Lecture 04

Standards

Ivan Rudik
AEM 4510

Roadmap

1. How do we model our problems going forward?
2. What are the different kinds of standards in theory and the real world?
3. What happens under a standard?

Pigouvian policy

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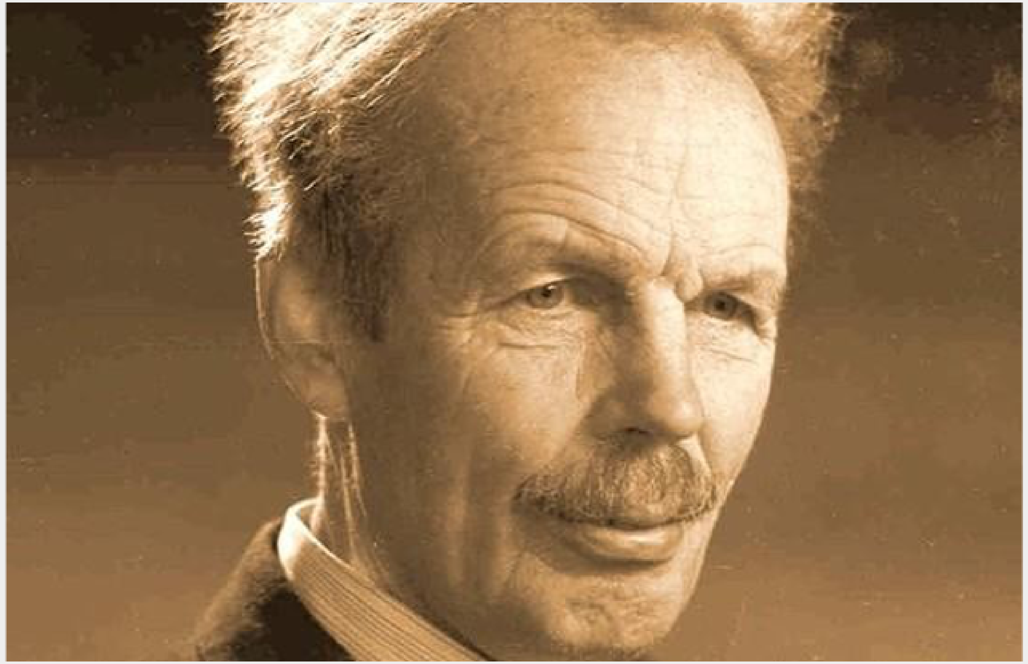
A Pigouvian policy aims to force polluters to realize the costs of their emissions (or forces the creator of a public good to realize the external benefit) in the absence of a market to do the same

Next we will look at command and control and emission standard regulations

Pigouvian policy: Arthur Pigou



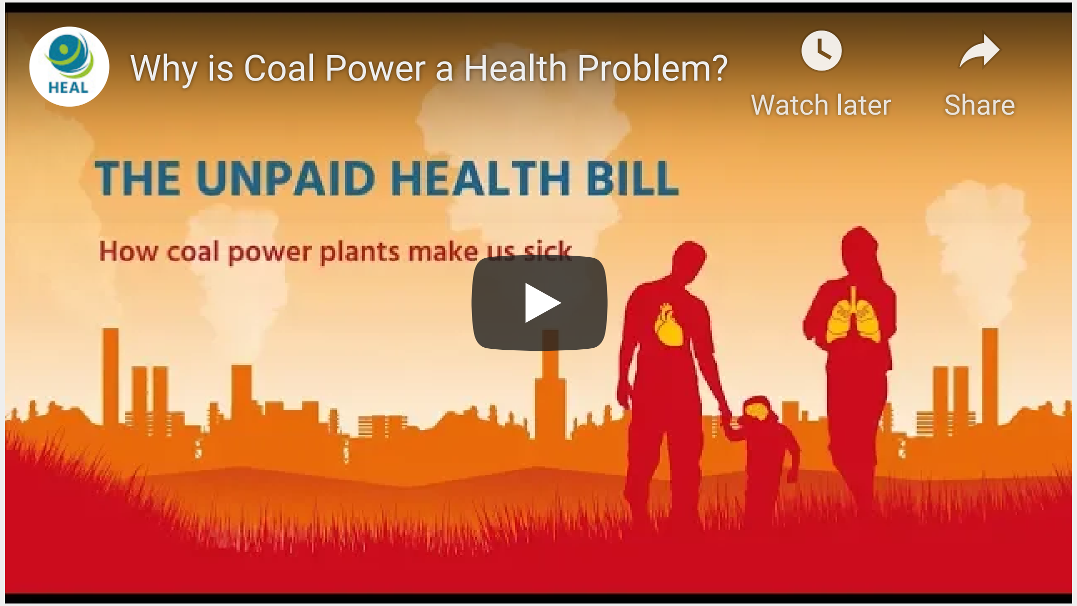
Pigou is responsible for the famous distinction between private and social marginal products and costs and the idea that governments can, via a mixture of taxes and subsidies, correct such market failures: "internalize the externalities"

