Introduction to Permit Trading

- Tradable permits work by addressing the *property rights* problem
  - Permits give a firm a property right to emit a certain level of a pollutant, but no more
  - A firm needs to obtain the right to exceed the limit by purchasing more permits
  - If the firm does not want to use all of its permits, it can sell them to someone else

Introduction to Permit Trading

- Two types of trading programs:
  - Credit trading programs
    - Firms can sell credits generated by reducing emissions more than required
    - Offset programs are an example
      - Offsets may be regulated or voluntary
  - Cap-and-trade programs
    - Government makes a centralized decision as to how much pollution is allowed, then distributes permits to all participants

Introduction to Permit Trading

- How permits work:
  1. Government begins by setting the desired level of emissions
     - Thus, like command and control policies, the government has control over the final amount of pollution
  2. Firms are issued permits to emit pollutants
     - Only the desired number of permits is issued
     - Thus, the amount of pollution is assured
  3. Firms can buy and sell permits
     - Firms with higher MAC will be willing to buy permits from firms with lower MAC

Offsets

- Offsets can be regulated or voluntary
  - *Regulated* offsets used to comply with environmental regulations
    - Clean Air Act requires firms building new facilities in non-attainment areas to offset new emissions by reducing emissions nearby
    - Purchasing credits to apply to a cap-and-trade program
  - *Voluntary* offsets purchased to reduce the environmental impact
    - Often used by firms (or other organizations) to demonstrate environmental commitments

Offsets

- Use of offsets is growing

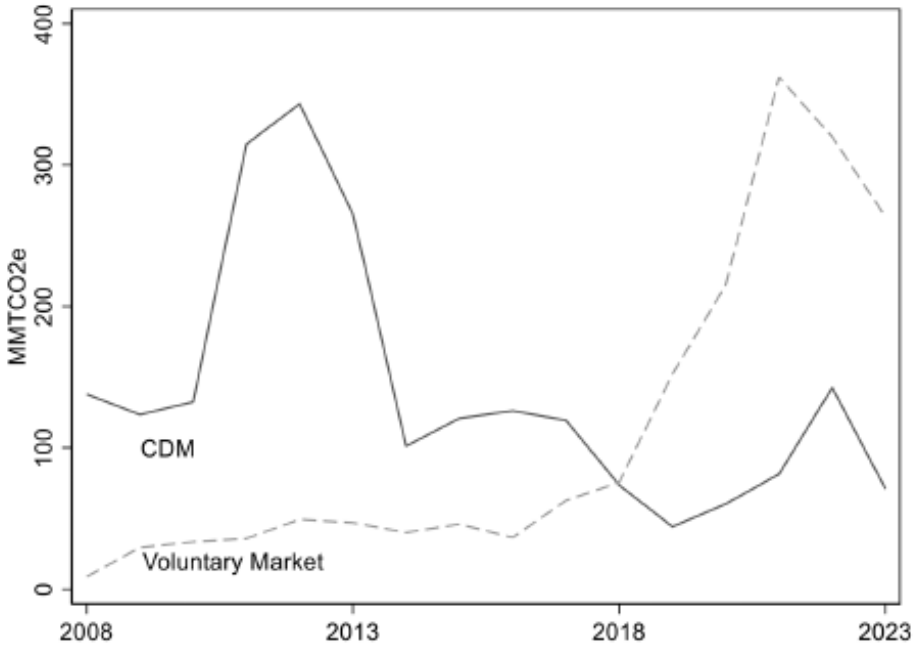

Figure 1 CDM and voluntary market offset volumes (issued credits), million metric tons of CO_2 equivalent, 2008–2023. Sources: Voluntary Carbon Market Dashboard, Climate Focus, available at https://climatefocus.com/initiatives/voluntary-carbon-market-dashboard/, and UNFCCC Clean Development Mechanism database, available at https://cdm.unfccc.int/Statistics/Public/files/202312/cershpnum.xls.

Source: Aldy and Halem, *Review of Environmental Economics and Policy*, 2024

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Offsets

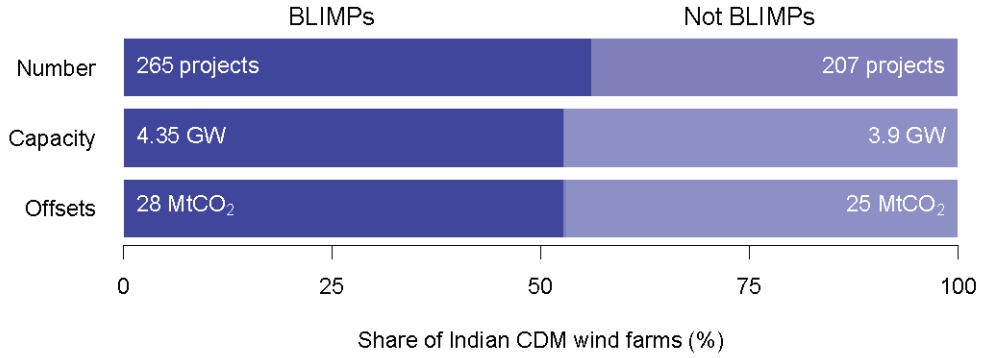
- A key principle for offsets is *additionality*
  - Would the emission reduction have occurred without the sponsored project?
    - We don't want to give others credit for something that would have happened anyway
    - However, how do we measure this? Requires knowing the no-intervention baseline

Offsets

- Example: additionality in the Clean Development Mechanism (CDM) considers four requirements
  1. *Identify alternative scenarios*: What other options are available to project participants? Do these alternatives comply with local regulations?
  2. *Barrier analysis*: Are there barriers to implementing the alternative scenarios? Are there barriers to completing the proposed CDM project that the project design overcomes?
  3. *Investment analysis*: Is the baseline scenario (i.e., the projection of what would have occurred in the absence of CDM investment) a better financial investment than the proposed CDM project?
  4. *Common practice analysis*: Is the proposed project currently common practice in the area?

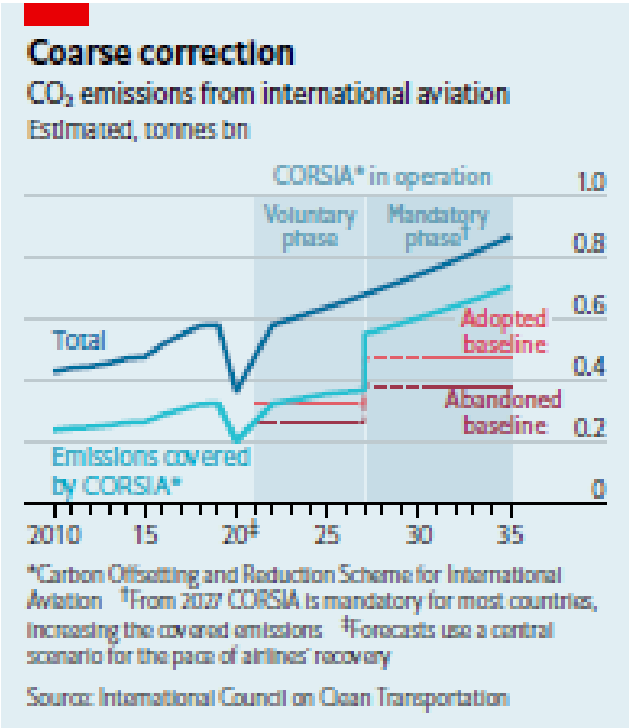
Offsets

- Does this work?
  - To test how well CDM identified additionality, Calel *et al*. (2021) compare wind turbines built under CDM in India to those not supported by CDM
  - They identify as **BLIMPs** (blatantly inframarginal projects) CDM projects built in the same state and the same year as an unsubsidized project that is less productive and is farther from the grid



Implementation Issues

- Initial allocation of permits
  - Auction permits to highest bidder
    - At least initially, additional trading shouldn't be needed, as permits go to firms willing to pay the most
    - Raises revenue for the government
  - Equal distribution among firms
    - May seem fairer, but what if firms are of different sizes?
  - Historical emissions rates (more permits to bigger polluters).
    - To reduce pollution by 10%, give each firm permits equal to 90% of their current emissions
    - Penalizes early actors. Should firms that have already reduced get fewer permits?
    - CORSIA article is an example: baseline year matters



Source: "Selling a new CORSIA," *The Economist*, July 4, 2020, 57-58.

Implementation Issues

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    - CORSIA article is an example: baseline year matters
- Combined systems are possible (e.g. hold back some permits for auction)

Implementation Issues

- Initial allocation of permits
  - If the market is competitive, the market should yield an efficient solution no matter what the initial allocation
  - However, the effects on individual firms (e.g. who benefits by selling permits, versus needing to buy them), will be different

Implementation Issues

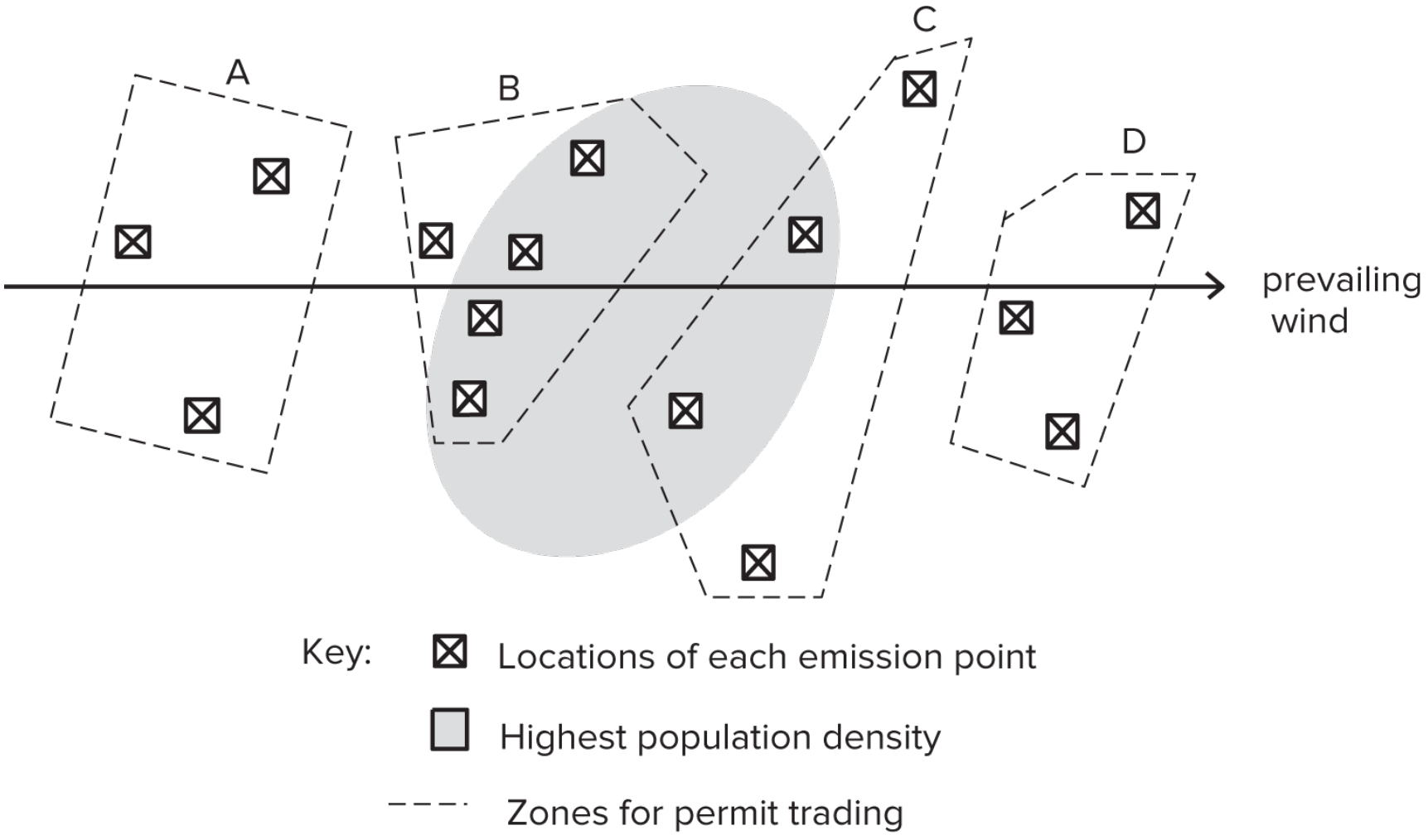
- Establishing trading rules
  - For a market to work, transactions costs must be low
  - However, at the same time, monitoring and enforcement will be necessary
    - Need to track both emissions and the number of permits each firm has
  - Are offsets allowed?
    - Usually have higher transaction costs
    - Should offsets with other geographic jurisdictions be allowed?
  - Who should be able to participate?
    - Should environmental groups or private individuals be able to buy permits and then not use them?
    - Which firms participate?
    - The EU-ETS, discussed later, illustrates the importance of these decisions

Implementation Issues

- Interaction with other policies
  - Because there is a hard cap, other policies that affect emissions may lower permit prices
    - E.g. in the EU-ETS, if an individual country adds additional regulations (e.g. UK carbon tax), demand for permits falls
    - Because supply is fixed, the price falls, but emissions do not change
  - This is known as the "waterbed" effect
  - Can address the waterbed effect by adding a price floor
    - If prices cannot fall below the price floor, emissions fall instead. Some permits go unused.

