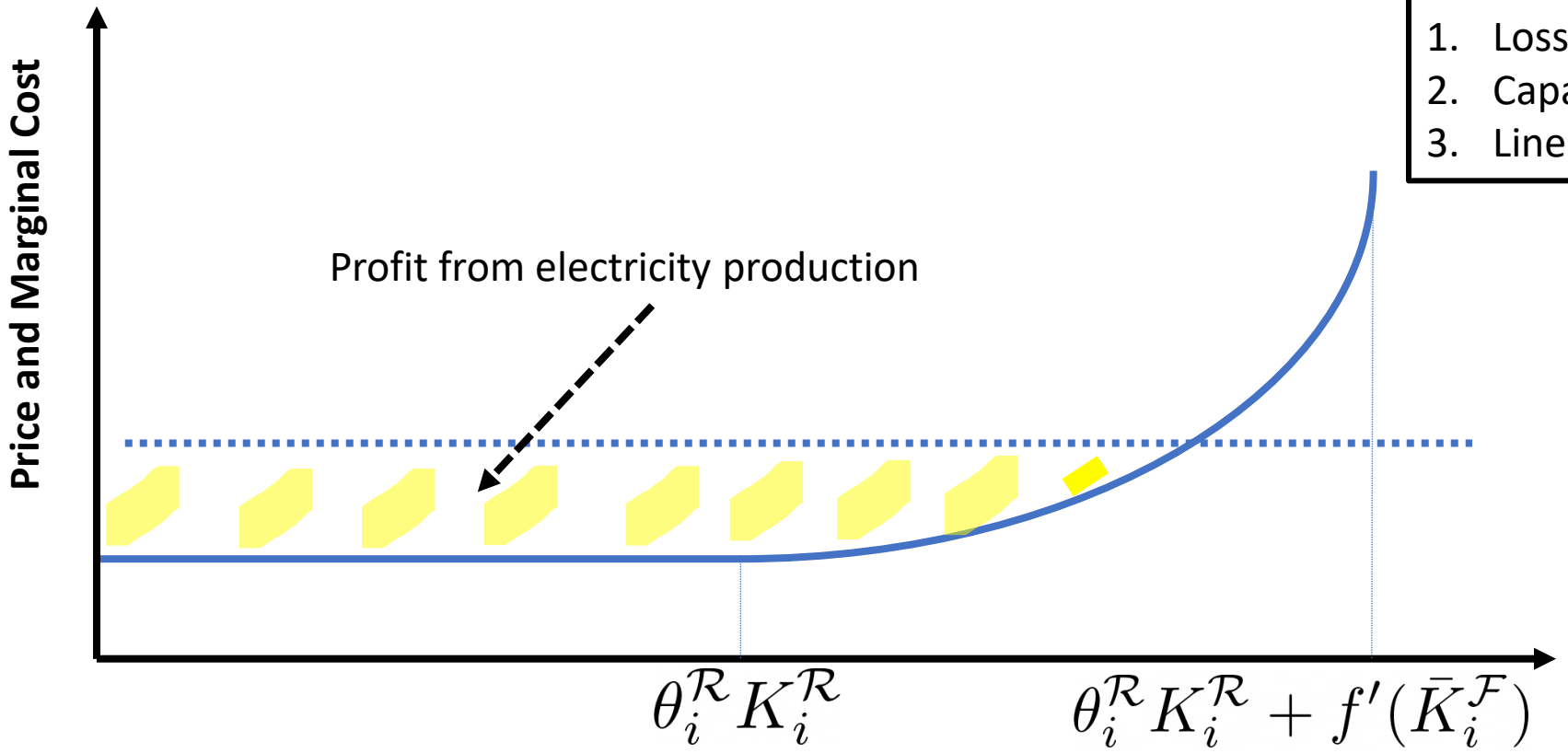
- Electricity in a region *i*, generated by traditional and renewable assets
  - Net supply of each region is $P_i = Y_i^{\mathcal{E}} - D(p_i^{\mathcal{E}})$
- Losses, λ, determined by physical constraints in transmission network
  - Matrix of links, resistance (inv of capacity) of lines, and net supply in each link