Working example: pollution from coal

When we're discussing these policies you can think about them as regulating emissions from coal-fired power plants

Coal power is one of the largest sources of several of the most harmful air pollutants

Coal power: air pollutants



Coal power: air pollutants

Sulfur dioxide: Coal plants are the leading source of SO_2 pollution

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Sulfur dioxide: Coal plants are the leading source of SO_2 pollution

- Forms small acidic particulates that can penetrate into human lungs and be absorbed by the bloodstream
- Causes acid rain which damages crops, forests, soils

Typical plant can emit > 14,000 tons per year

Typical plant with control equipment (e.g. scrubbers) emits 7,000 tons

Coal power: air pollutants

Nitrogen oxides: NO_x causes ground-level ozone which harms respiratory systems, damages crops

Coal power: air pollutants

Nitrogen oxides: NO_x causes ground-level ozone which harms respiratory systems, damages crops

Typical plant can emit > 10,000 tons per year

Typical plant with control equipment (e.g. catalytic tech) emits > 3,000 tons

Coal power: air pollutants

Particulate matter: PM is a catch all for small stuff, causes respiratory, cardiovascular issues, death, haze, negative effects on cognition, etc, etc

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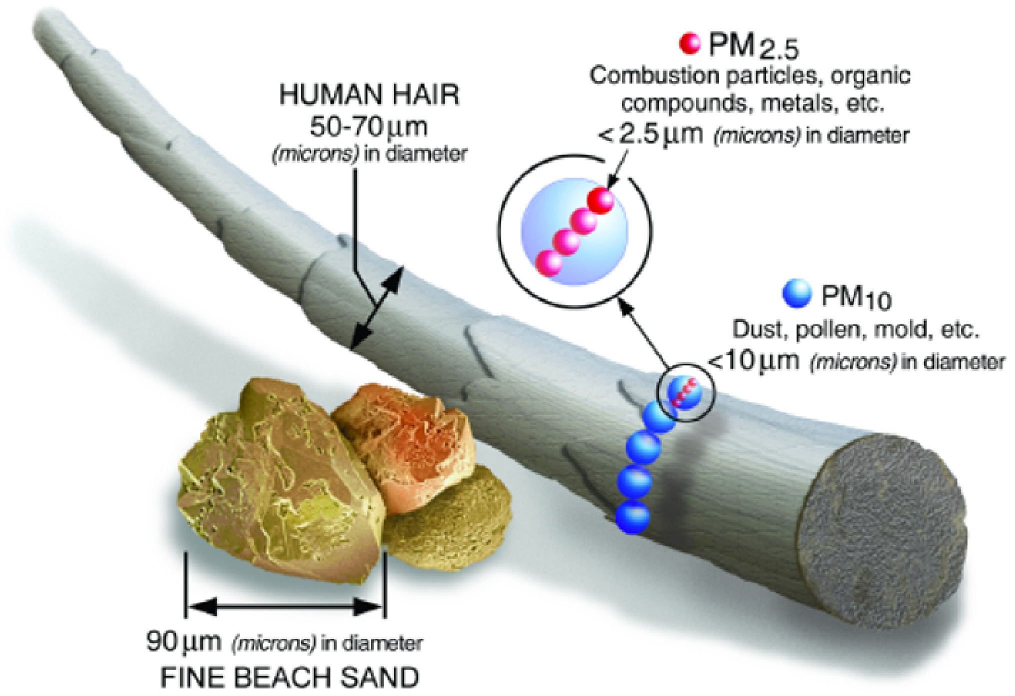
Particulate matter: PM is a catch all for small stuff, causes respiratory, cardiovascular issues, death, haze, negative effects on cognition, etc, etc