Implementation Issues

- Geographic considerations:
  - For some types of pollution (e.g. CO2), where it is emitted doesn't matter
  - For others, (e.g. carbon monoxide in a city), location does matter
  - A tax system would deal with this by charging higher fees in areas where pollution is a bigger concern


A
B
C
D
prevailing
wind
Key:
Locations of each emission point
Highest population density
Zones for permit trading

Implementation Issues

- Ways for permit system to deal with geographic concerns:
  - Ambient-based permit system: permits needed for pollution as measured at each receptor
    - E.g. a firm downwind might need to buy two permits from a firm upwind to be able to emit one unit of pollution

Implementation Issues

- Ways for permit system to deal with geographic concerns:
  - Ambient-based permit system: permits needed for pollution as measured at each receptor
  - Limit trading to within regions

Implementation Issues

- Ways for permit system to deal with geographic concerns:
  - Ambient-based permit system: permits needed for pollution as measured at each receptor
  - Limit trading to within regions
  - Limits trades to areas where the emissions have the same effect
    - For example, New York State has tried to prohibit NY power plants from selling SO2 permits to plants in neighboring states
    - The EPA divides the country into two regions (East and West) for NOX trading
    - However, such rules may prohibit some beneficial trades
    - This also limits competition, which might keep the market from working correctly

Implementation Issues

- Incentives for innovation
  - The incentives for innovation are the same as with an emissions fee
  - Consider two cases:
    - A firm has enough permits to cover its pollution.
      - The opportunity cost of polluting is that it cannot sell a permit
      - Thus, innovation not only lowers marginal abatement costs, but allows the firm to sell more permits
    - A firm does not have enough permits to cover its pollution
      - The opportunity cost of polluting is that the firm must buy a permit
      - Thus, innovation not only lowers marginal abatement costs, but saves the firm from the need to buy additional permits
  - Remember that innovation need not lower *total* emissions, since the number of permits remains the same

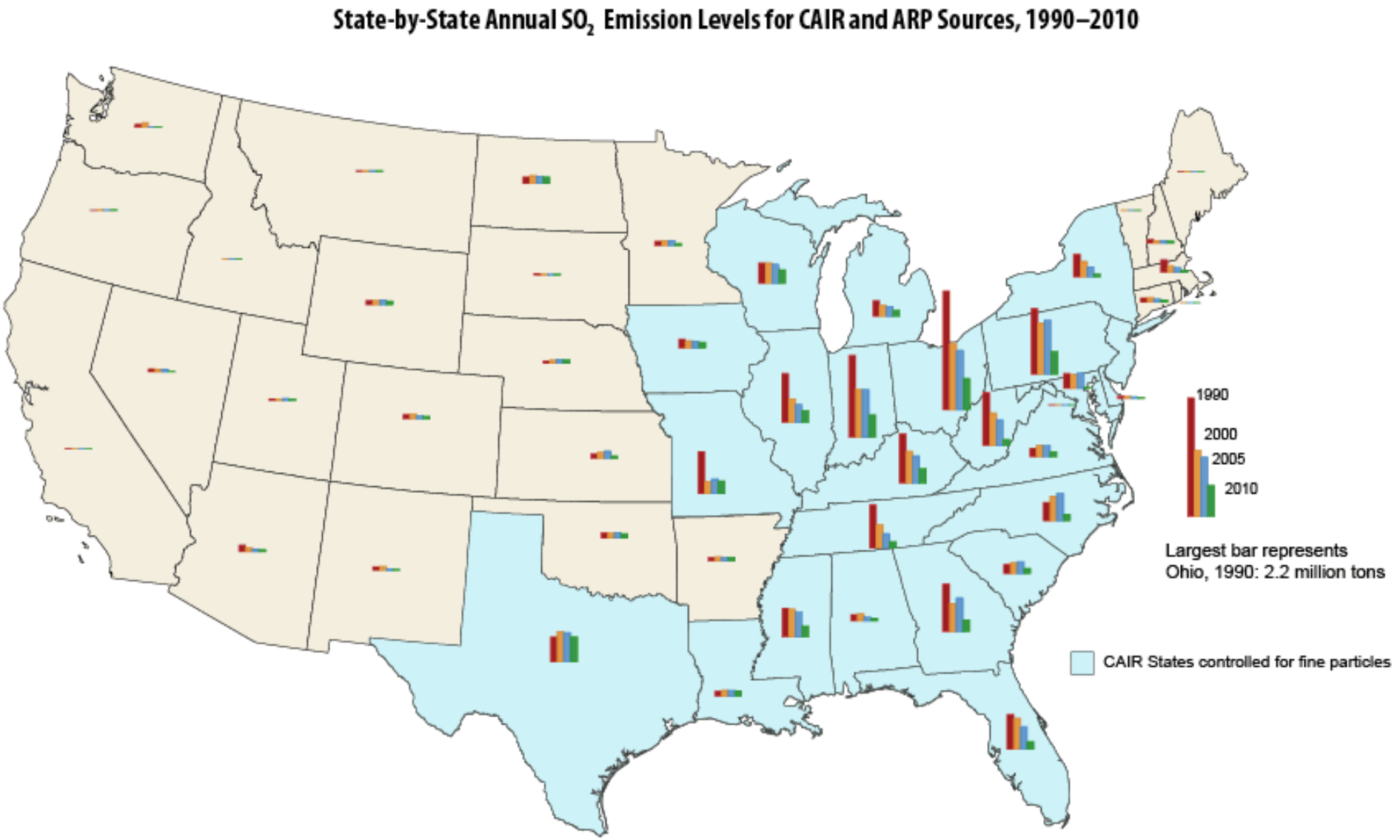
SO_2 Permits: Motivation for 1990 Clean Air Act

- Before the 1990 Clean Air Act, SO_2 and NO_x were only regulated as local pollutants
  - Plants could build large smokestacks to carry emissions away

- Results of the 1970 & 1977 Acts
  - Emissions, and acid rain, remained a problem
  - Because of BACT regulations, firms had incentives to extend lives of units
  - By 1985, 83% of SO_2 emissions came from plants that didn't meet 1971 standards for new units

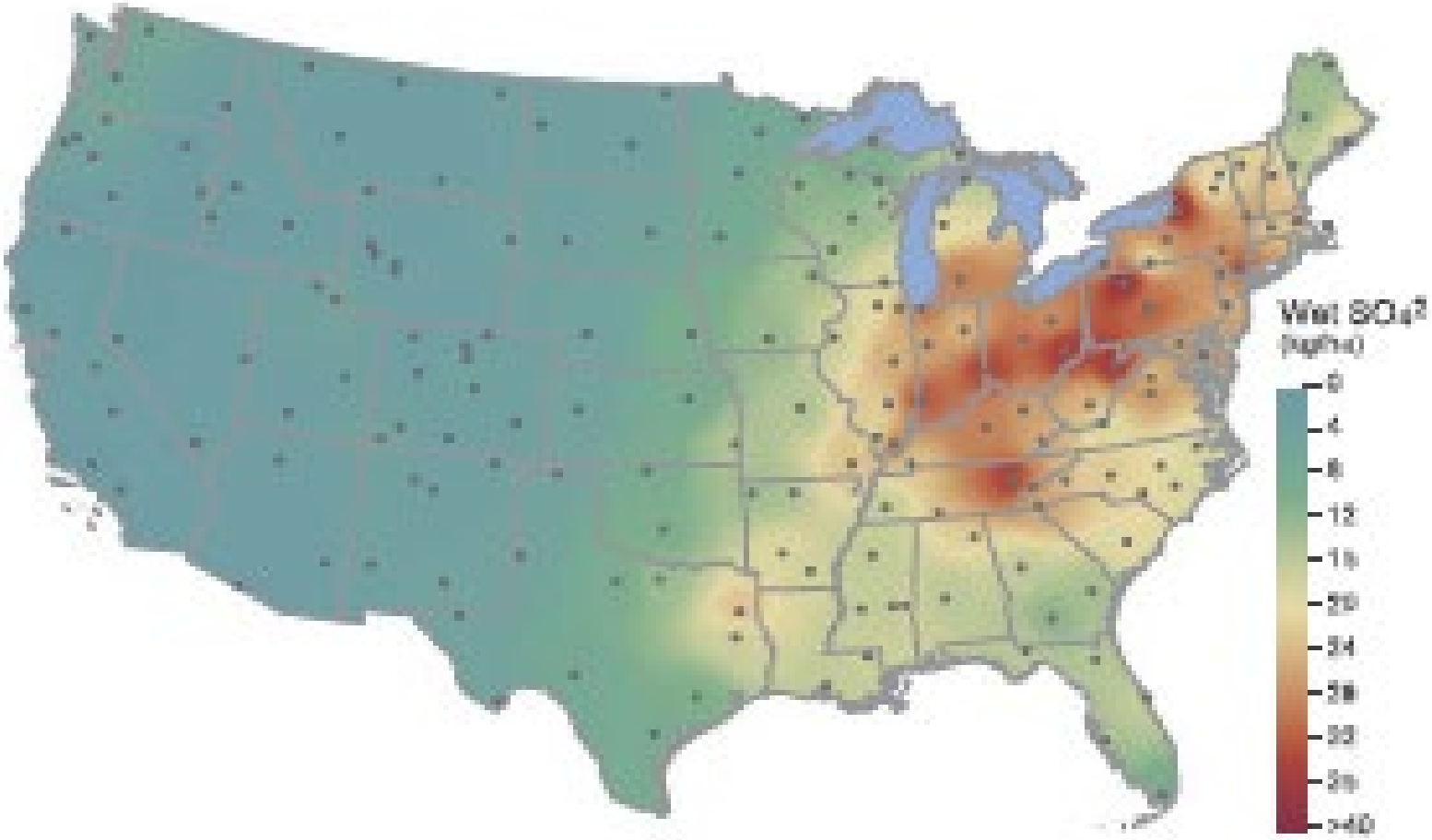
- Heterogeneity of plants made market solution useful

State by State SO2 Emissions



Source: EPA, 2011, http://www.epa.gov/airmarkt/progress/ARPCAIR10_01.html

Figure 20a: Annual Mean Wet Sulfate Deposition, 1989–1991



Source: National Atmospheric Deposition Program

History of SO_2 regulation in the U.S.

