WORLD BANK
DEVELOPMENT RESEARCH GROUP

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Strategic Subsidies for Green Goods

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Policy background

- Economists generally advocate pricing emissions as the most efficient way to get greenhouse gas reductions

Carbon Pricing Dashboard

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KEY STATISTICS ON REGIONAL, NATIONAL AND SUBNATIONAL CARBON PRICING INITIATIVE(S)

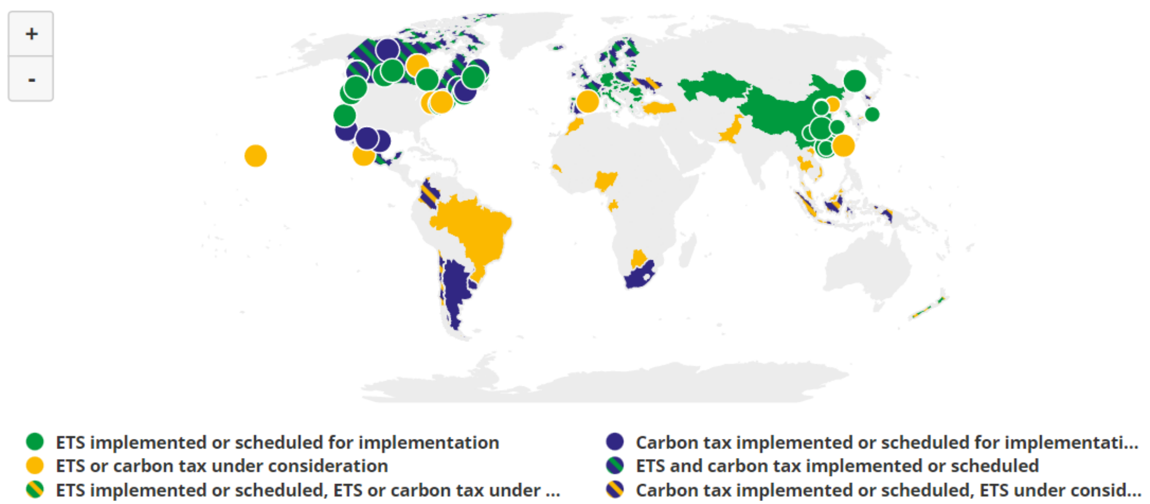
70 Carbon Pricing initiatives implemented

47 National Jurisdictions are covered by the initiatives selected

36 Subnational Jurisdictions are covered by the initiatives selected

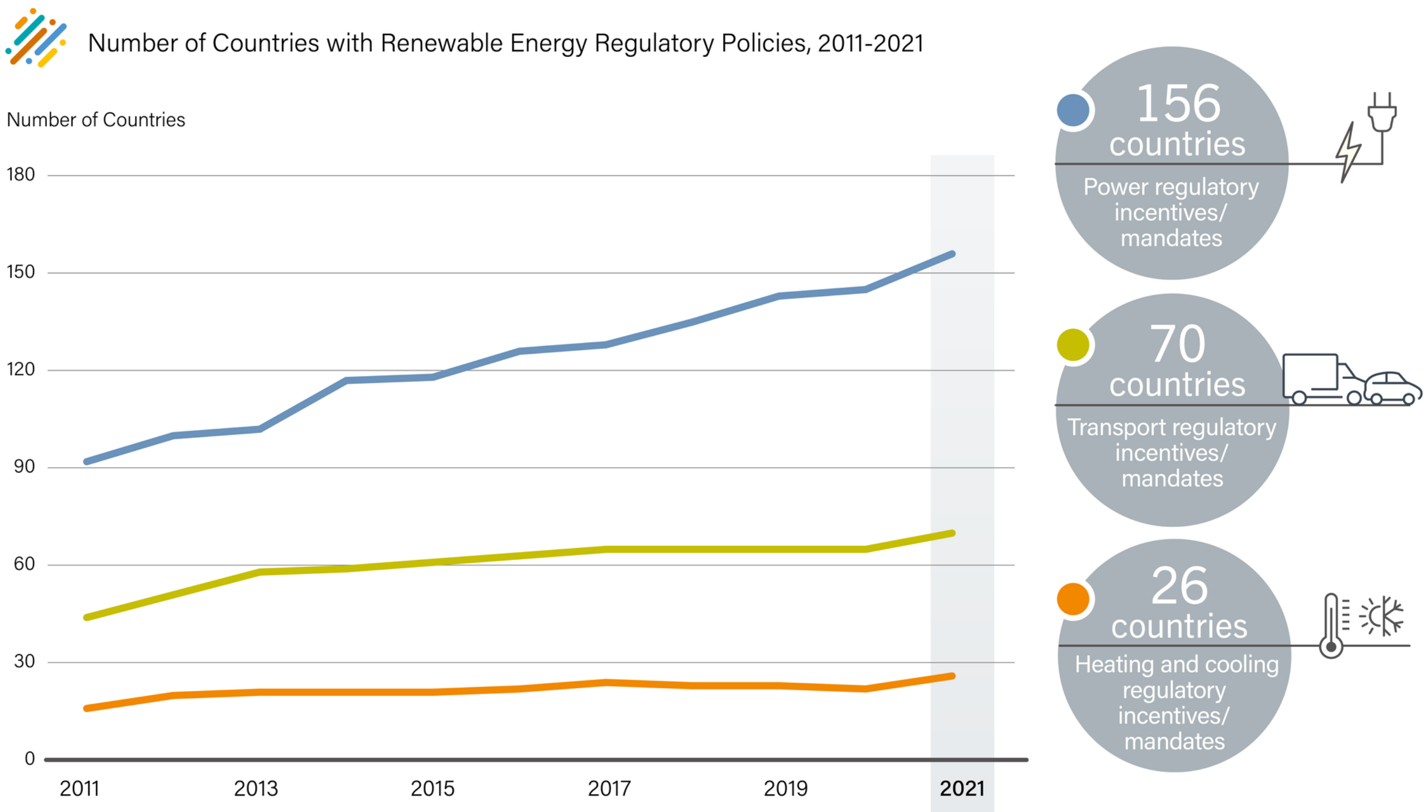
In 2022, these initiatives would cover **11.86 $GtCO_2e$**, representing **23.17%** of global GHG emissions