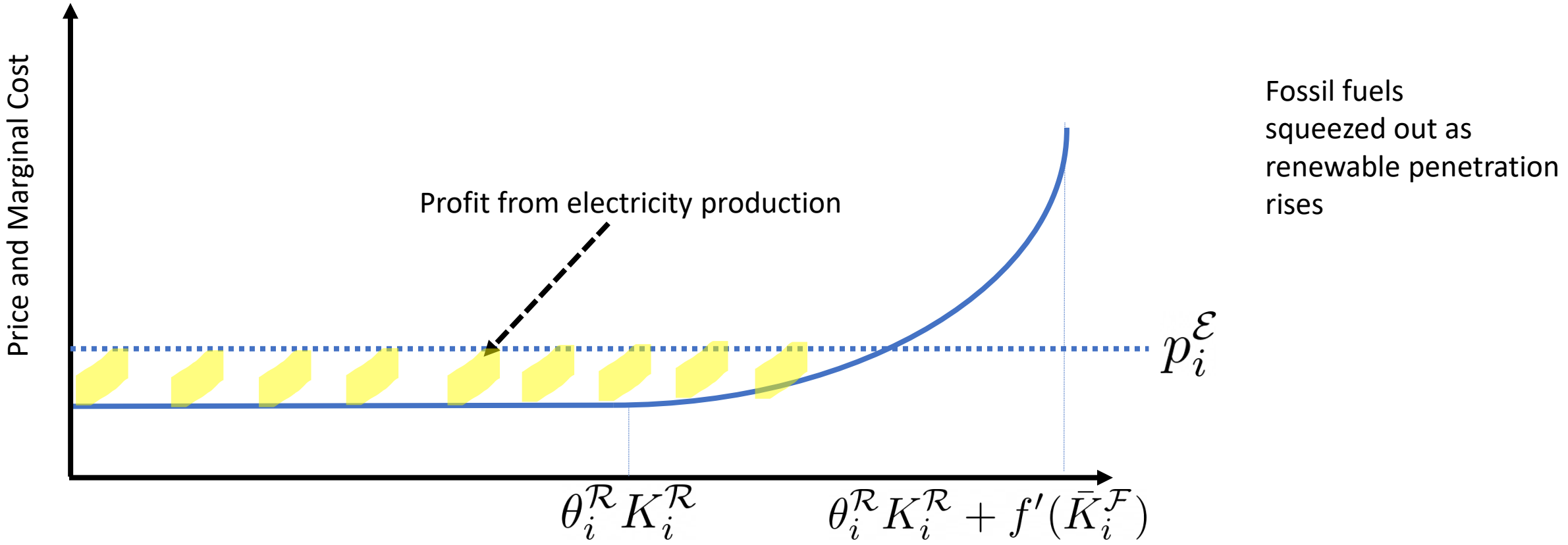
Electricity Markets: Merit Order Dispatch

Prices set by grid planner
Maximize total welfare (all regions in grid)
subject to
1. Losses+Supply=Demand (Kirkoff law)
2. Capacity constraints
3. Line capacity constraints