- 1990 Clean Air Act
  - Goal: Reduce emissions by 10 million tons (1/2 of 1980 levels) by 2010
    - Note level set based on possible threshold effect and political goals, not cost-benefit analysis
  - Created a national market
  - Began a system of tradable permits for SO_2
    - Removed individual emissions requirements
  - Initial permits were freely allocated
    - To maximize political support
    - Since most plants were under cost-of-service regulation, cost savings expected to be passed on to consumers

Implementation

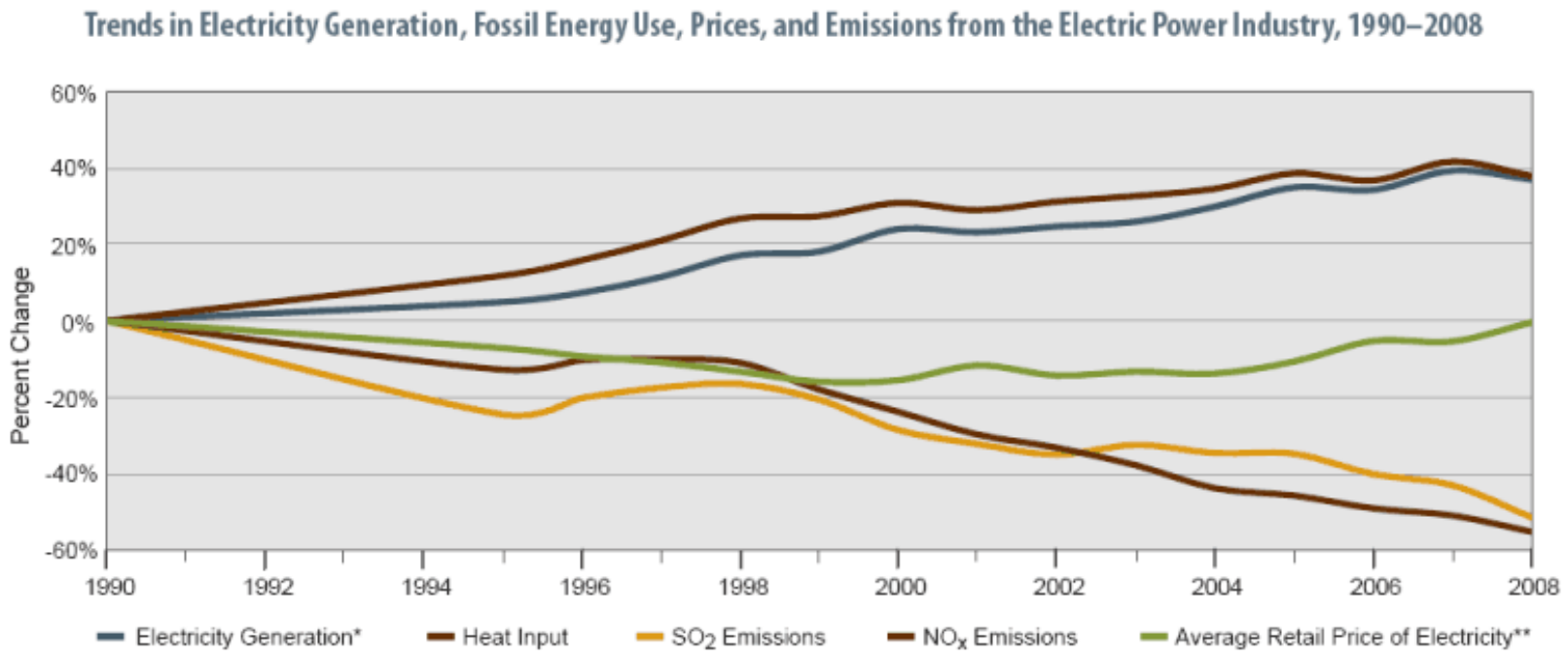
- Phase I (1995-1999)
  - Permits required for the 263 dirtiest plants
  - Permits allocated based on current emission levels
  - 2.8% held back and auctioned
    - Purpose: to stimulate trading

- Phase II (2000+)
  - Limits total SO_2 emissions to 8.95 million tons by 2010
    - Achieved by 2007
  - Permits required of virtually all plants

Monitoring

- Firms use Continuous Emissions Monitoring (CEM) and report data to the EPA
- All trades are recorded by the EPA
- At the end of each year, a firm's total emissions cannot exceed their final allocation of permits
- Initial $2,000/ton fine for exceeding permits, adjusted for inflation over time

What happened

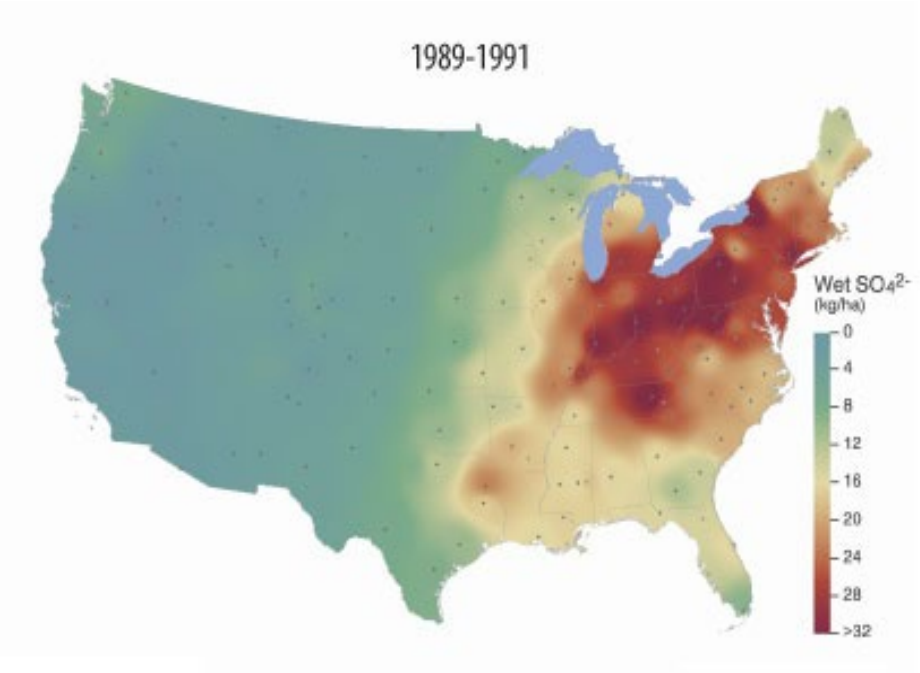


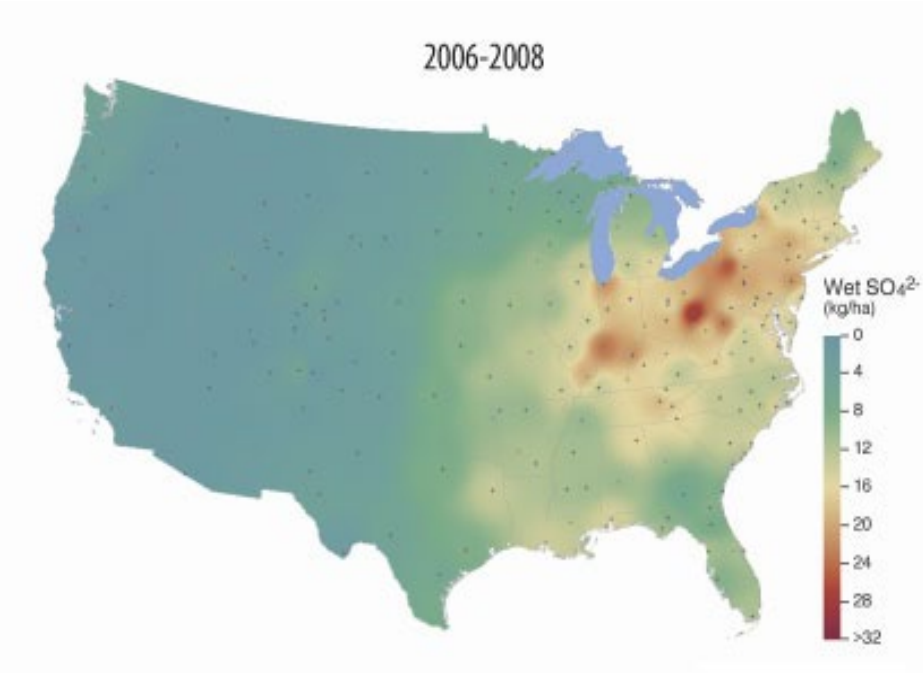
* Generation from fossil fuel-fired plants.

** Constant year 2000 dollars adjusted for inflation.

Source: Energy Information Administration (electricity generation, retail price); EPA (heat input and emissions, representing all affected ARP units), 2009

Acid Rain Has Been Reduced





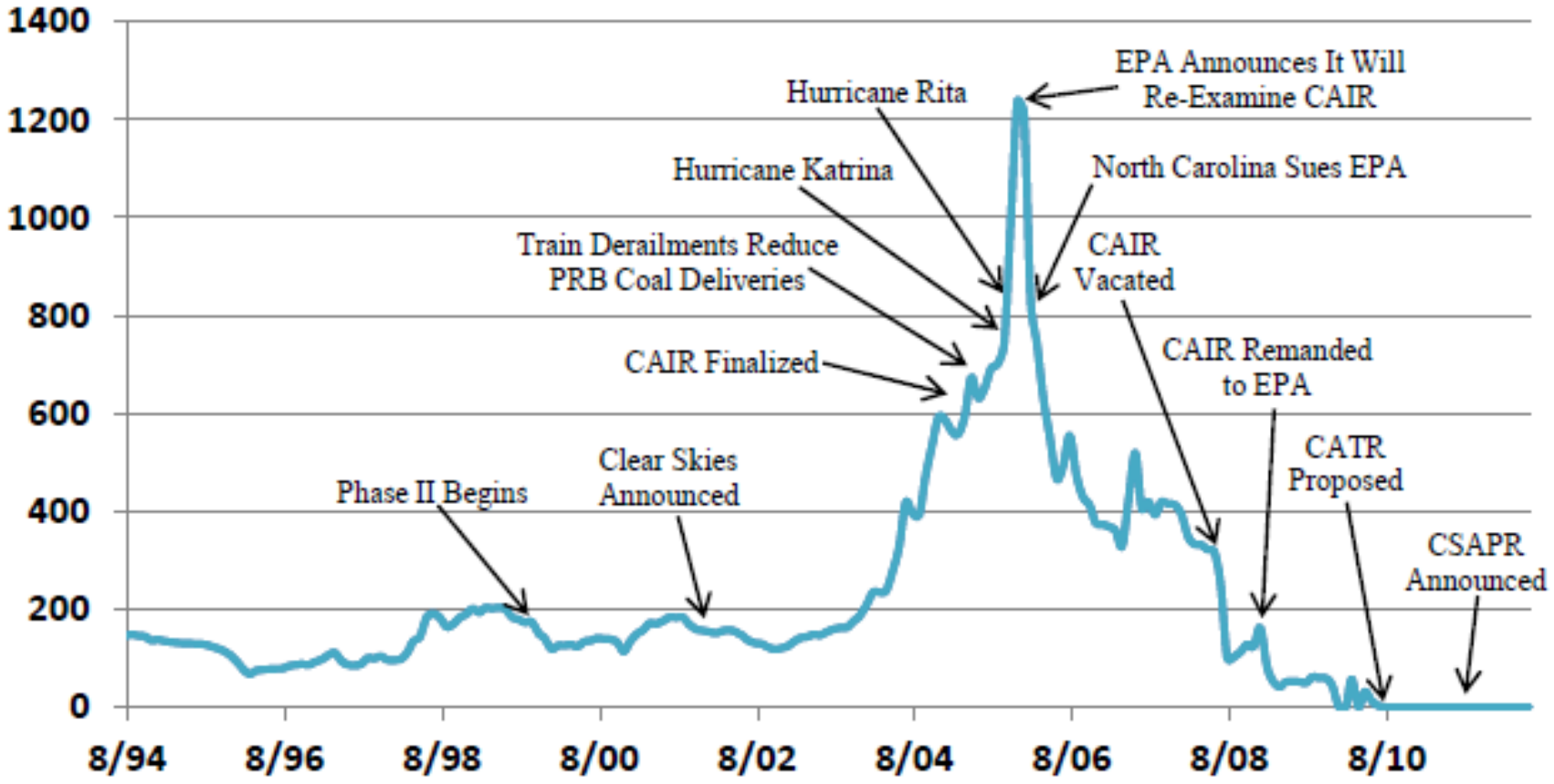
What happened

- The initial price of permits was lower than expected
  - Early projections between $250-$500/ton
  - Actual prices:
    - Phase I: $100-$150/ton
    - Phase II: Initially around $215
- Compliance was excellent
- Simulations suggest costs were 15-90% lower than under command and control