Summary map of regional, national and subnational carbon pricing initiatives

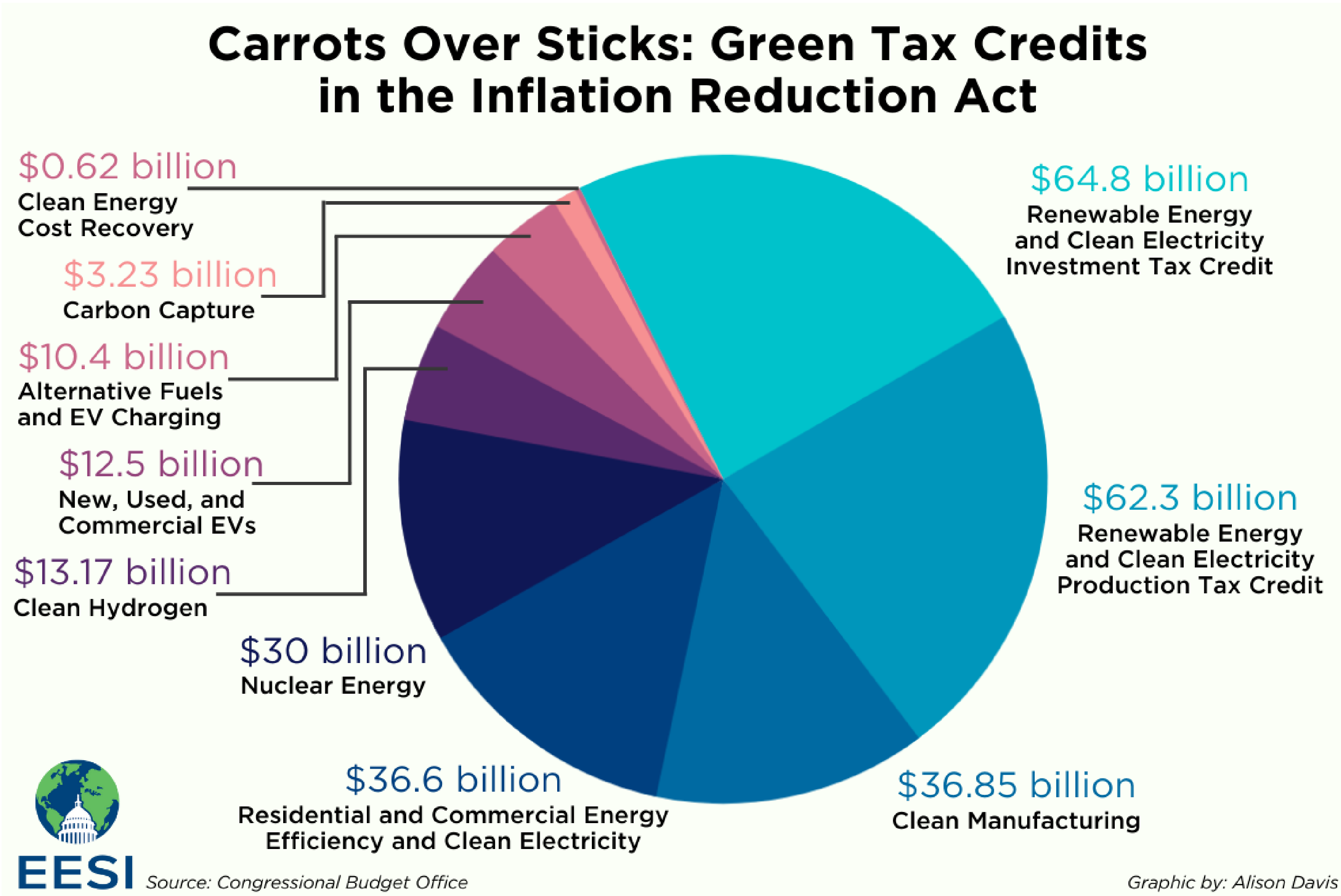


- Carbon pricing is expanding, but coverage still limited

Renewable energy policies are even more widespread



Note: The figure does not show all policy types in use. In many cases countries have enacted additional fiscal incentives or public finance mechanisms to support renewable energy. A country is considered to have a policy (and is counted a single time) when it has at least one national or state/provincial-level policy in place. Power policies include feed-in tariffs (FITs) / feed-in premiums, tendering, net metering and renewable portfolio standards. Heating and cooling policies include solar heat obligations, technology-neutral renewable heat obligations and renewable heat FITs. Transport policies include biodiesel obligations/mandates, ethanol obligations/mandates and non-blend mandates.


Carrots Over Sticks: Green Tax Credits in the Inflation Reduction Act
$0.62 billion
Clean Energy Cost Recovery
$3.23 billion
Carbon Capture
$10.4 billion
Alternative Fuels and EV Charging
$12.5 billion
New, Used, and Commercial EVs
$13.17 billion
Clean Hydrogen
$30 billion
Nuclear Energy
$36.6 billion
Residential and Commercial Energy Efficiency and Clean Electricity
$36.85 billion
Clean Manufacturing
$62.3 billion
Renewable Energy and Clean Electricity Production Tax Credit
$64.8 billion
Renewable Energy and Clean Electricity Investment Tax Credit
EESI
Source: Congressional Budget Office
Graphic by: Alison Davis