$p_i^{\mathcal{E}}$

Electricity Markets: Merit Order Dispatch

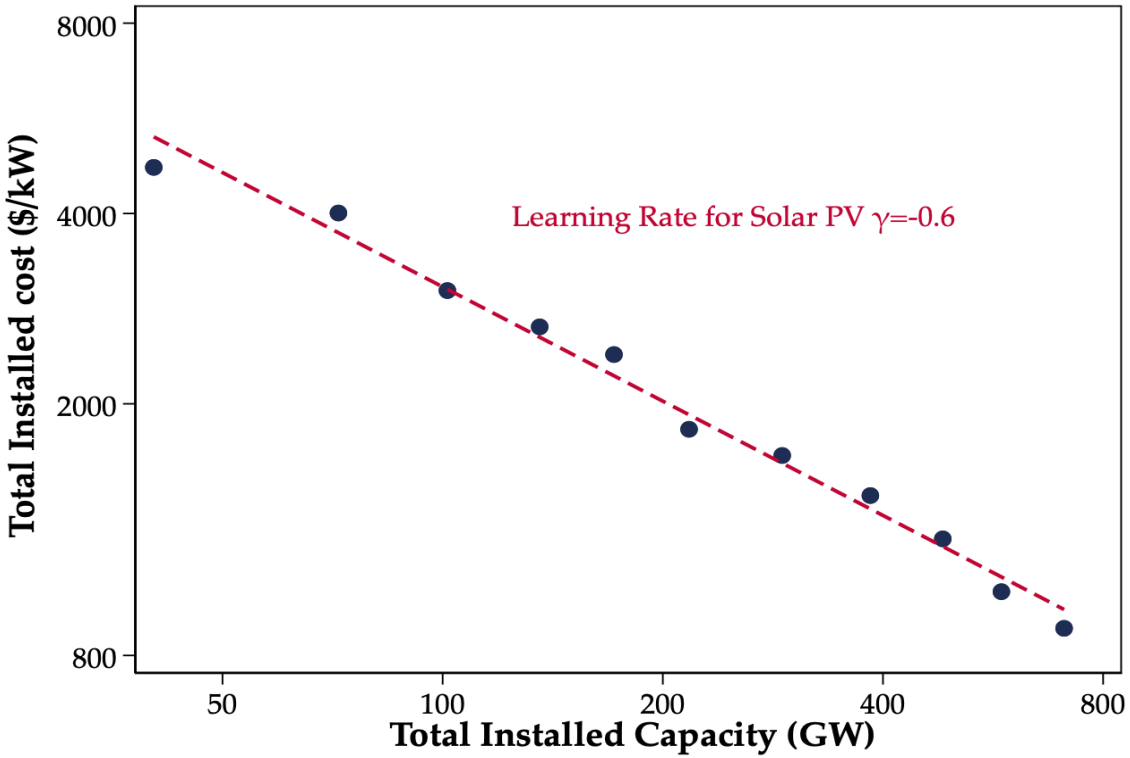


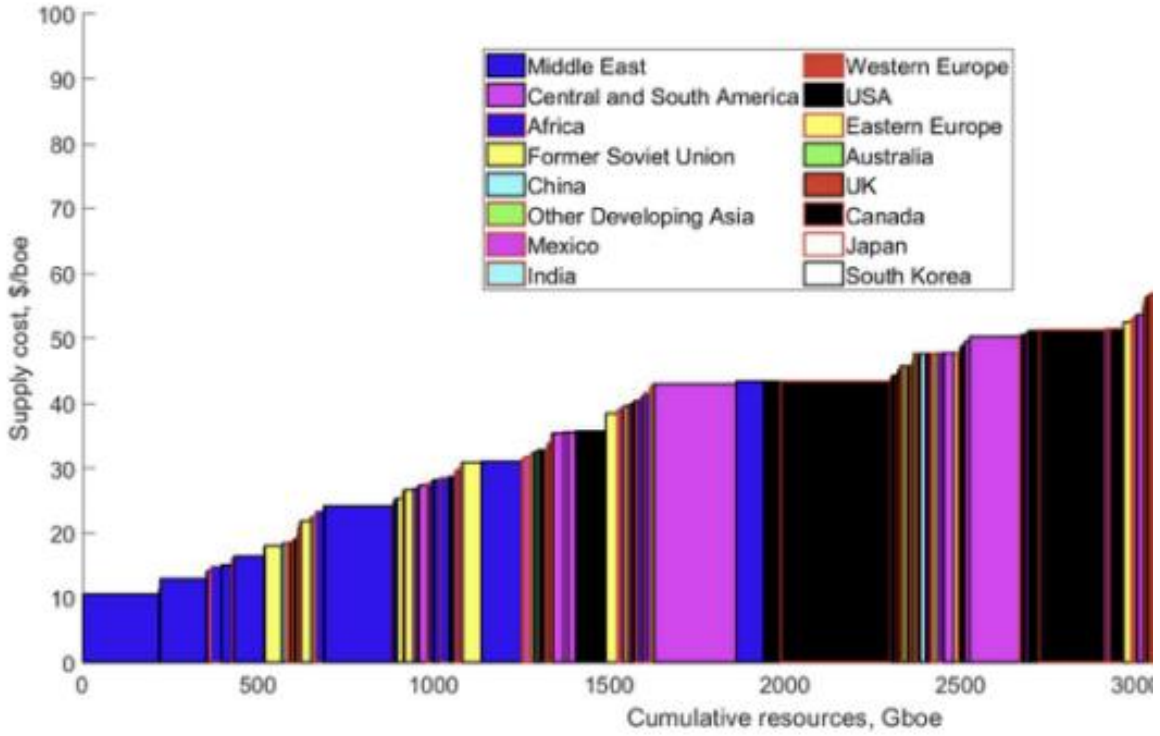
Fossil fuels squeezed out as renewable penetration rises

Renewable Investment and Fossil Extraction

- **Renewable investment**
  - Is modular
  - Has (close to) zero marginal cost
  - Is subject to learning by doing (*lbd*)
- Solve value function in Walsh ’21
  - Add *lbd* scale effects

- **Fossil Extraction**
  - Not modular
  - Has increasing marginal costs
  - Little lbd (some technol. progress)
- Hotelling ‘31 resource extraction
  - Extraction costs key for wealth effects