What happened

- However, changing regulations led to price spikes and eventual market collapse
  - 2005: Clean Air Interstate Rule (CAIR) proposed lowering SO2 emission cap 70%
    - Because of banking, permit prices peaked over $1,200/ton

SO2 Allowance Prices
(1995 $ per ton)



Source: Schmalensee/Stavins (2013)

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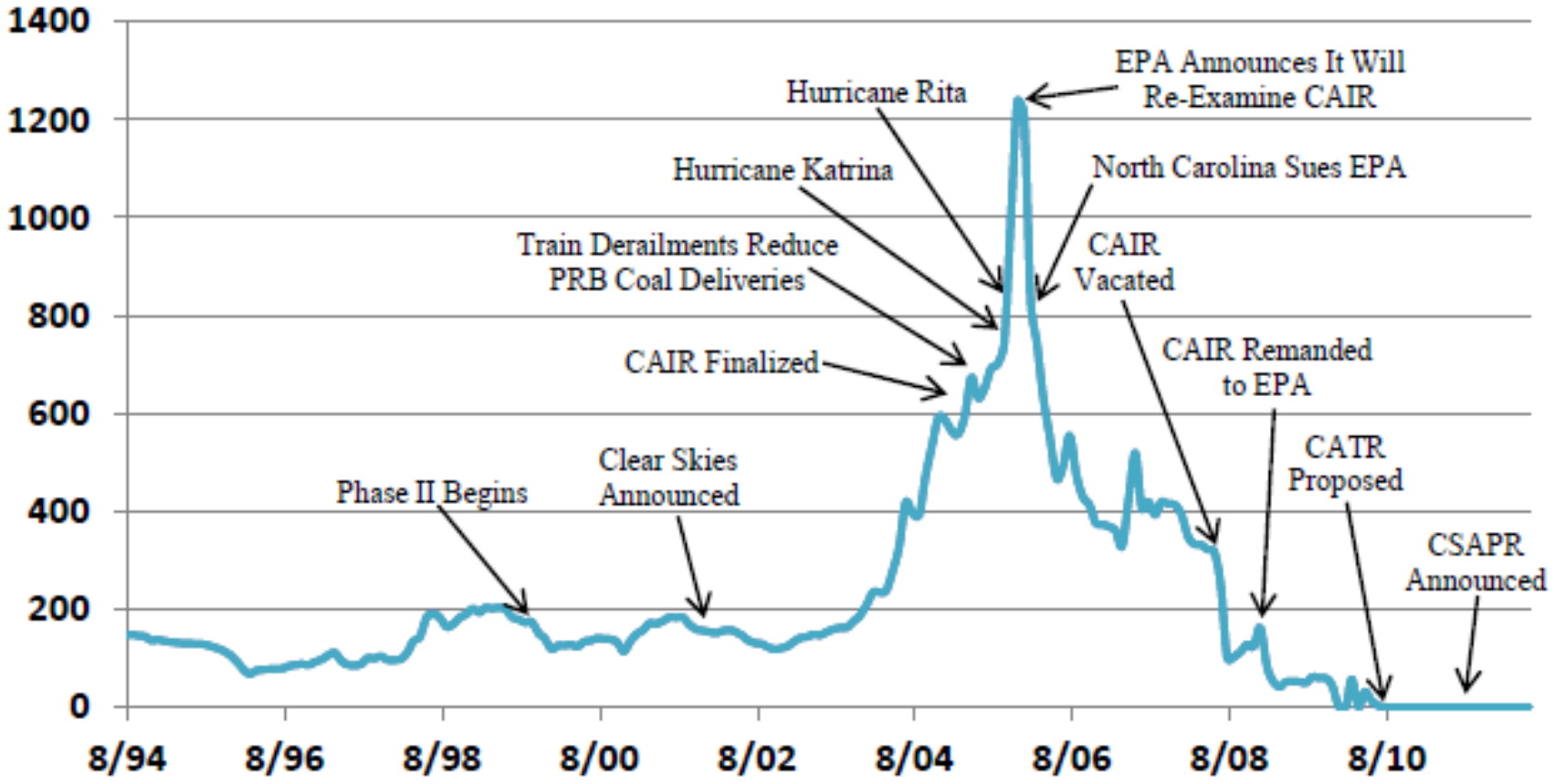

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- Key lesson: What the government creates can be taken away
  - Policy uncertainty becomes a concern!

Permits and Climate Change: EU-ETS

- EU Emissions Trading Scheme (EU-ETS)
  - World's largest carbon market: accounts for nearly 90% of the value of global carbon markets
  - Helps Europe meet its emission reduction goals
    - Started to help the EU meet its commitments from the Kyoto Protocol
    - In July 2021, the European commission devised plans to achieve carbon neutrality by 2050, including a 55% net reduction in GHG emissions by 2030

Permits and Climate Change: EU-ETS

- EU Emissions Trading Scheme (EU-ETS)
  - Based on an overall cap on carbon emissions from Kyoto, the EU sets a national CO_2 emissions limit for each country
  - From this, the EU has specified the industries that will participate in trading
    - Initially, four industries could trade:
      - iron and steel
      - some mineral industries (e.g. cement)
      - energy production
      - pulp and paper
  - Implemented in phases
    - Phase I: 2005-2007
    - Phase II: 2008-2012
    - Phase III: 2013-2020
      - Included more industries and a lower cap
      - More permits to be auctioned
    - Phase IV: 2021+

Permits and Climate Change: EU-ETS

- Control over permits is given to each country
  - Each country gets allowances based on its national cap in Kyoto. It faces two allocation decisions:
    1. Total allowances are spread between the trading & non-trading sector
    2. Permits in the trading sector must be allocated among individual firms.
  - Some permits (initially about 3%) set aside for new entrants
    - Most permits were freely allocated at first
    - Now, more than half are auctioned off

- Makes predicting outcomes hard, as we don't know how many permits will be available for trade
  - Also makes it difficult for an individual country to control emissions from its trading sector, because market prices will be determined by the allocation decisions of all countries

- Countries have incentives to give more allowances to industries that trade goods

Permits and Climate Change: EU-ETS

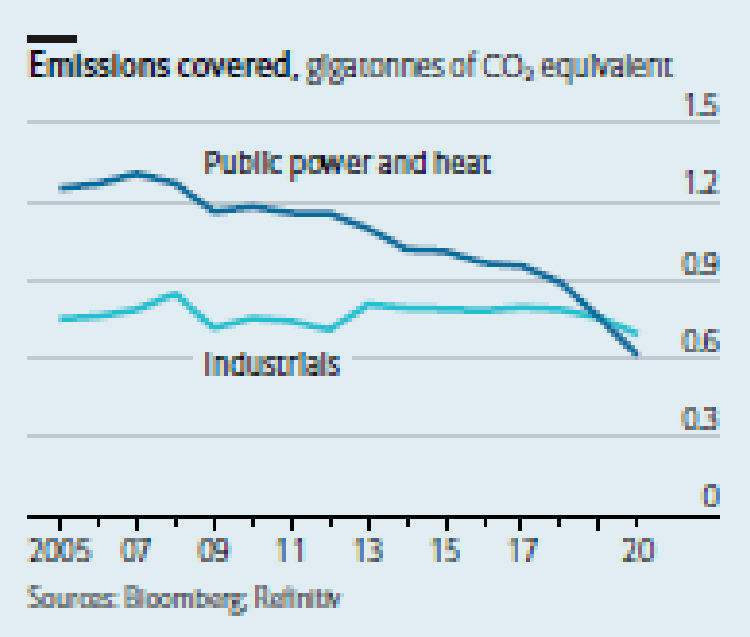
- Phase 4 began in 2021. New rules announced in 2018, Key changes:
  - Cap falls by 2.2% per year. Goal is to reduce emissions 43% compared to 2005 levels
  - Most allowances (57%) now sold at auction
  - Added Market Stability Reserve (MSR)
    - If too many allowances banked for future use, some allowances withheld from the next year's auction
      - Placed in MSR, which cannot be bought or sold
    - If bank of unused allowances falls below a threshold, some allowances taken out of MSR and put back into circulation
    - Addresses "waterbed effect"
      - With a firm cap, other reductions simply reduce permit prices
      - MSR reduces, but does not eliminate waterbed effect

Permits and Climate Change: EU-ETS

- Use of offsets
  - Allowed use of Clean Development Mechanism (CDM) projects
    - Disallowed certain project types
    - Supervision by CDM Executive Board
  - As a result, offsets widely used
    - Allowed to cover 11% of emissions
    - CDM credits were even cheaper than ETS allowances

Permits and Climate Change: EU-ETS

- What happened?
  - Overall, emissions were down about 3.4% in 2005, compared to a BAU baseline
  - Electric utility industry did not have enough permits, but other sectors did