Recent WTO renewable energy disputes

- United States — Certain Measures Relating to the Renewable Energy Sector (Complainant: India, 2016; China, 2018)
- European Union — Certain Measures on the Importation and Marketing of Biodiesel and Measures Supporting the Biodiesel Industry (Complainant: Argentina, 2013) … — Certain measures concerning palm oil and oil palm crop-based biofuels (Complainant: Malaysia, 2021)… — Countervailing duties on imports of biodiesel from Indonesia (Complainant: Indonesia, 2023)
- India — Certain Measures Relating to Solar Cells and Solar Modules (Complainant: United States, 2013)
- European Union and Certain Member States — Certain Measures Affecting the Renewable Energy Generation Sector (Complainant: China, 2012)
- Canada — Measures Relating to the Feed-in Tariff Program (Complainant: European Union, 2011)
- Canada — Certain Measures Affecting the Renewable Energy Generation Sector(Complainant: Japan, 2010)
- China — Measures concerning wind power equipment (Complainant: United States, 2010)

Many forms of green industrial policy

- Upstream interventions to drive down costs
  - R&D support
  - Technology production incentives
    - Tax incentives, preferential finance, below-cost inputs, land, etc.

  → Lowers global technology prices

SCM Agreement

- Downstream incentives to drive up demand
  - Production tax credits, feed-in tariffs, renewable portfolio standards
  - Investment incentives

  → Pulls up global technology prices
    - Unless scale economies very large

Economic rationales for subsidizing green goods

- Upstream market failures
  - R&D spillovers
  - Network / scale / learning externalities
  - Imperfect competition
    - New industries
    - Patented technologies

- Downstream market failures
  - Underpriced emissions
    - including subsidies for fossil fuels
  - Behavioral gaps
- Other goals: jobs and exports

Trade literature on subsidies with concentrated industries

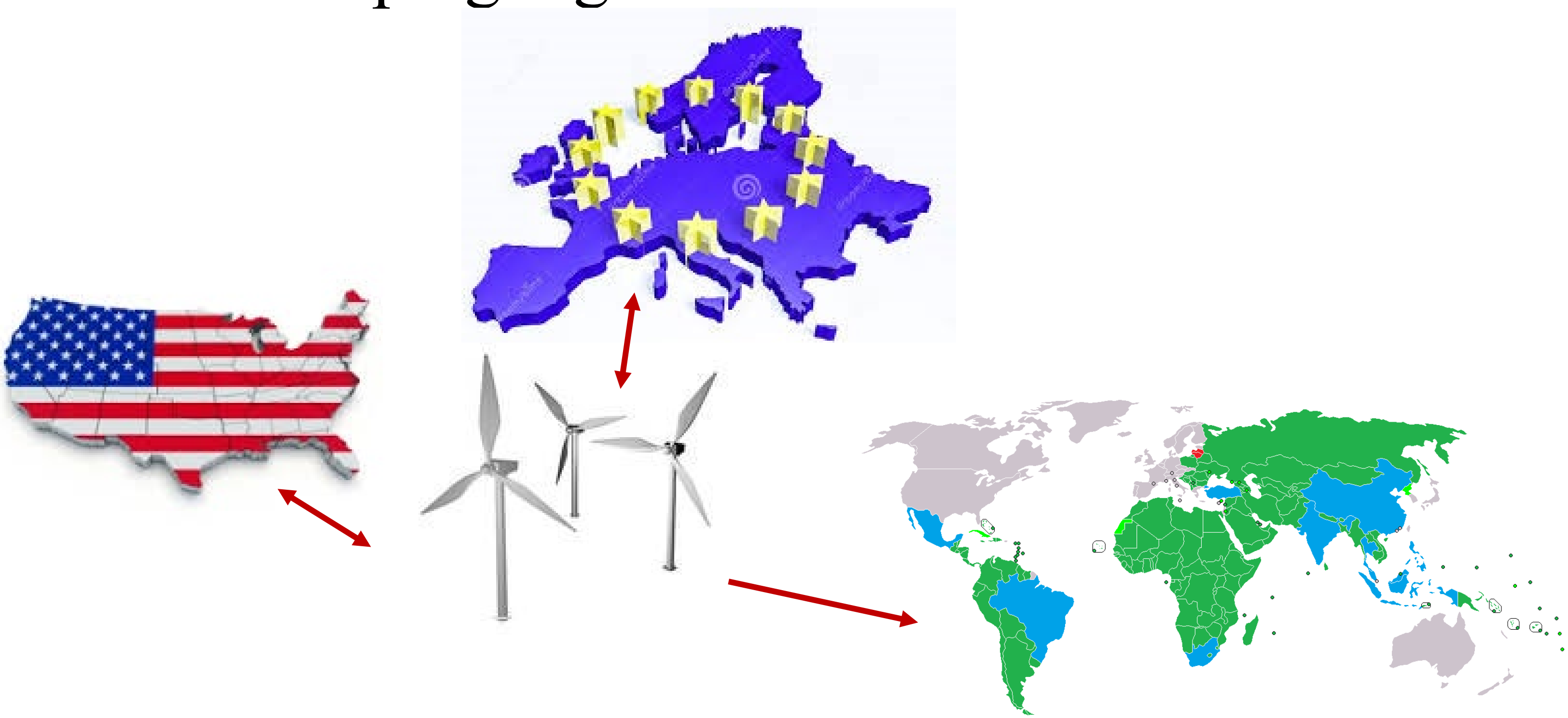
- Spencer and Brander (1983), Brander and Spencer (1985)
  - 2 Cournot producer countries with 3rd party export market
  - Focus on export / production subsidies, not in tandem with consumption subsidies
- Find that joint profits would be maximized with *lower* upstream subsidies than a Nash equilibrium obtains
  - Thus recommend negotiating restrictions on subsidies
- Ignores that global welfare is maximized with *higher* subsidies…

More trade literature on subsidies

- Extensions of Brander and Spencer:
  - Eaton and Grossman (1986) for Bertrand competition
  - Dixit (1984) for multiple firms
  - Krugman (1984) for increasing returns to scale
  - Leahy and Neary (1999) for R&D spillovers
- Questions of global welfare or correcting market failures are de-emphasized or ignored
  - Key aspects of international environmental policy