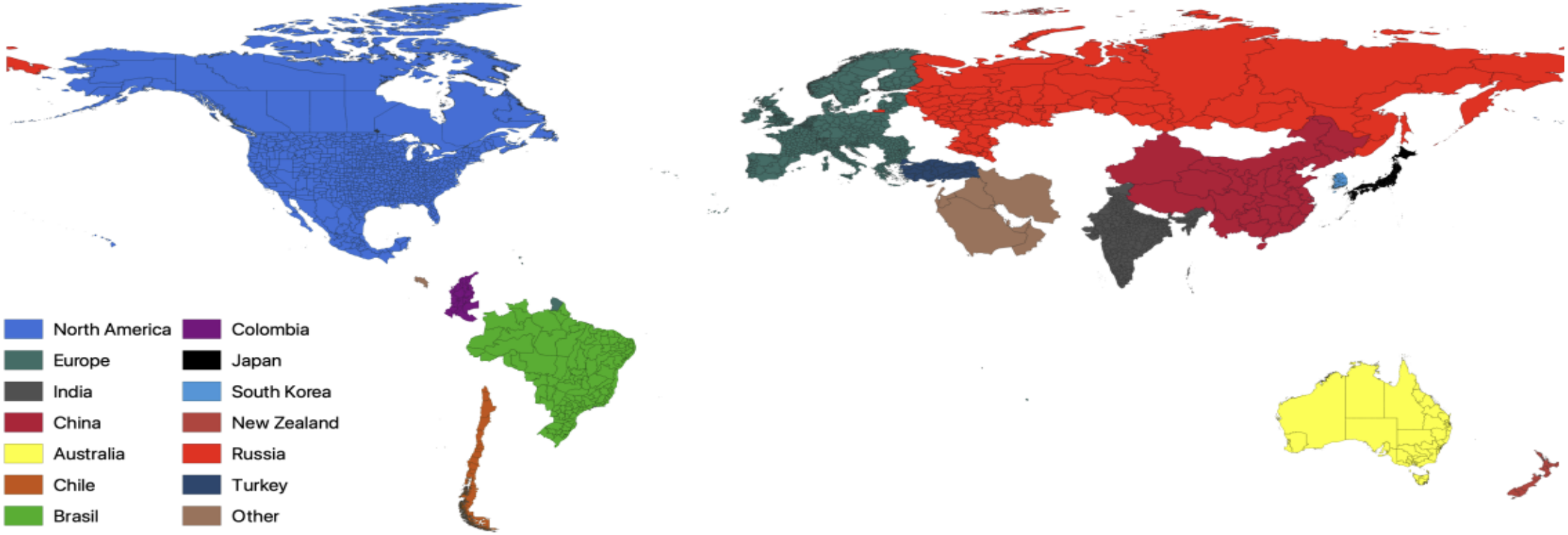




Predictions and Counterfactual Policies

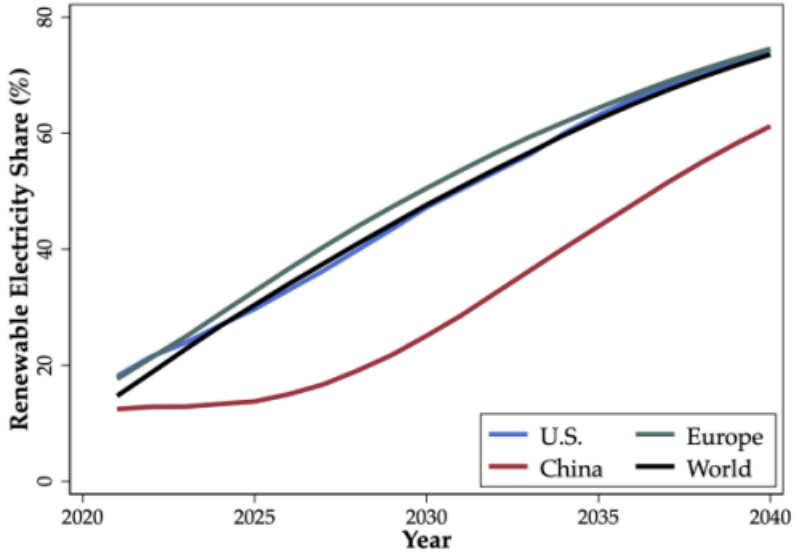
The Regional-Global Data

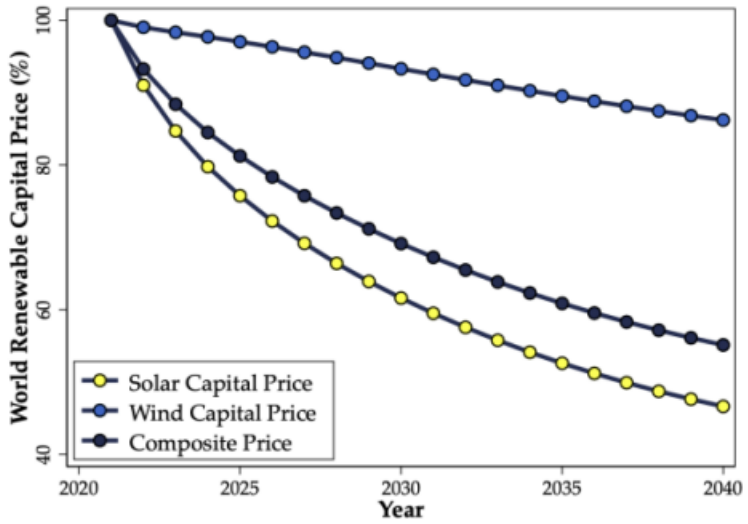
- Compile, combine, harmonize regional datasets (e.g. commuting zone)
  - 56 countries, 2531 regions



Clean Growth Across the Globe

- Renewables dominate
  - Countries with ample fossil resources experience slower transition
  - Prices fall globally