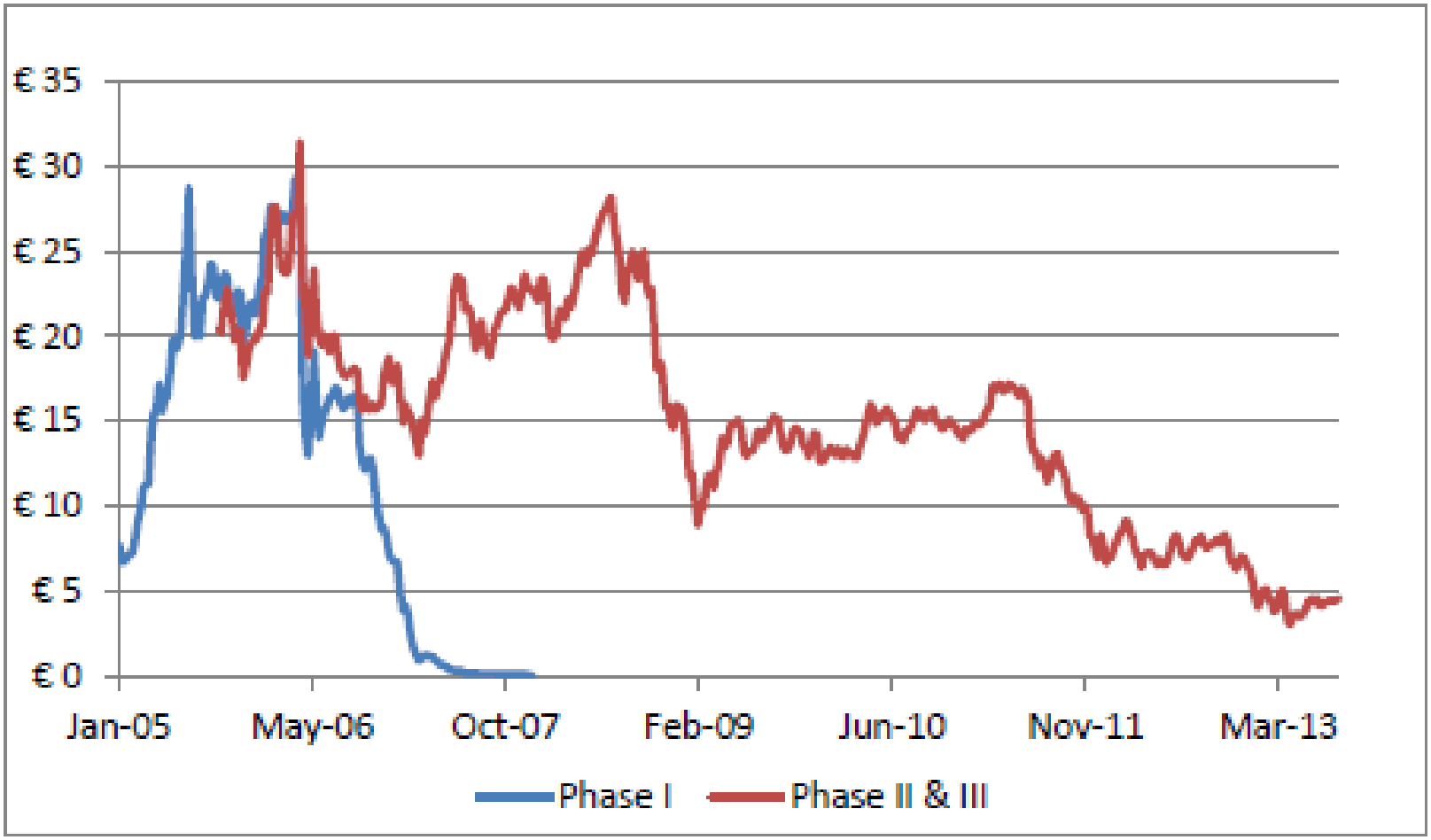


Source: "Coming into its own," *The Economist*, February 27, 2021, 63-64.

Permits and Climate Change: EU-ETS

- Prices over time
  - Because of initial permit allocation, prices in Phase I were low

Figure 4: Prompt-future Prices for EUA in Phase I and Phase II & III.



Source: Point Carbon.

Source: Ellerman *et al.* (2014)

Permits and Climate Change: EU-ETS

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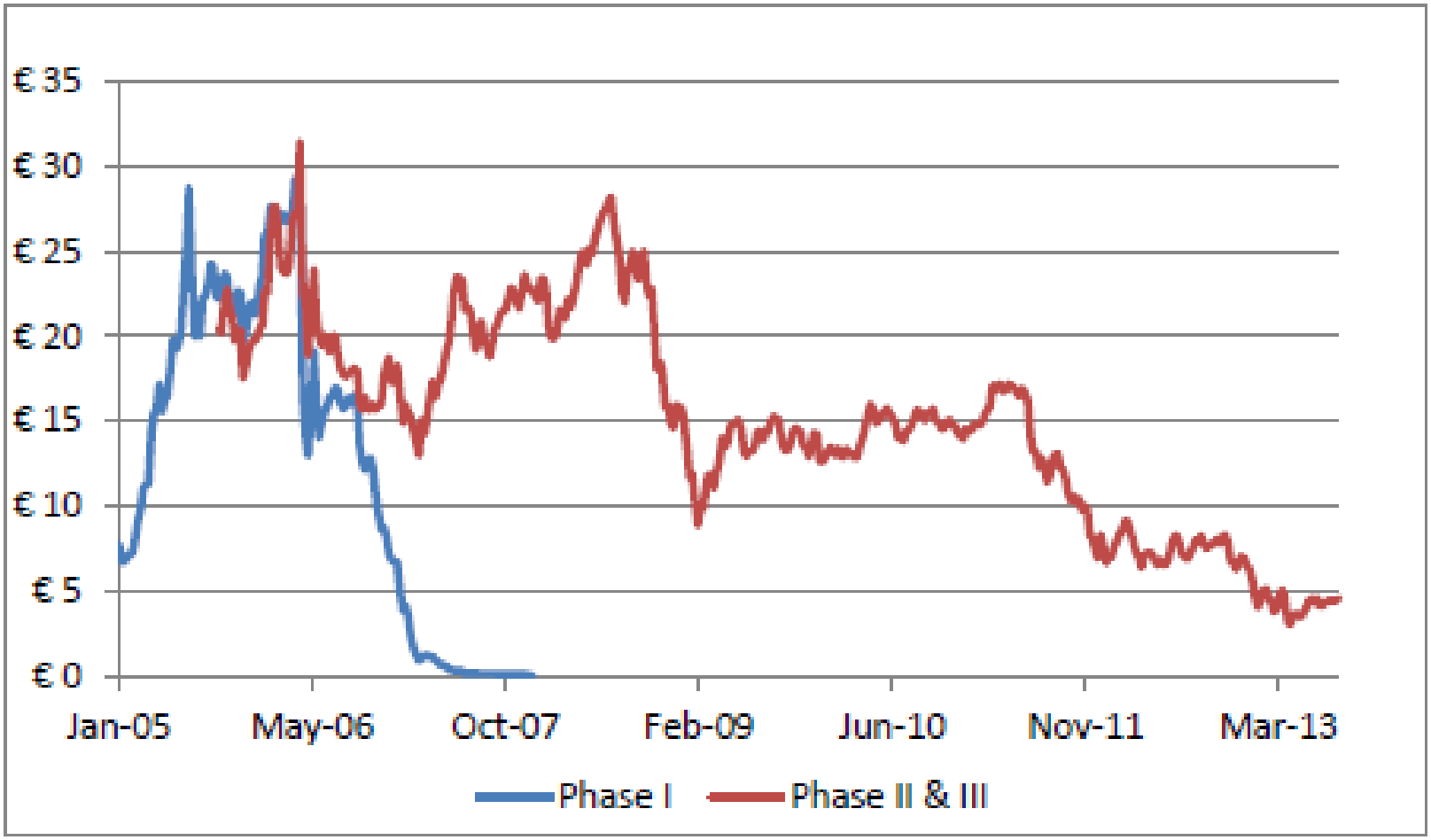

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Permits and Climate Change: EU-ETS

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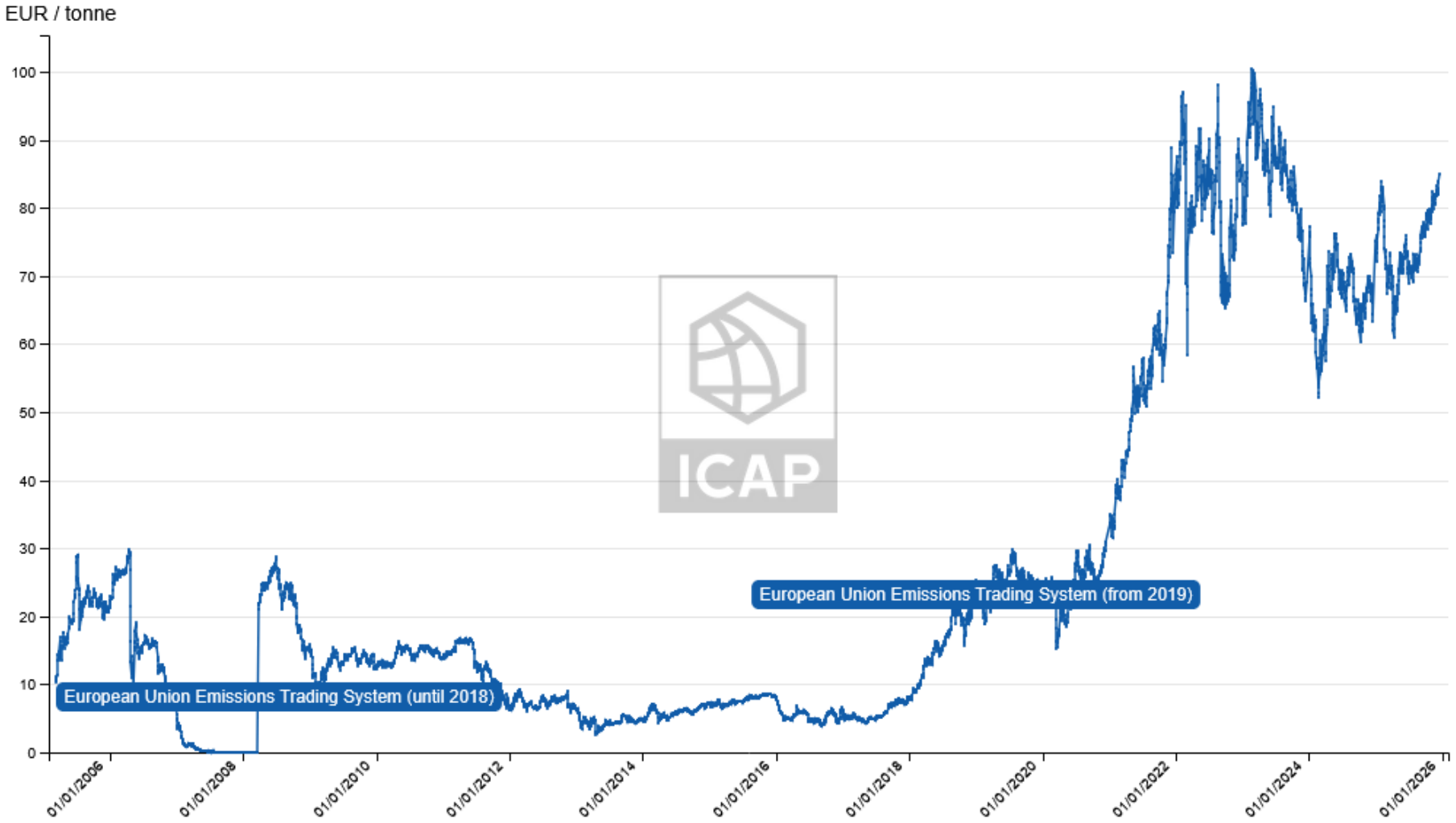
  - Similarly, prices in Phase II fell during the Great Recession
  - While Phase III begin in 2013, including more industries and a lower cap, prices didn't increase right away
    - A "rescue plan" delayed the allocation of a third of new permits scheduled for 2014-16
    - Prices began to grow in early 2018

EU-ETS allowance prices



David Popp

Source: https://icapcarbonaction.com/en/ets-prices

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Permits and Climate Change: EU-ETS