PM is one of the most costly pollutants on the planet

Typical plant can emit > 500 tons per year

Typical plant with control equipment (e.g. baghouses) emits just a few tons a year

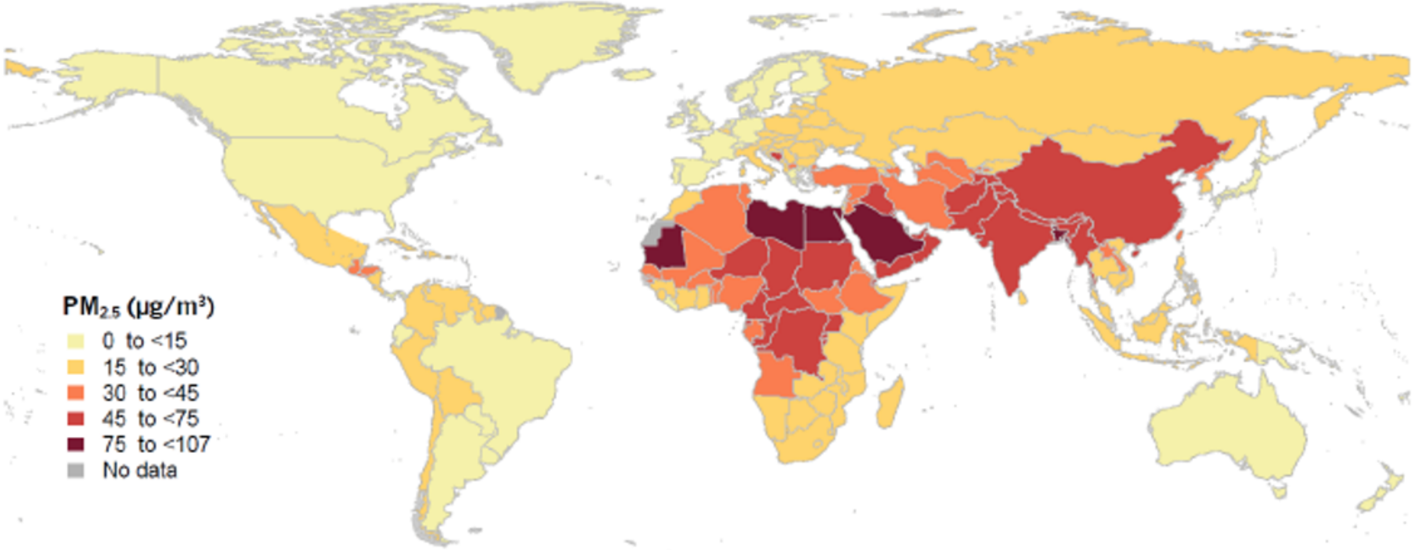
Costs of particulate matter



- Airborne PM is a well-known cause of cardiovascular and respiratory diseases.
- Fine particles ($PM_{2.5}$) penetrate deep into our lungs. Toxins can migrate to other organs. Heart attacks, stroke, lung disease, lung cancer, aggravated asthma, low birth weight and preterm delivery