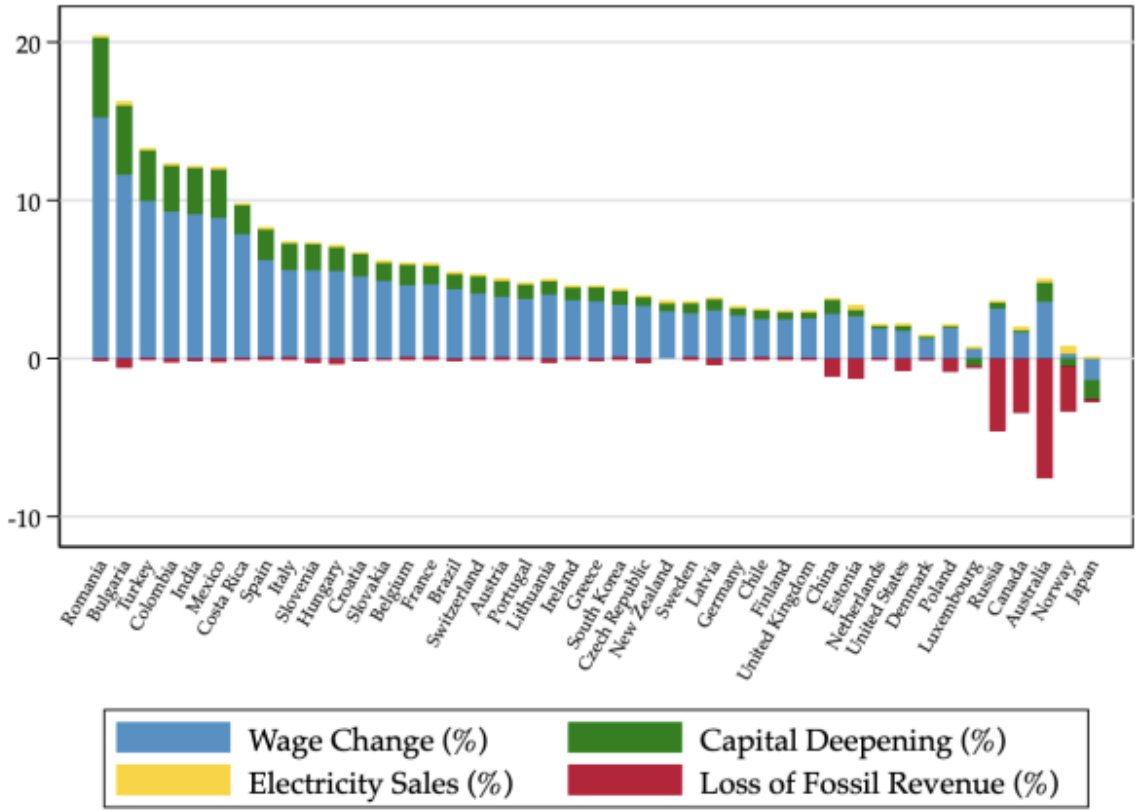




The left panel shows the share of electricity coming from renewables in each country or region in the baseline scenario. This right panel shows the model's projection for the world capital prices in the baseline scenario, normalized to 100 in 2021.