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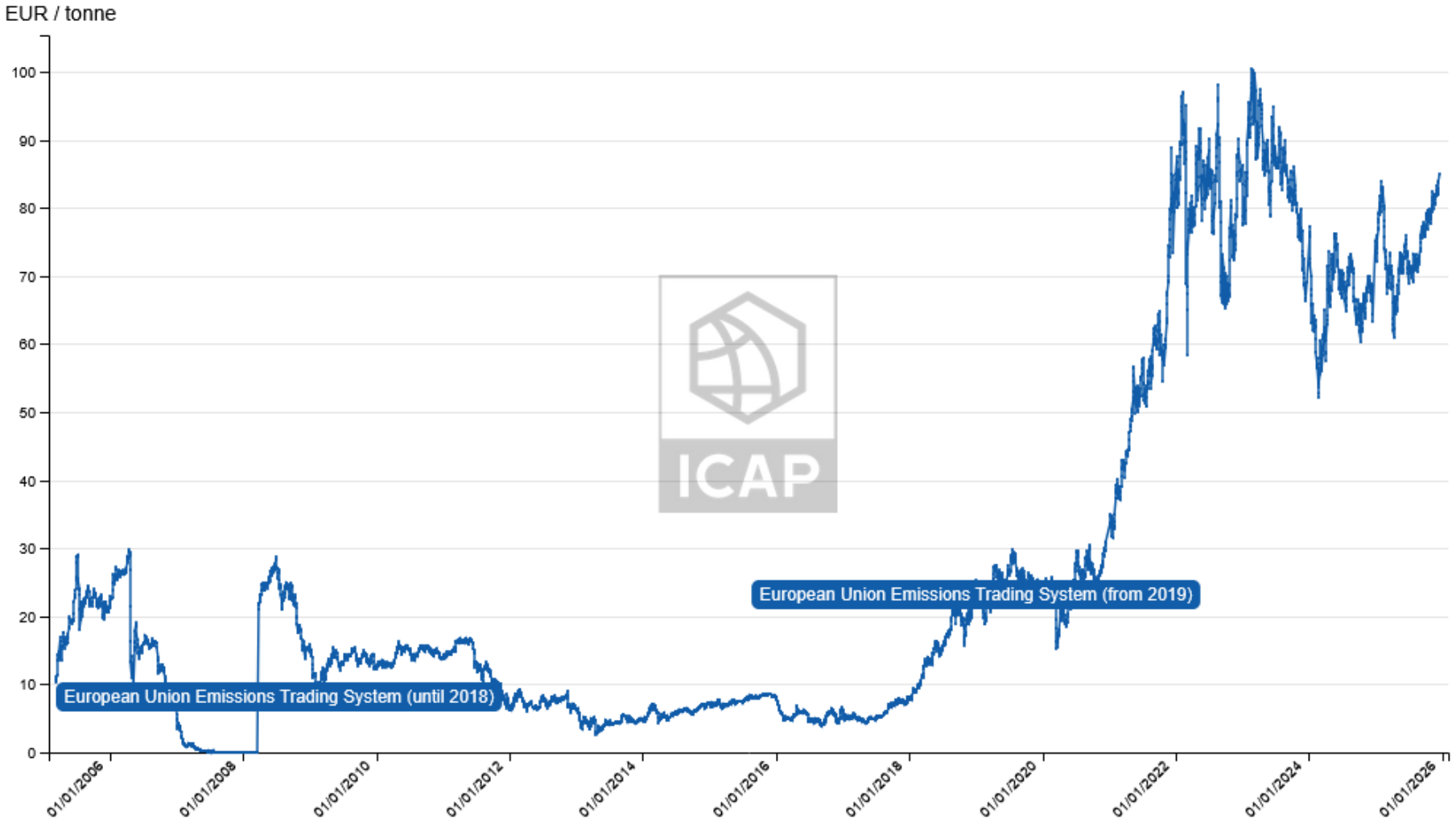
    - Prices began to grow in early 2018
  - Prices do increase in Phase IV
    - Currently around €85

EU-ETS allowance prices



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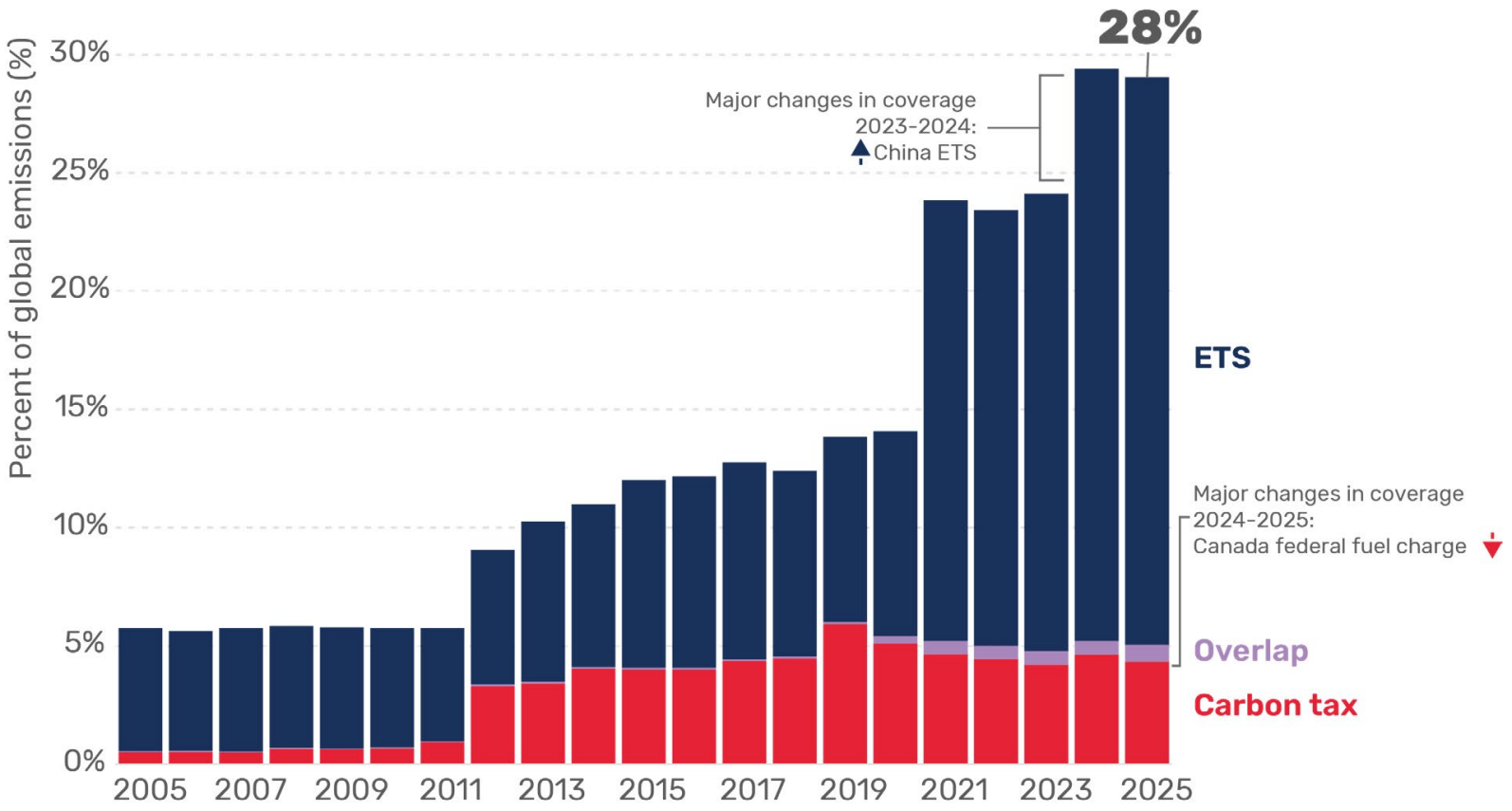
Other Greenhouse Gas Trading Markets

- In 2025, 28% of global emissions covered by carbon pricing
  - Most often through cap-and-trade



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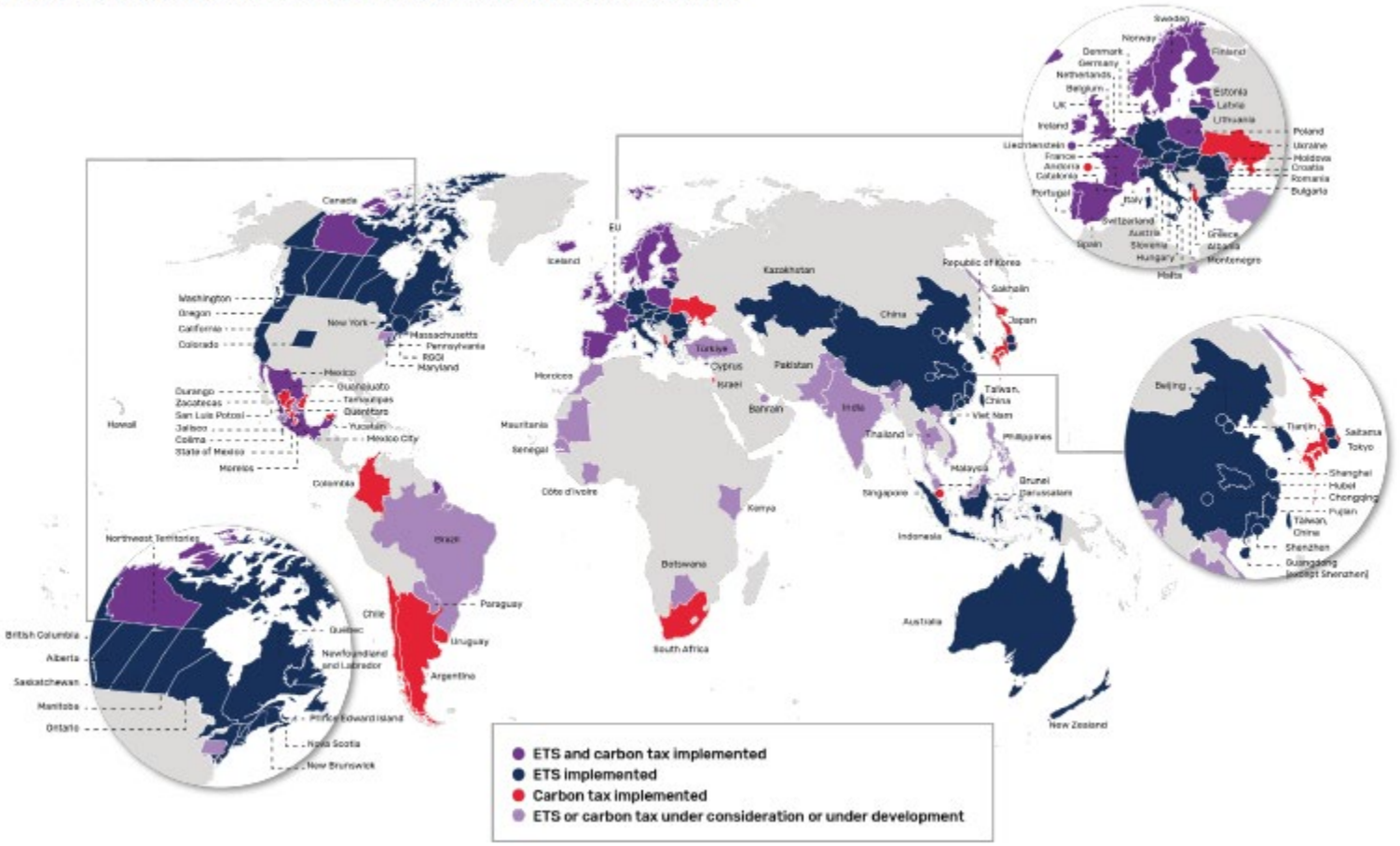
Lots of Countries Use Carbon Pricing…

FIGURE 2
Global map of ETS and carbon taxes implemented, under development, or under consideration



Source: World Bank State and Trends of Carbon Pricing (2025)