Costs of particulate matter

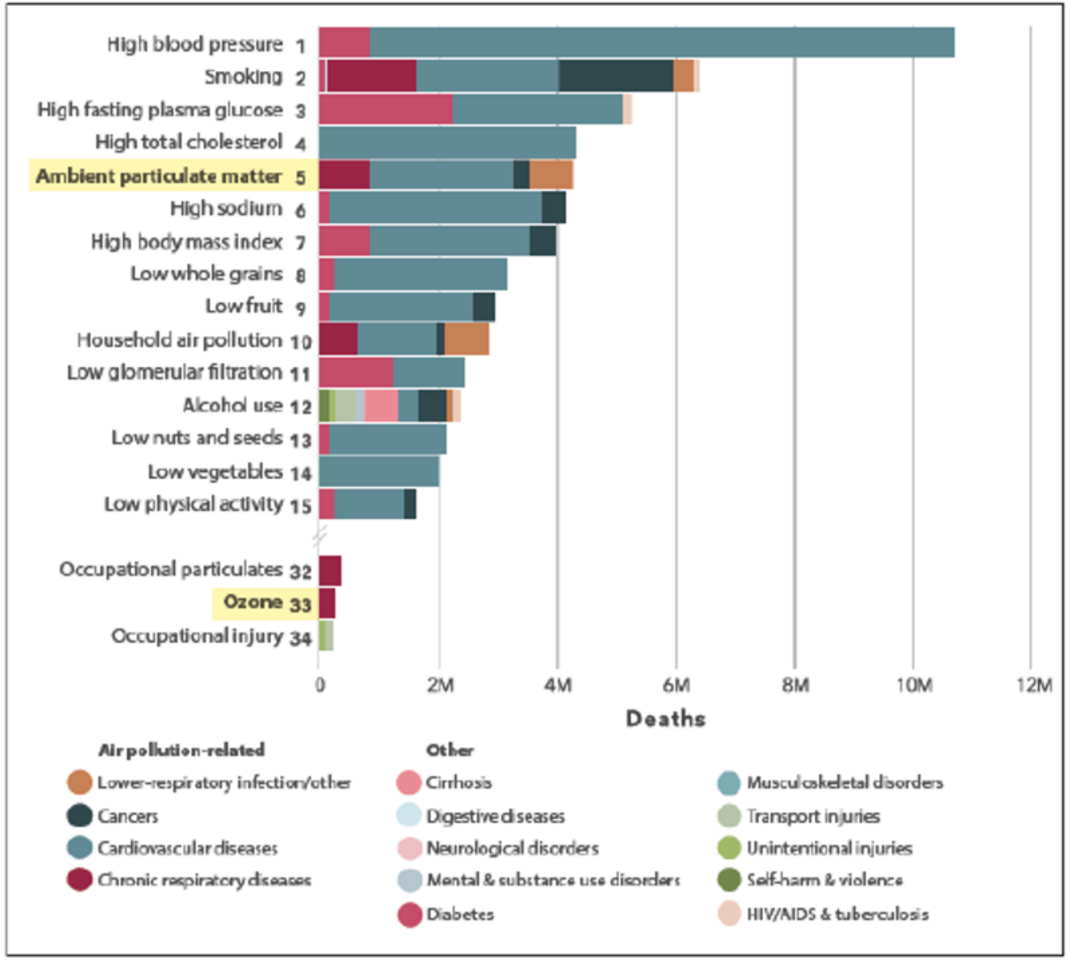
- 92% of the world's population live in places where WHO air quality guidelines are violated
  - WHO standard: 10 $\mu g/m^3$. China national average: 56 $\mu g/m^3$.



Source: State of Global Air 2017

Costs of particulate matter

- Exposure to $PM_{2.5}$ is a leading environmental risk factor for mortality, accounting for about 4.2 million deaths



Source: State of Global Air 2017

Coal power: air pollutants

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Mercury causes brain and heart damage

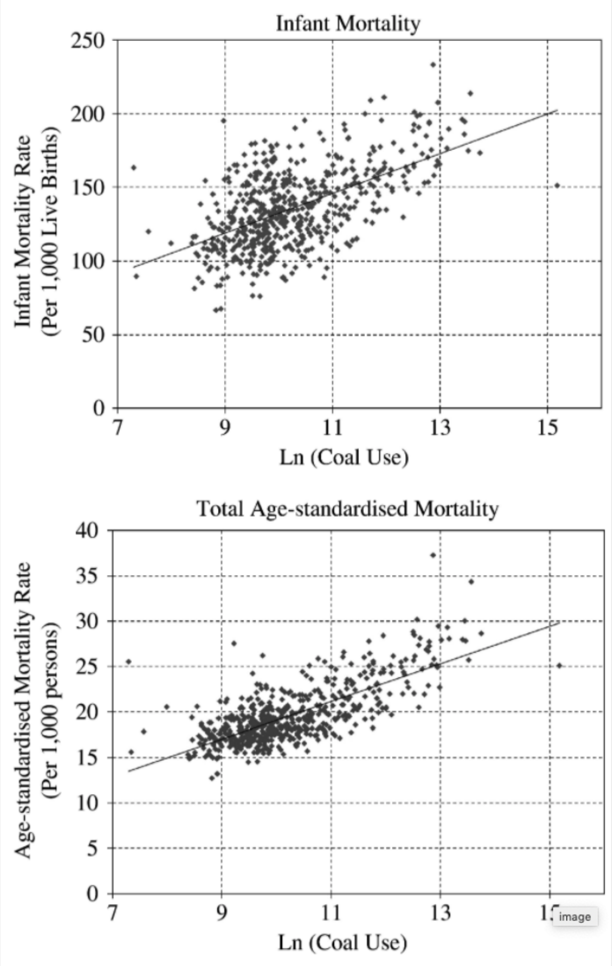
Just 1/70th of a teaspoon of mercury deposited on a 25-acre lake can make the fish unsafe to eat