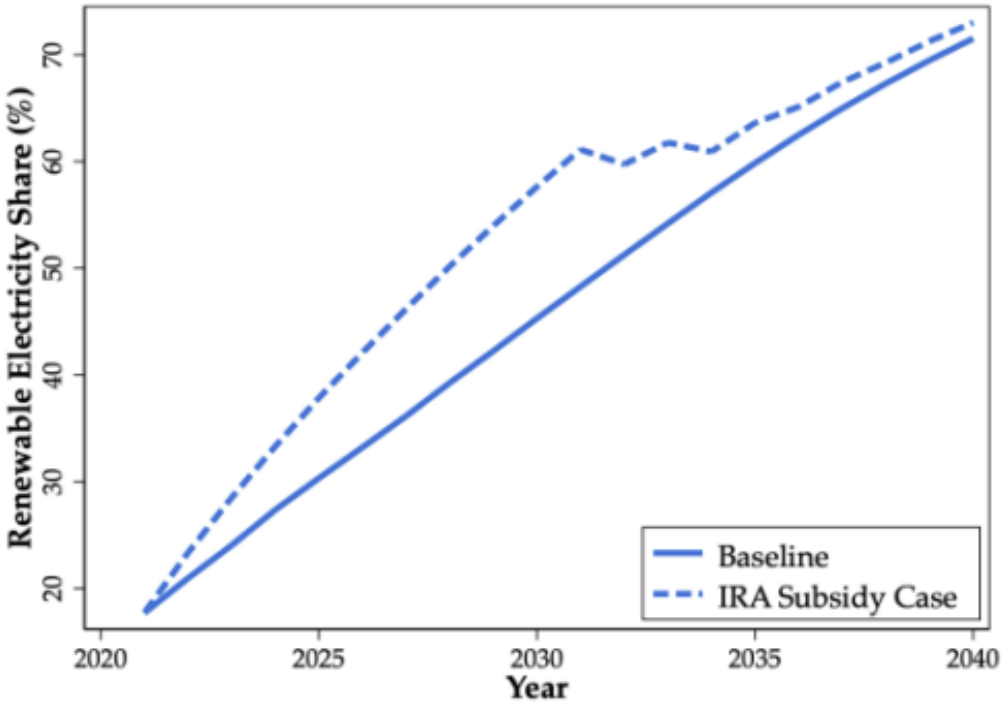
Winners and Losers Across the Globe

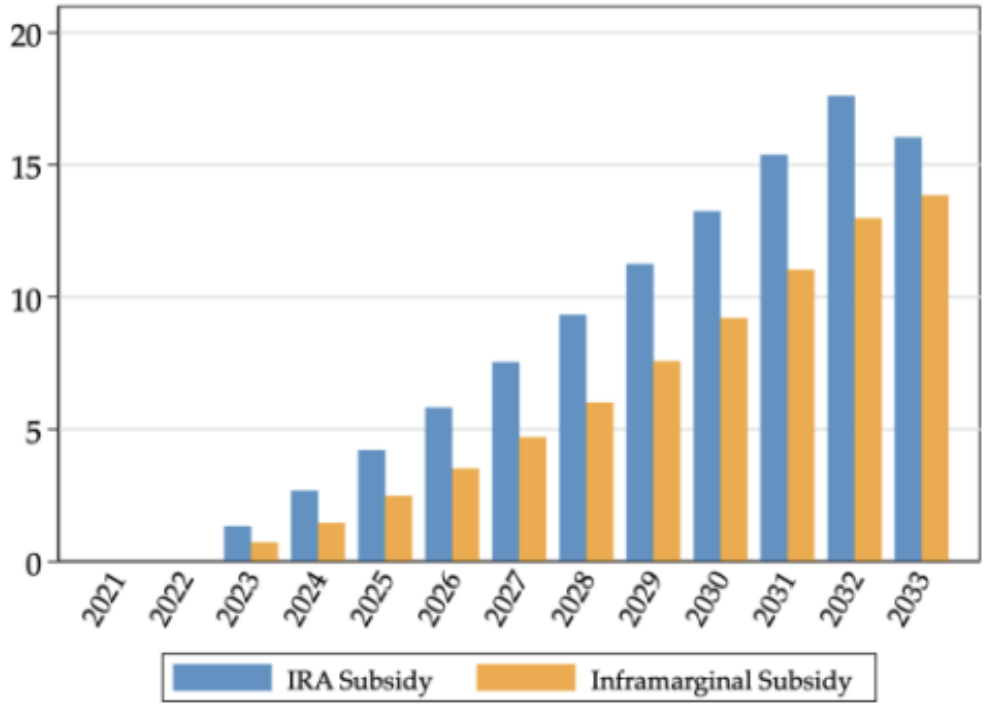
- Countries with connected grid, developing countries win
  - Countries specializing in exporting fossil fuels experience negative wealth effects



Inflation Reduction Act

- Signed into law Aug ’22. Provides (retains) tax credit to renewable energy
  - $5 in our counterfactual ($5-26). Phases out in 2033





Renewable Transition Challenges

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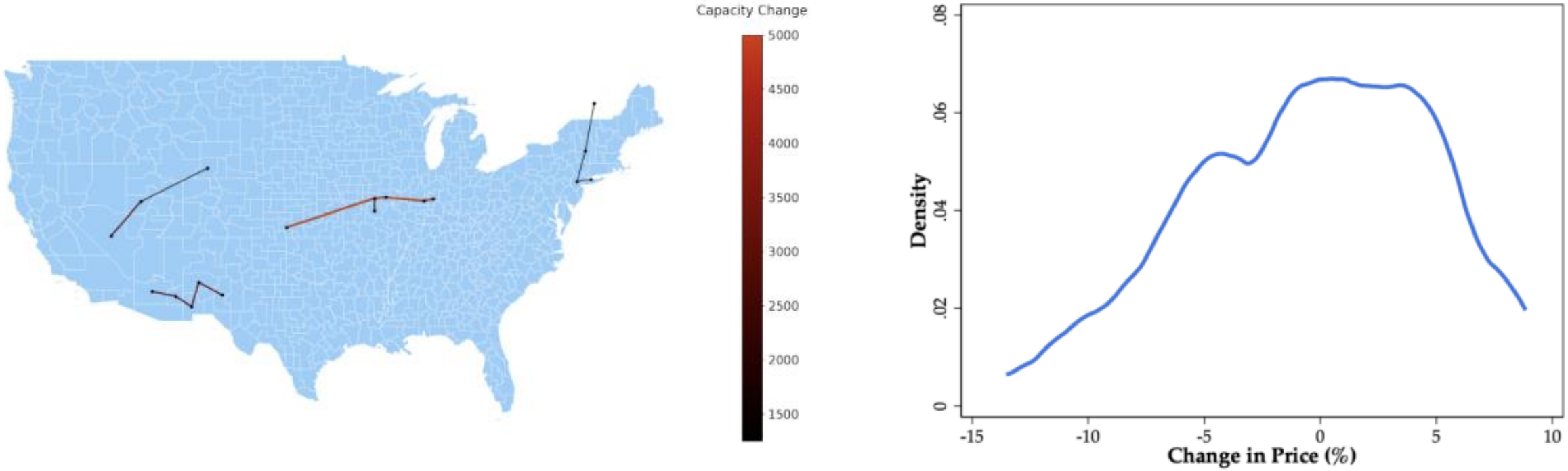
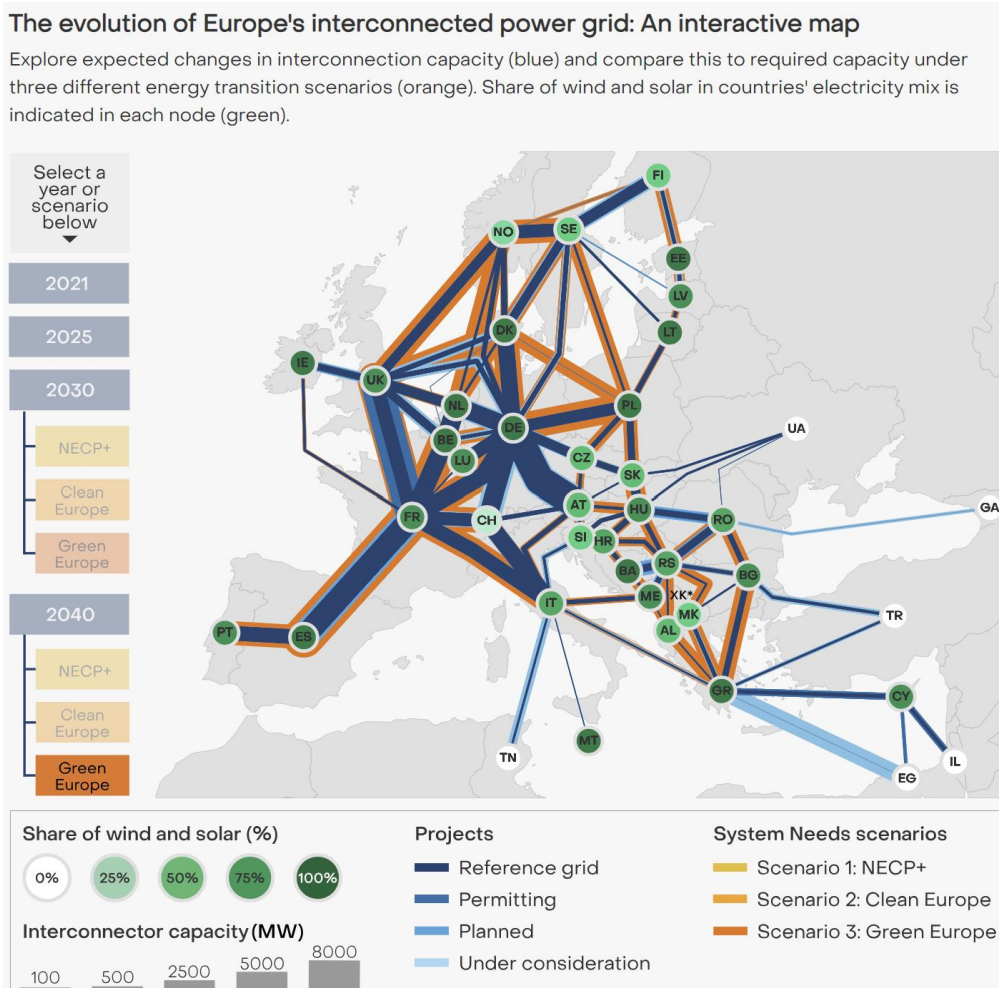
Grid Constraints: Infrastructure & Jobs Act