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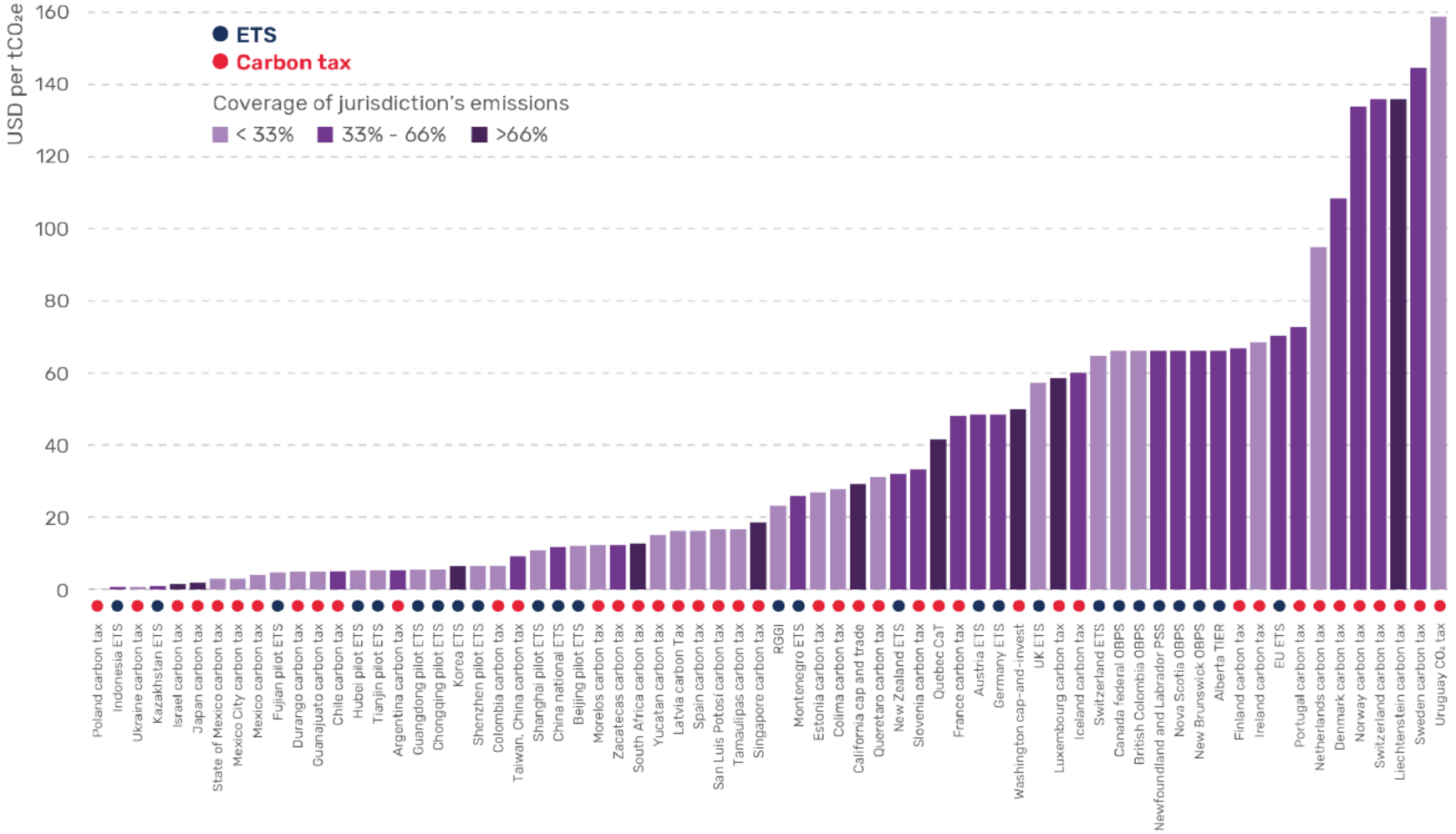
Other Greenhouse Gas Trading Markets

- In 2025, 28% of global emissions covered by carbon pricing
  - Most often through cap-and-trade
  - *Questions*: How well do these work? What are their strengths and weaknesses?

… But Prices are Low

FIGURE 4
Prices and coverage across ETSs and carbon taxes, as of April 1, 2025



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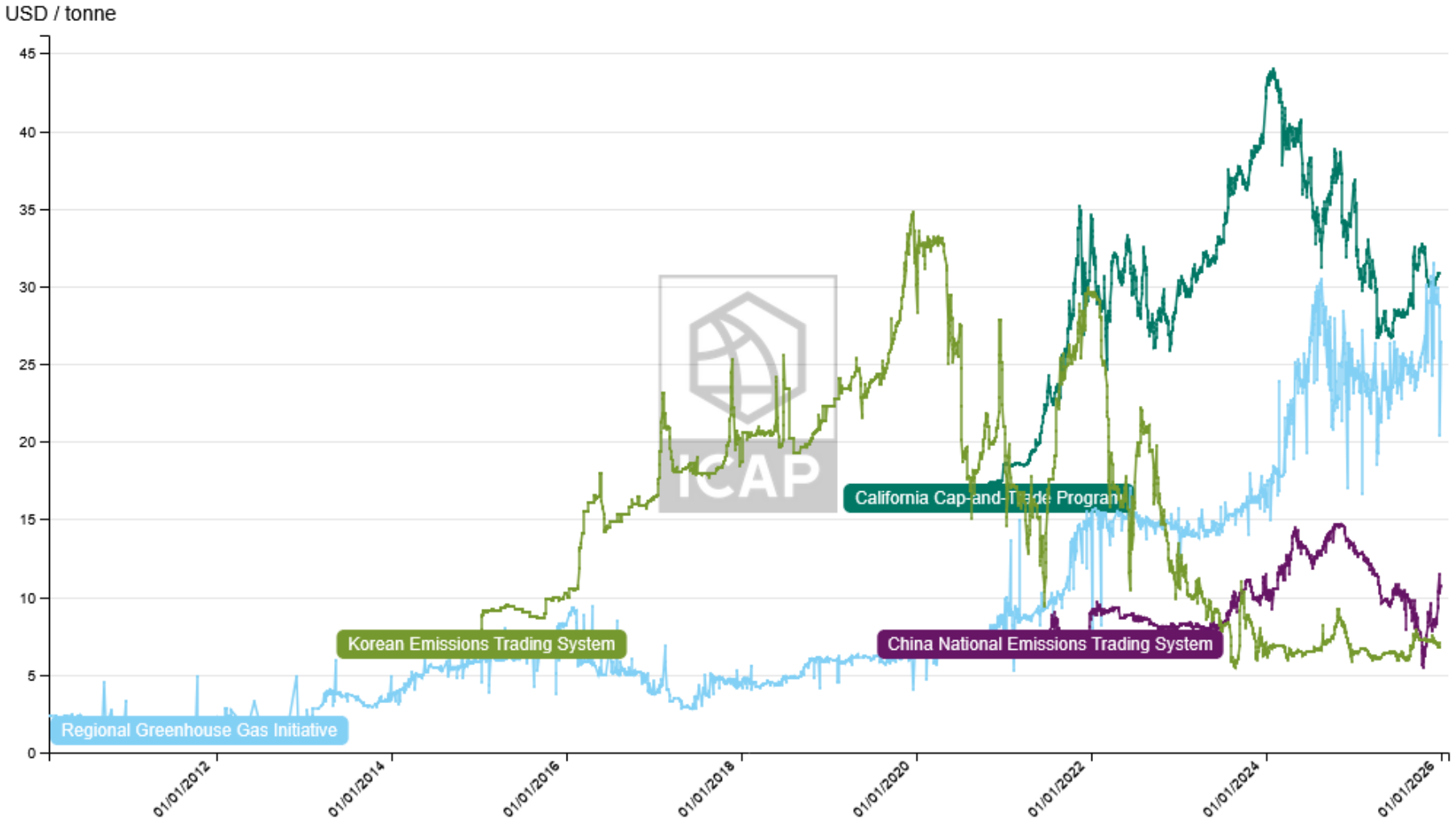
Other ETS allowance prices



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Other Examples

China's New Emissions Market

- China's emissions trading market began February 1, 2021
  - Initially, it only covers the electric power sector
  - Ultimate goal is to cover at least 70% of China's GHG emissions.
  - Trading will be rate-based (e.g. emissions per unit of electricity output)
    - Thus, allows for future economic growth
  - Firms only need to pay for 20% of the emissions that exceed their cap, and fines are low
  - Benchmarks are based on the type of fuel
    - Based on the average carbon intensity of each sector
    - Thus, rewards better than average performance within sectors, but doesn't encourage fuel switching
  - Allowance price has been $5-15/ton

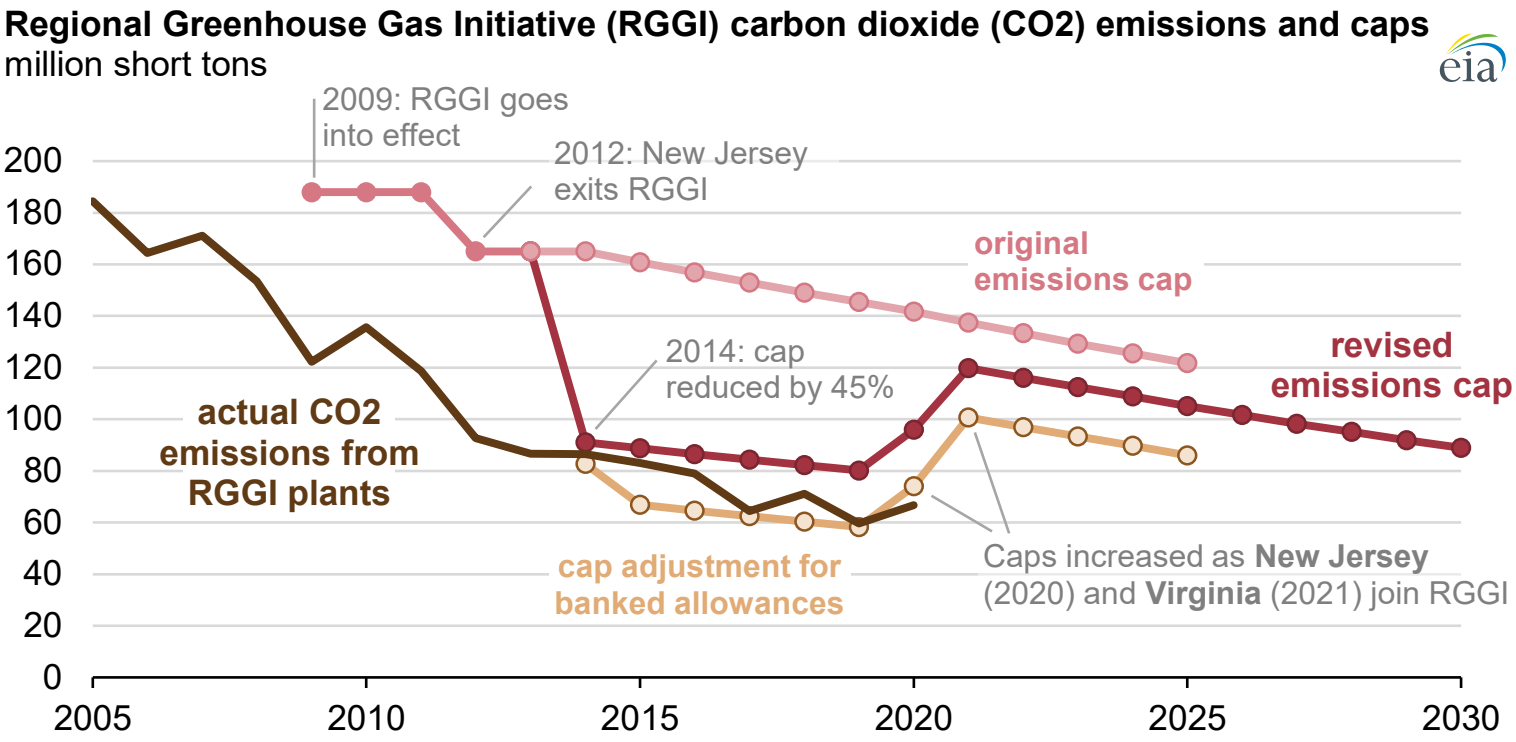
China's New Emissions Market

- China's proposed emissions trading market
  - Challenges
    - Many energy companies are state-owned
      - Prices often set by administrators, rather than the market
        - » Higher prices from abatement might not be passed on to consumers
      - Dispatch of power determined by planners, rather than by costs
        - » Lowest cost power not necessarily chosen first
    - Need accurate monitoring of emission for enforcement
      - This has been a problem with earlier environmental policies in China
      - China proposed third-party verification of emissions to address
    - Penalties for enforcement left to provinces
      - National environmental agency does not have authority to issue penalties for non-compliance

Regional Climate Markets in the U.S.