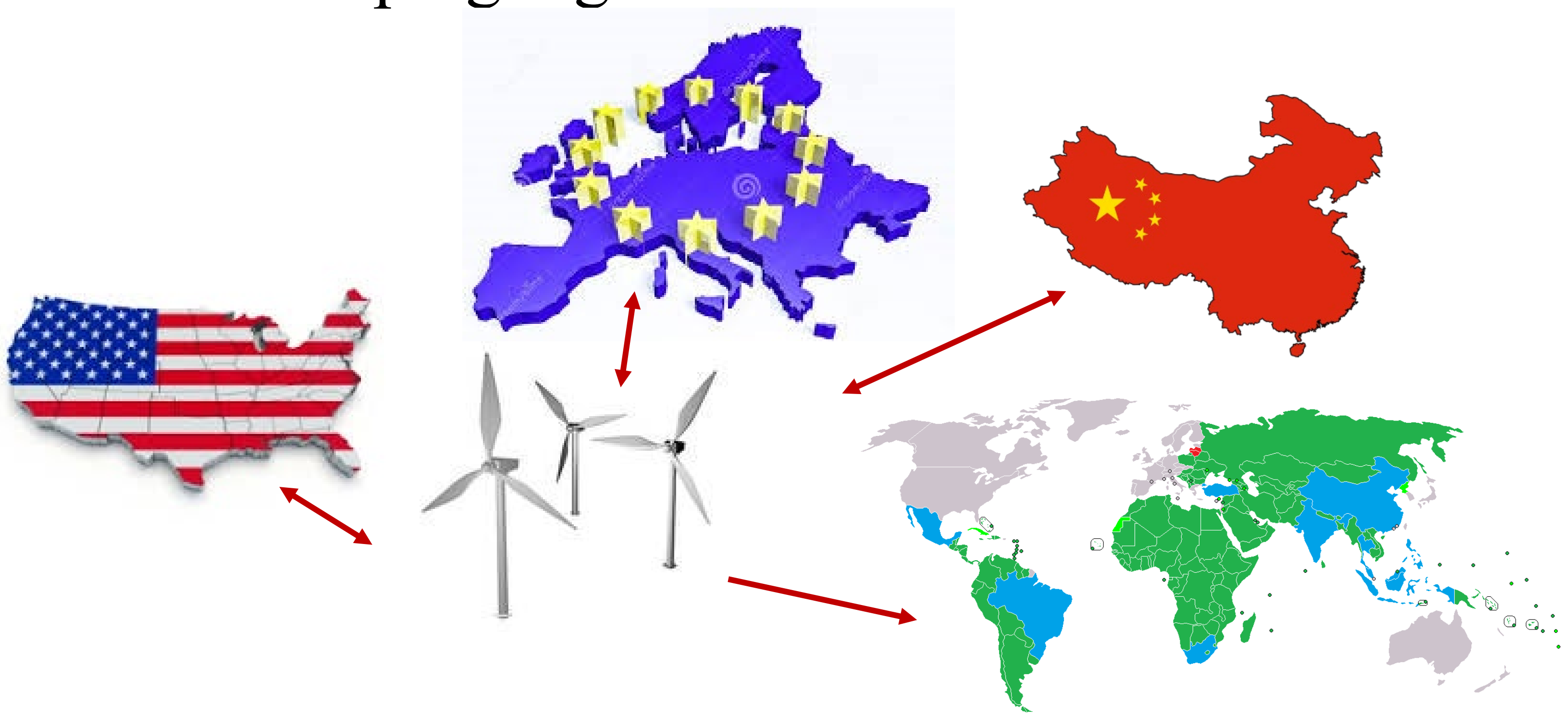
Theory model setup

- 2 regions produce and consume a green technology and export to ROW
  - E.g., technology leaders and follower / developing region



(Numerical model setup)

- 3 regions produce and consume a green technology and export to ROW
  - E.g., technology leaders and follower / developing region



Policy instruments

- Upstream subsidy to manufacturing, γ_i
- Downstream subsidy to deployment, η_i

- Only available in producing regions; ROW is assumed to have no policies

Model structure: Downstream consumption of the green good

- Linear demand function
  - Market share weight of *m* to explore demand heterogeneity

$$x_i = m_i\left(a-(P-\eta_i)\right)/b; \quad \sum_i m_i = 1$$

- Leads to linear inverse demand function for upstream producers of

$$P = A - BX = a + \overline{\eta} - bX$$

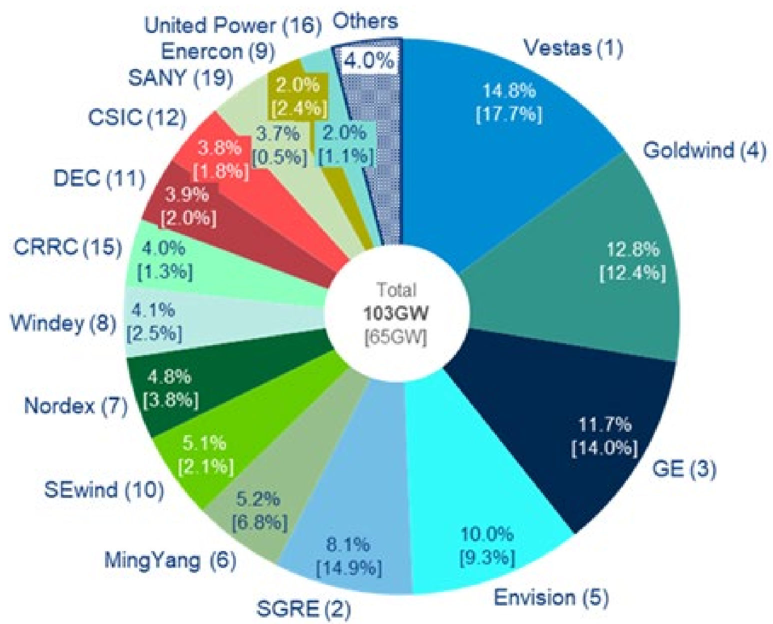
- (Unpriced) External benefits of consumption
  - Region-specific avoided emissions factors, μ_i

$$E_G = \mu_1 x_1 + \mu_2 x_2 + \mu_3 x_3$$

Model structure: Upstream production of the green good

- Cournot competition
  - Producers can keep prices higher by withholding output
  - n_i symmetric firms with unit cost c in country i