- Model specific lines under completion. Add them to our network
  - Estimated cost of $10 billion. Generate $1.5 billion annual net benefit. Effects not uniform



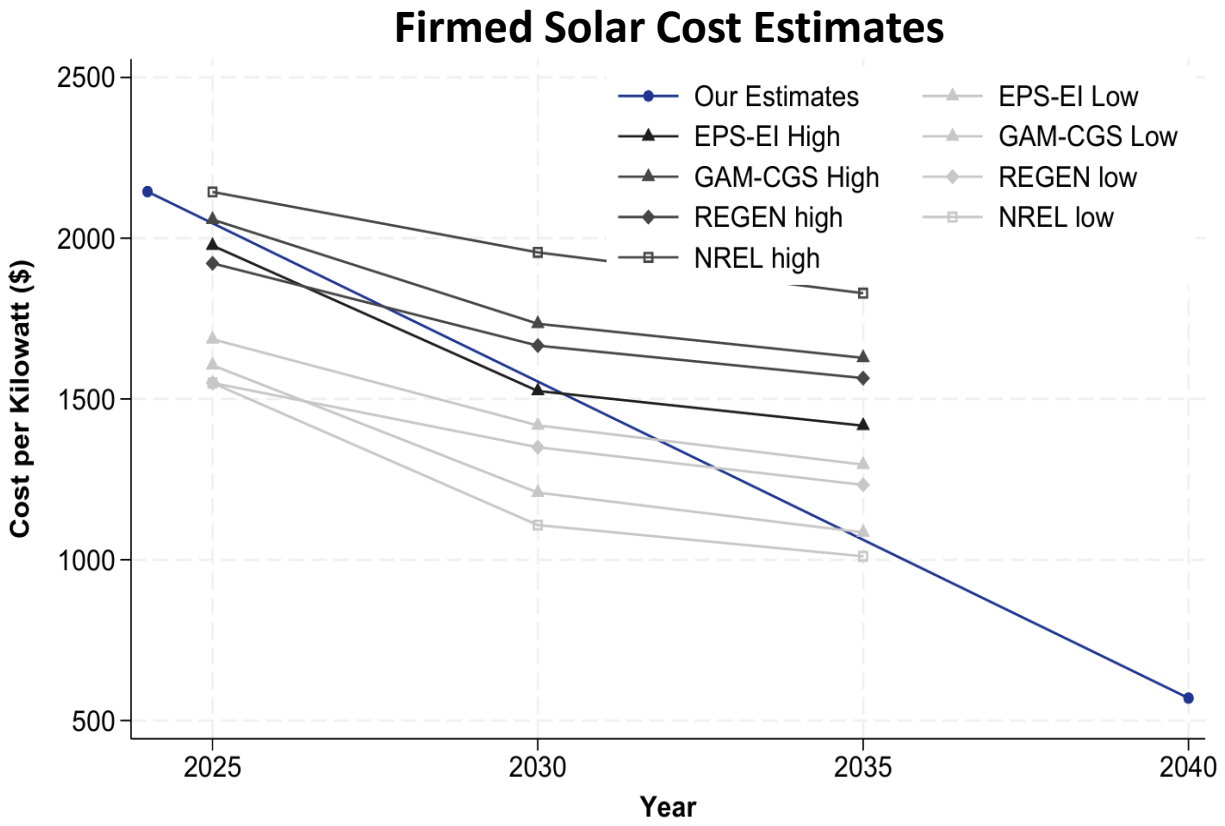
Grid Interconnectivity & Green Transition: Is Europe There?