- The Regional Greenhouse Gas Initiative (RGGI)
  - Currently includes 10 northeastern states (6 New England states, plus NY, MD, DE, and NJ) committed to reducing CO2 emissions from power plants
    - NJ left but rejoined in January 2018; VA joined in 2020, left in 2023
  - Goal of capping emissions at current levels in 2009, and reducing emissions 10% by 2019.
    - Initially allowed emissions were 188 million tons CO2 annually through 2014
    - This then fell 2.5% per year through 2018
    - Announced plans for extending RGGI in 2017
  - Because of recession, initial cap appeared unlikely to be binding
    - Thus, after a 2012 review, the states agreed to a lower cap beginning in 2014
    - 2026 cap 78.5 million short tons

RGGI Emission Caps



Source: EIA Today in Energy, March 23, 2021. https://www.eia.gov/todayinenergy/detail.php?id=47256

Regional Climate Markets in the U.S.

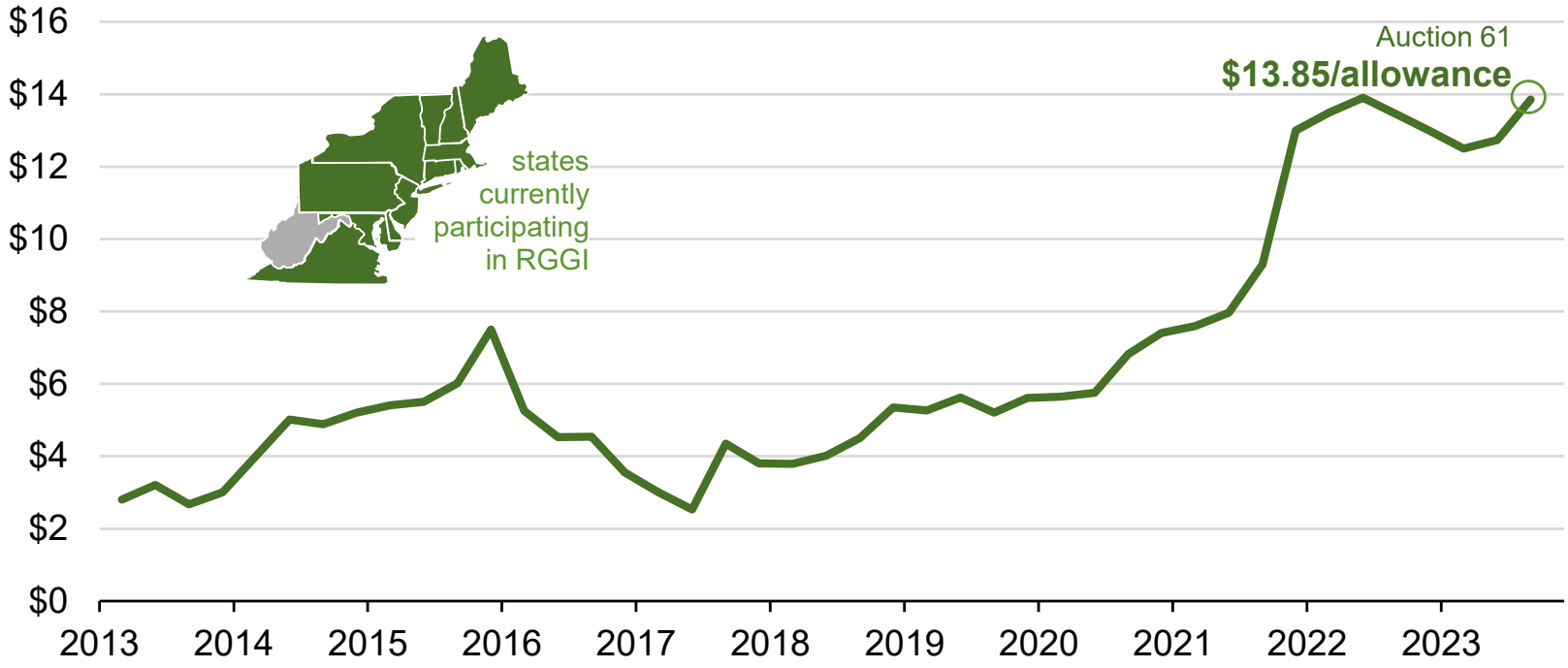
- How RGGI works
  - States are apportioned their share of allowances from the overall cap
  - States set limits for carbon dioxide emissions, and can decide how many to auction versus freely allocate
    - Each state must auction at least 25%
    - Most states auction nearly all permits
    - Revenues support clean energy technology
  - Auctions are held quarterly
    - Proceeds from permit auction will be used for energy-saving and renewable energy programs in each state
    - Auctions have raised over $1 billion in revenue
  - Utilities bid for allowances, which can be sold later
    - Covers power plants of 25 MW or more burning at least 50% fossil fuels
  - Banking allowed
  - Compared to EU-ETS, RGGI is more restrictive about the number of outside credits plants can use to offset emissions
    - Offsets allowed for 3.3% of a plant's emissions, or about half of their obliged reductions

Regional Climate Markets in the U.S.

- RGGI prices
  - RGGI includes both a price cap and price floor
    - Extra permits held in reserve and released if price hits the cap ($18.22 in 2026)
    - The minimum reserve price is the lowest allowable bid ($8.41 in 2026)
    - Unsold allowances retired after three years
      - Tightens cap if there is an unexpected surplus
  - Price history
    - Two “pre-compliance” auctions were held
      - 9/25 price: $3.07/ton CO2
      - 12/17 price: $3.38/ton CO2
    - Prices fell to a low of $1.86/ton in 2010
    - Prices are low because emissions cap overestimated current CO2 output, which fell between 2005 & 2006
      - Estimated 2007 emissions were 172.4 million tons CO2, although cap for 2009 is 188 million tons CO2
    - With more stringent cap, rose to $5.50/ton in 2015
    - Last clearing price: $26.73/ton in December 2025

RGGI allowance prices

Regional Greenhouse Gas Initiative (RGGI) allowance clearing price (Mar 2013–Sep 2023)
dollars per allowance (one allowance = one short ton of carbon dioxide)



Source: EIA Today in Energy November 15, 2023. https://www.eia.gov/todayinenergy/detail.php?id=60982

Regional Climate Markets in the U.S.

- California AB-32 Cap and Trade
  - Established in 2006 to reduce California GHG emissions to 1990 level by 2020
    - The law includes several components: cap and trade is just one part of it
  - Cap and trade market began in 2013
    - By 2015, covered 85% of state emissions
  - Most permits initially allocated freely
  - Banking allowed
  - Has a price ceiling and price floor
    - Prices were around $11-$14/ton in 2014
    - Allows offset projects for up to 49% of reductions

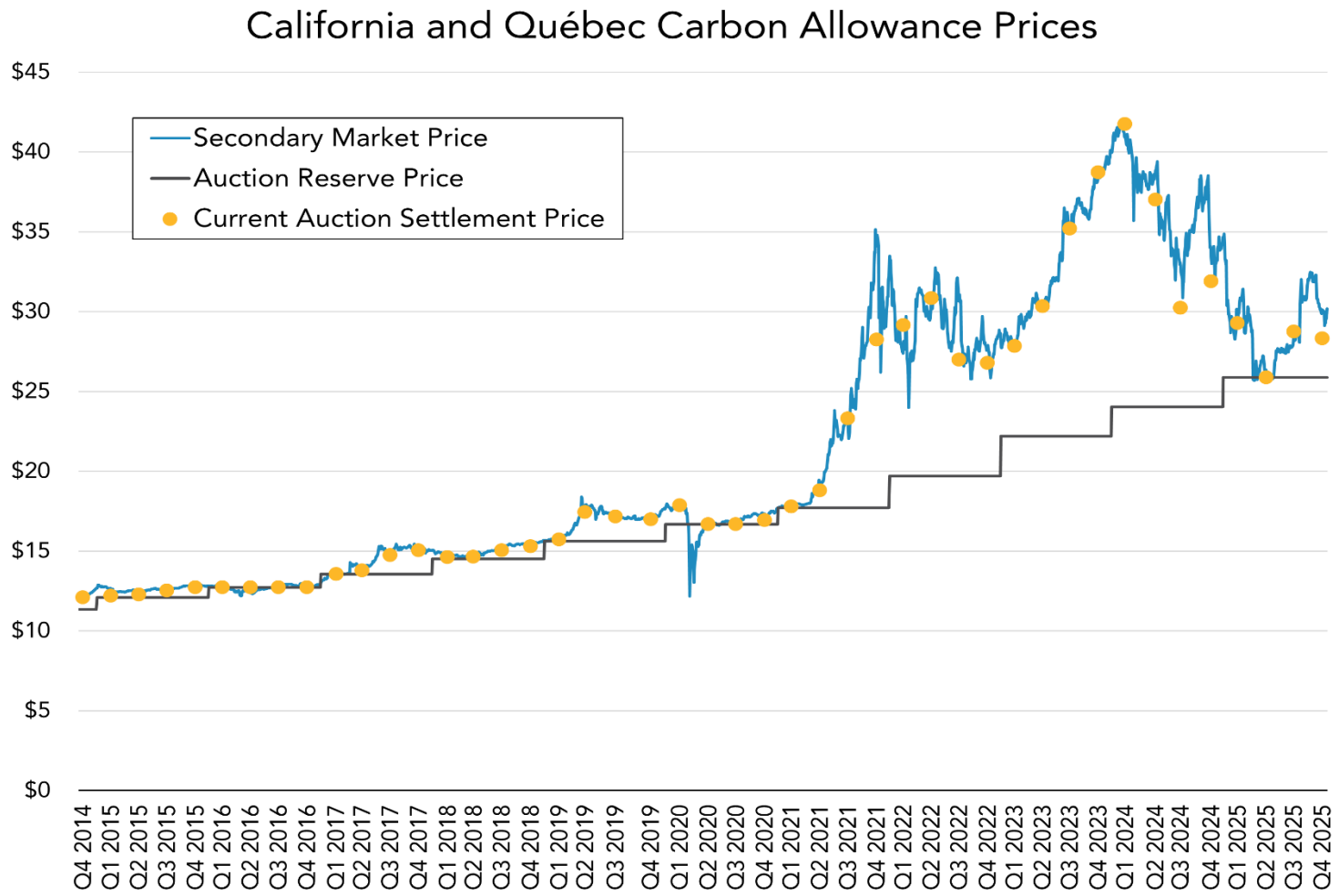
Regional Climate Markets in the U.S.

- 2017: California's new target reduces emissions by 40% by 2030
  - Up to now, other policies have had a bigger effect on emissions than cap-and-trade
    - But, most easy things have been done
  - Cap-and-trade expected to account for up to ¼ of emission reductions by 2030
    - Some offsets allowed, but these will be phased out over time
  - Most permits will be auctioned, creating revenue
    - Free allocation to industries that may relocate
  - Maintains a ceiling on permit prices

Regional Climate Markets in the U.S.

- 2025: Re-authorization extends “cap-and-invest” to 2045
  - Goals for covered sectors:
    - Reduce emissions 40% below 1990 levels by 2030
    - Net zero emissions by 2045

California Carbon Allowance Prices



Source: California Air Resources Board, https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/program-data/cap-and-trade-program-data-dashboard