Global top 15 wind turbine OEMs: market share 2020



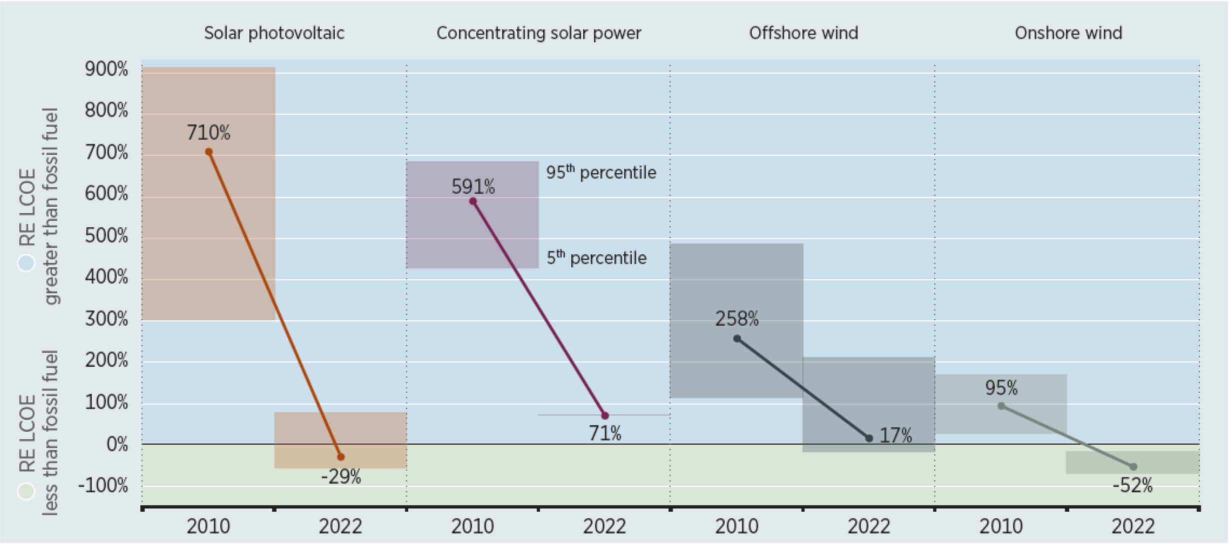
Source: Wood Mackenzie.

Note: [%] indicates 2019 market share; (#) indicates 2019 ranking. Chinese turbine OEMs based on installed capacity.

Model structure: Scale economies

- Encapsulated in static framework
  - Unit costs are a decreasing linear function of global supply: $c_0 - gY$
  - To allow comparison with no scale effects, calibrated so production is the same with no policies: $c_0 = c + (a - c)g/B$

Figure S.1 Change in competitiveness of solar and wind by country based on global weighted average LCOE, 2010-2022



Note: The global weighted average LCOE data by technology and the fossil fuel LCOE data used to derive this chart is presented in detail in Chapter 1; RE = renewable energy.

Source: IRENA (2023).
The analysis excludes government incentives and system balancing costs.

Different objectives

- Global planner wants to maximize all welfare:
  upstream profits, downstream surplus, total revenues, and environmental benefit of v_G

$$W_G = \Pi_1 + \Pi_2 + CS_1 + CS_2 + CS_3 + TR_1 + TR_2 + v_G E_G$$

- Governments of individual regions maximize own welfare, with their own environmental valuation v_i:

$$W_i = \Pi_i + CS_i + TR_i + v_i E_G$$

Theory results: imperfect competition

- Social planner subsidizes only upstream;
  Nash: regions subsidize both up- and downstream;
- Without 3rd market, Nash equilibrium replicates the social optimum

$$\eta_{C,i}^{\text{Nash}} = \eta^{*} = 0, \;\; \overline{\gamma}_{C}^{\text{Nash}} = \gamma^{*}$$

- With 3rd market, the sum of the Nash subsidies are less than the planner's subsidy.
  - Joint-profit maximizing subsidies are even lower

Theory results: environmental benefits

- Global planner sets subsidies so the sum = MEB in all regions $\left\{\gamma_i^* = v_G \mu_3;\ \eta_i^* = v_G(\mu_i - \mu_3)\right\}, i = \{1,2\}$
- Without imperfect competition, regions subsidize downstream $\eta_i^{\text{Nash}} \to v_G \mu_i$ as $N \to \infty$
- Without 3rd market, Nash duopoly replicates the social optimum *if* they value at the global SCC

$$\bar{\gamma}^{\text{Nash}} + \eta_i^{\text{Nash}} = v_G \mu_i$$

- With 3rd market, strategic producers offer insufficient upstream subsidies and lower environmental gains

Theory results: scale economies

- Social planner subsidizes only upstream, more than with IC alone
- Symmetric strategic countries subsidize both downstream and upstream, and the presence of scale effects lowers that sum.
- Symmetric strategic countries offer total subsidies that are less than those desired by the global planner, even in the absence of a third-party downstream market.