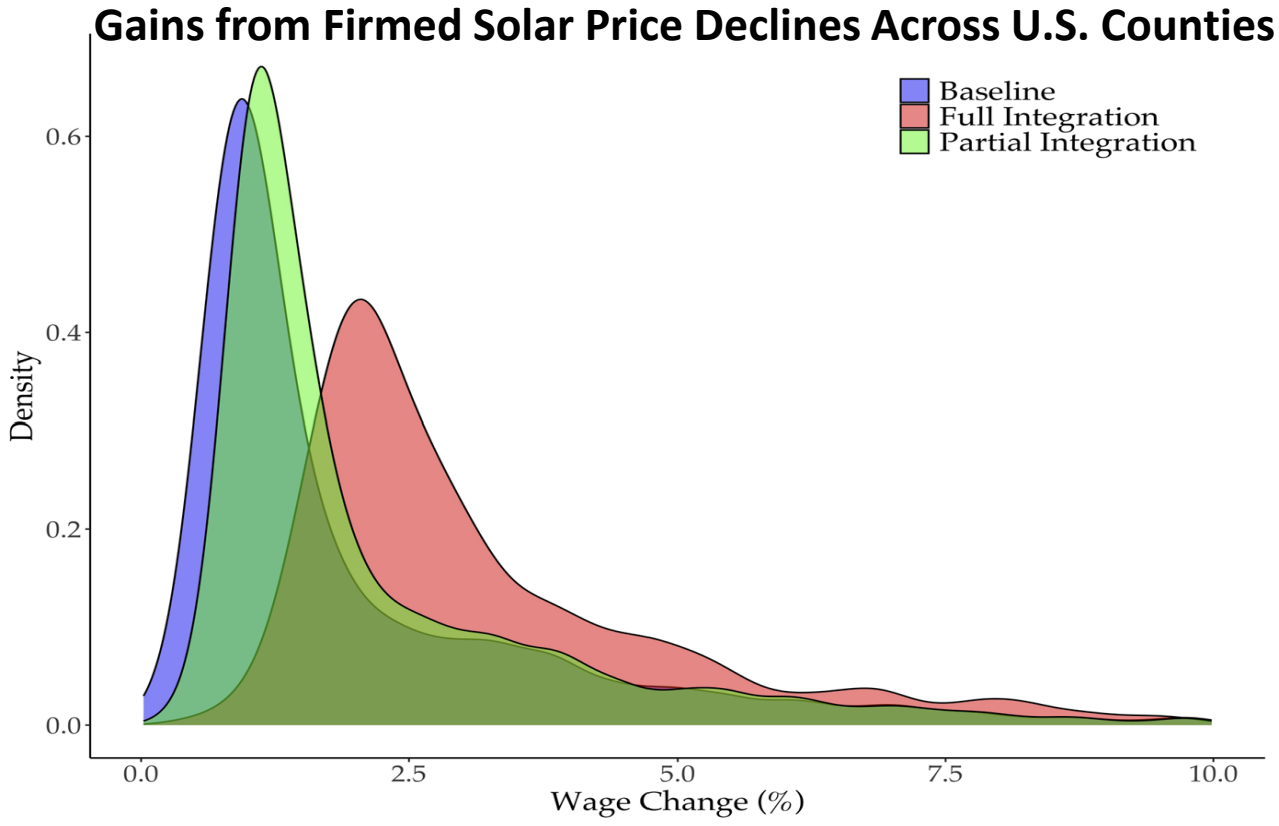
- What are planned investments? How many upgrades do we need for transition?



The Intermittency Challenge & the Storage Solution

- To deal with the intermittency storage is needed
  - Photovoltaics with sufficient storage (e.g. 8 hours) is called “firmed solar”





Challenges: Local Opposition and Policy Barriers

- Renewables are deploying extremely fast
  - For some they are an eye shore, and large land clearance for their use (>1% for Greece!)
  - It is not long until resistance to renewables develops

- In the United States local governments or states set increasingly more barriers
  - Europe plowing through new regulations facilitating renewables. Centralization is key
  - Needs to be done with care or else opposition will mount. Offsetting payments to locals
  - Data indicates opposition comes from variety of reasons. Increases when more land used

Conclusions and Food For Thought

- Age of renewables has begun!
  - Lower capital costs spur adoption, which further lower capital costs and prices

- Are we the optimists?