Summary of theory

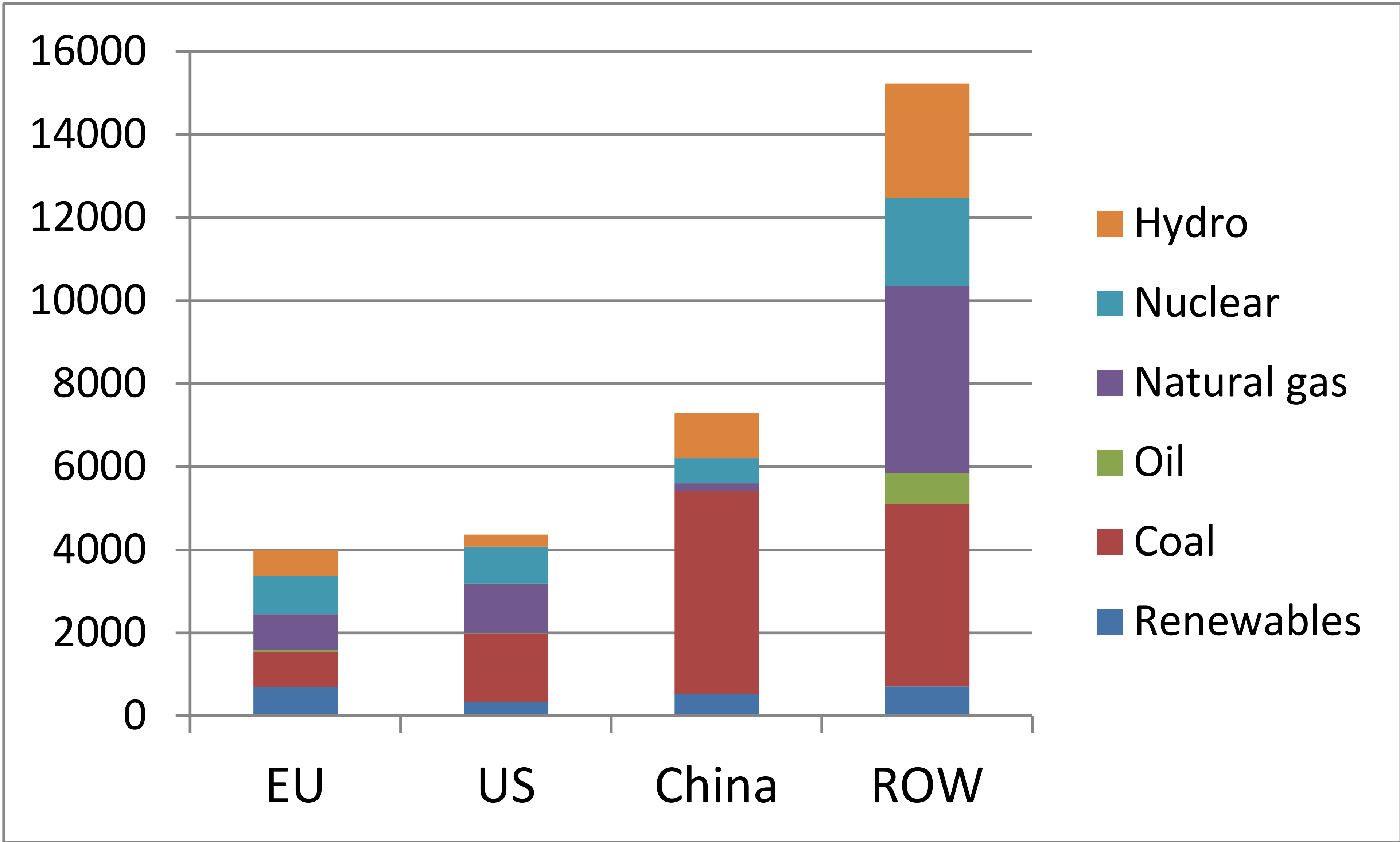
- These kinds of market failures suggest that restrictions on upstream subsidies are counterproductive for the environment and global welfare

- Quantitatively, how important are they?

Numerical simulations: an application to renewable energy

- EU, US, China + ROW
- Downstream electricity markets with linear supply curves for fossil and renewable energy
  - 2020 projections from International Energy Outlook
  - Market equilibrium derives renewables as function of the policy variables
- Parameterized based on other exercises
  - Fischer, Newell and Preonas (2013) for US
  - Fischer, Huebler and Schenker (2014) for EU
  - No dynamics here; 2015-2020 stage
  - China and ROW assumed to have same supply elasticities at the baseline point

Generation in 2020 by source



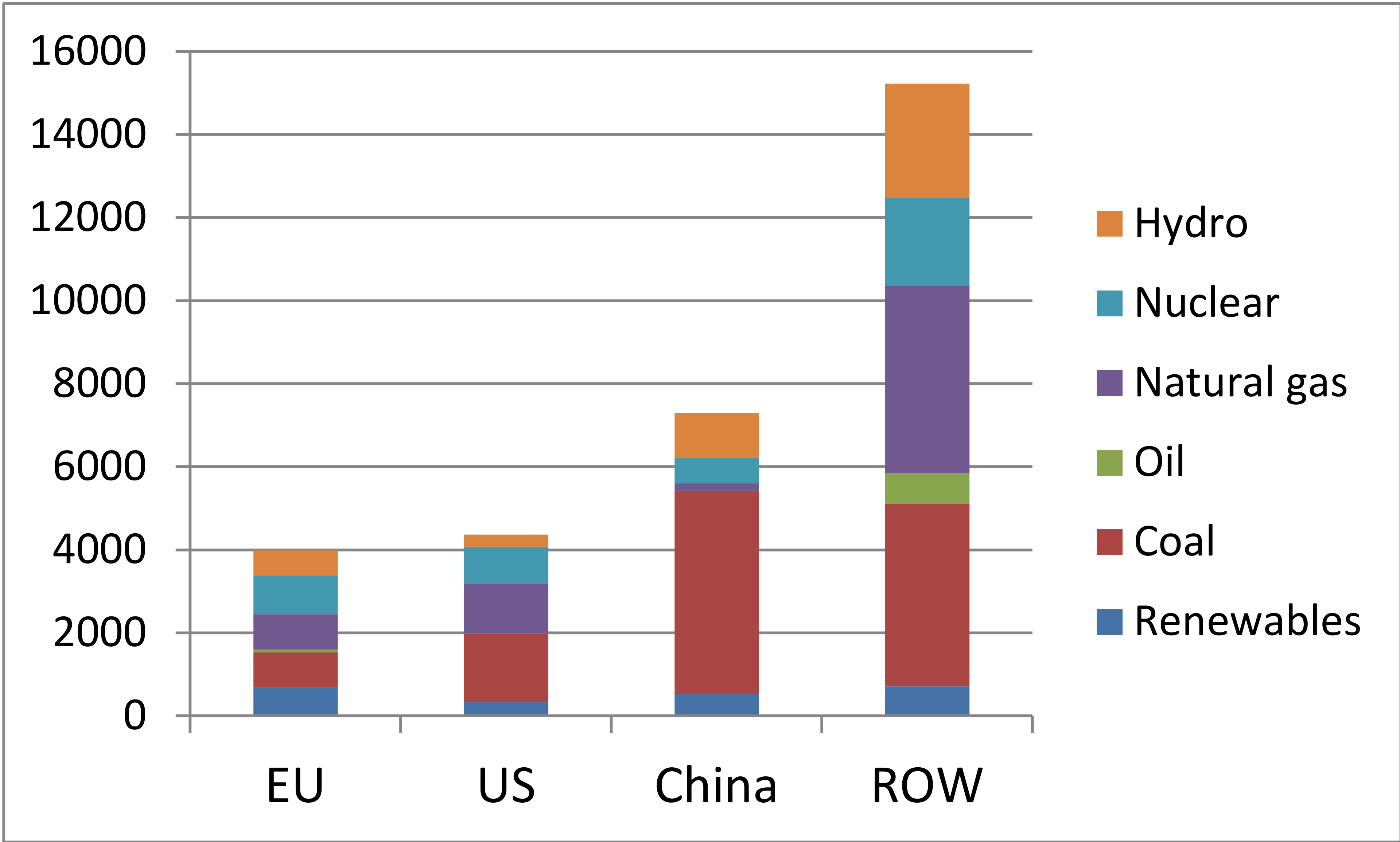
Upstream market stylized for wind

- Top individual producers' market shares (2015-2020):

11%	GE Energy	USA
16%	Vestas	EU
12%	Goldwind	China

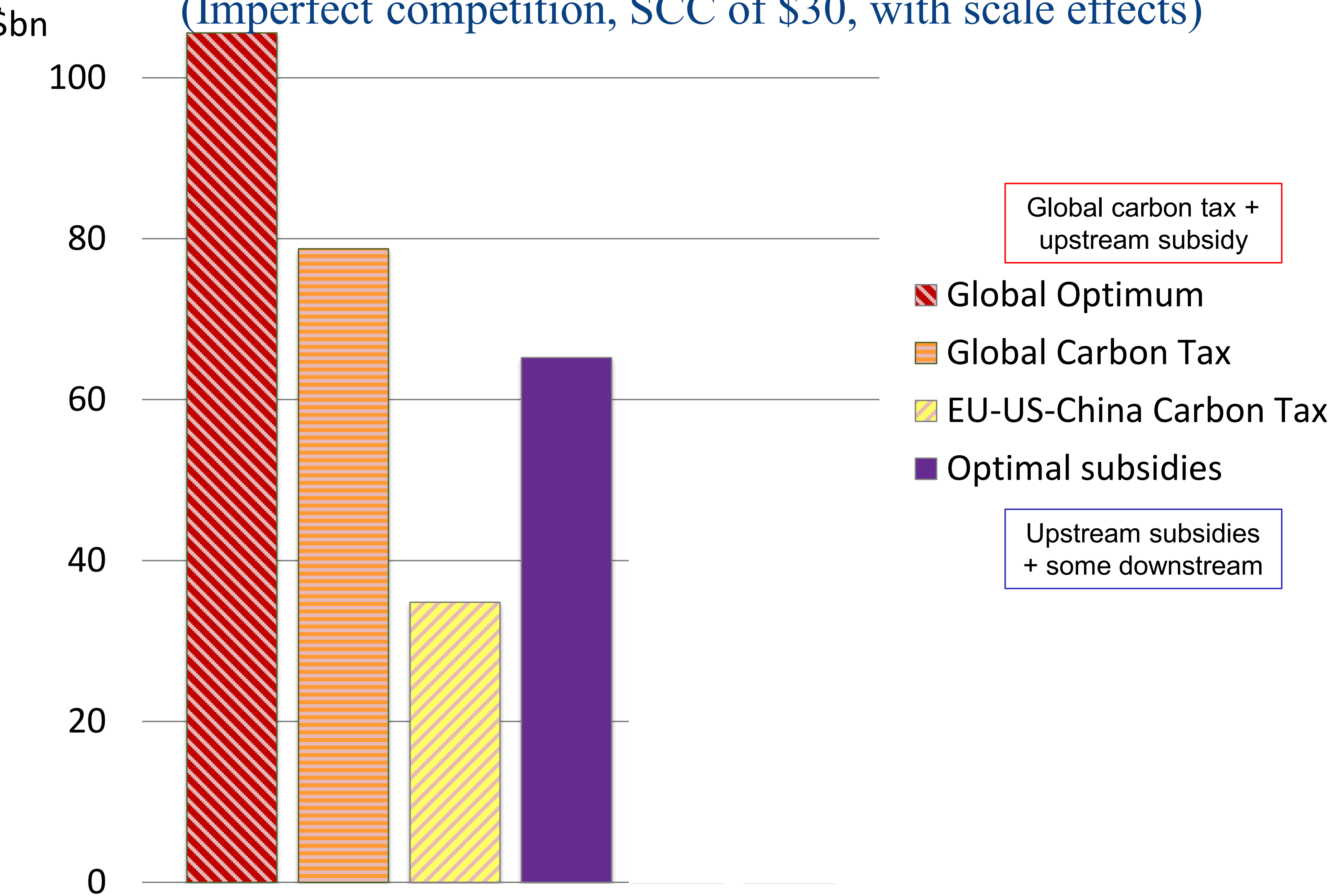
- Imply 7ish firms in Cournot setup
- Market share of top EU producers is 38%
- Assumptions
  - Imperfect competition (IC):
    2 firms each in US & China, 4 in EU
  - Perfect competition (PC):
    200 in US & China, 400 in EU

Generation in 2020 by source
(IEO)



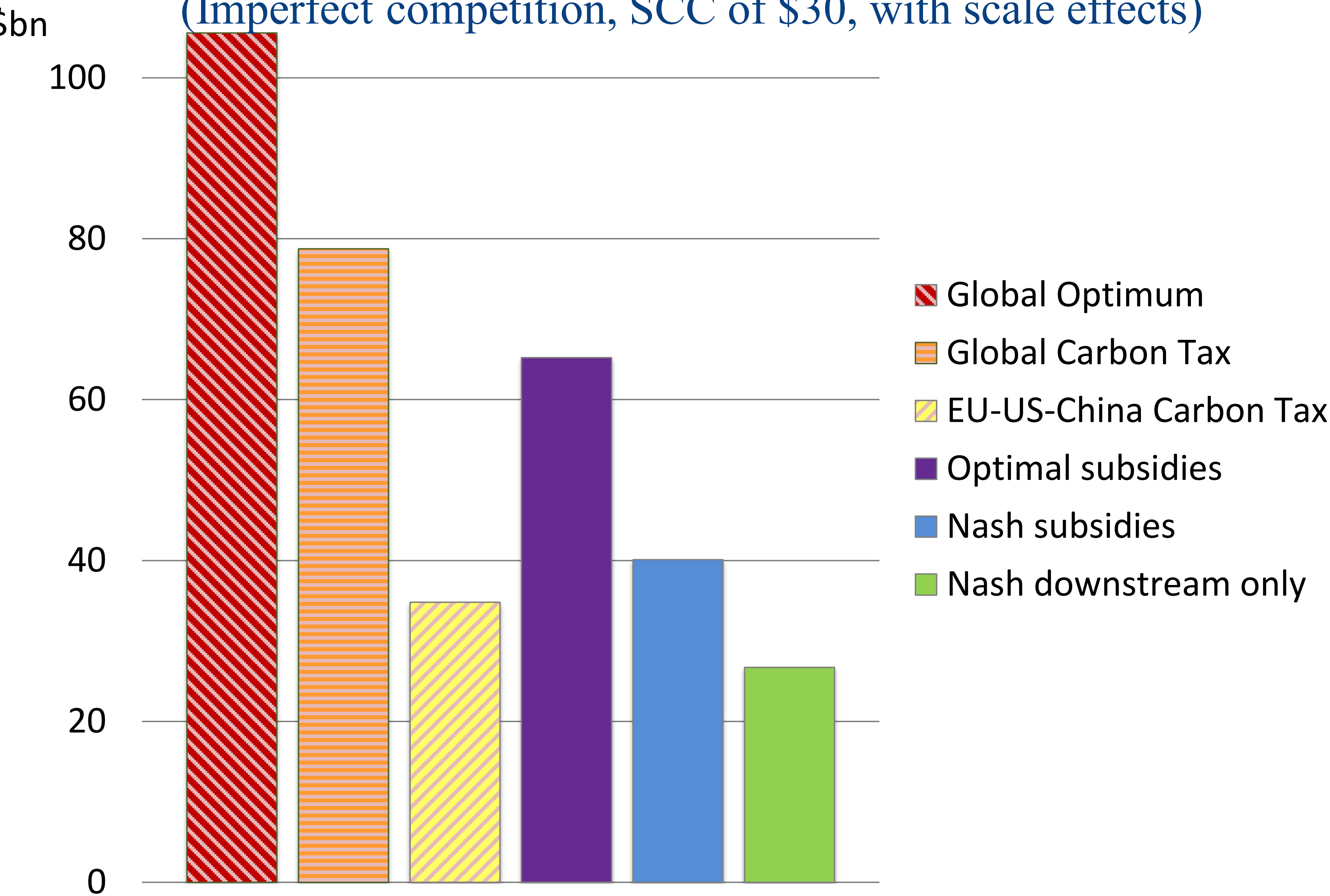
Global welfare gains from policy

(Imperfect competition, SCC of $30, with scale effects)



Global welfare change from No Policy

(Imperfect competition, SCC of $30, with scale effects)



Conclusion from "Strategic Subsidies…"

- We are in a highly imperfect world
- Requires more nuance from economists and technologists
- Carbon pricing is important but not enough
  - Just as we should address competitiveness effects in carbon pricing to avoid carbon leakage,
  - We should address global effects of technology policies to maximize negative leakage

More on strategic technology policies

Fischer, C., M. Greaker, and K.E. Rosendahl. 2018. Strategic technology policy as supplement to renewable energy standards. *Resource and Energy Economics*. 51: 84–98 (February). https://doi.org/10.1016/j.reseneeco.2017.05.006

Fischer, C., M. Greaker, and K.E. Rosendahl. 2017. Robust Technology Policy Against Emission Leakage: The Case for Upstream Subsidies. *Journal of Environmental Economics and Management*. 84 (July): 44–61. doi:10.1016/j.jeem.2017.02.001

Fischer, C. 2017. Environmental Protection for Sale: Strategic Green Industrial Policy and Climate Finance. *Environmental and Resource Economics*. 66 (3): 553–575 (March). doi:10.1007/s10640-016-0092-5