Typical plant can emit $>$ 170 pounds per year

Activated carbon injection technology can reduce mercury emissions by up to 90 percent when combined with baghouses, but is only on 8% of the coal fleet

Coal power: air pollutants

Coal and health in 1800s Britain



Coal production in Britain was STRONGLY associated with mortality

Coal is super bad for your health

Beach and Hanlon (2018)

Coal going forward

Coal production

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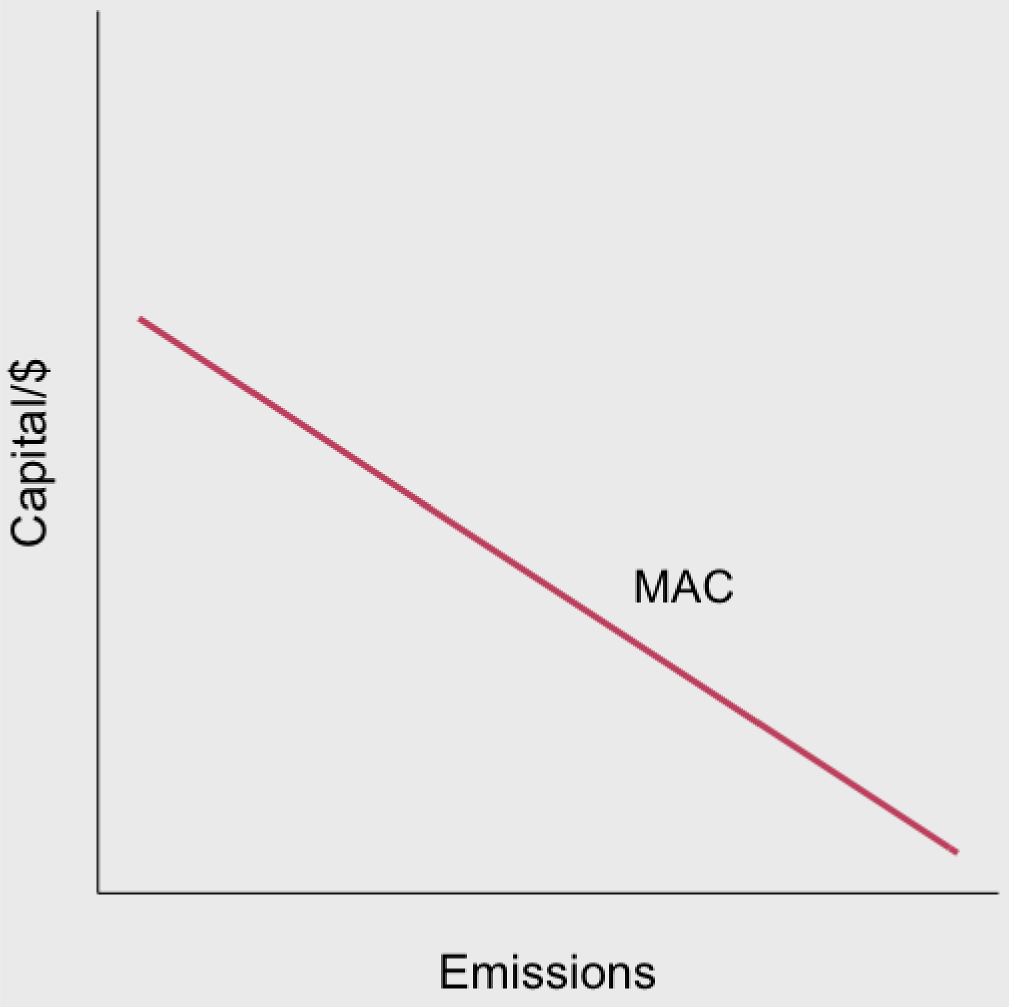
Repeated reductions in emissions require larger and larger increases in capital to hold electricity production fixed (i.e., movement along a convex isoquant)

Setting up our model

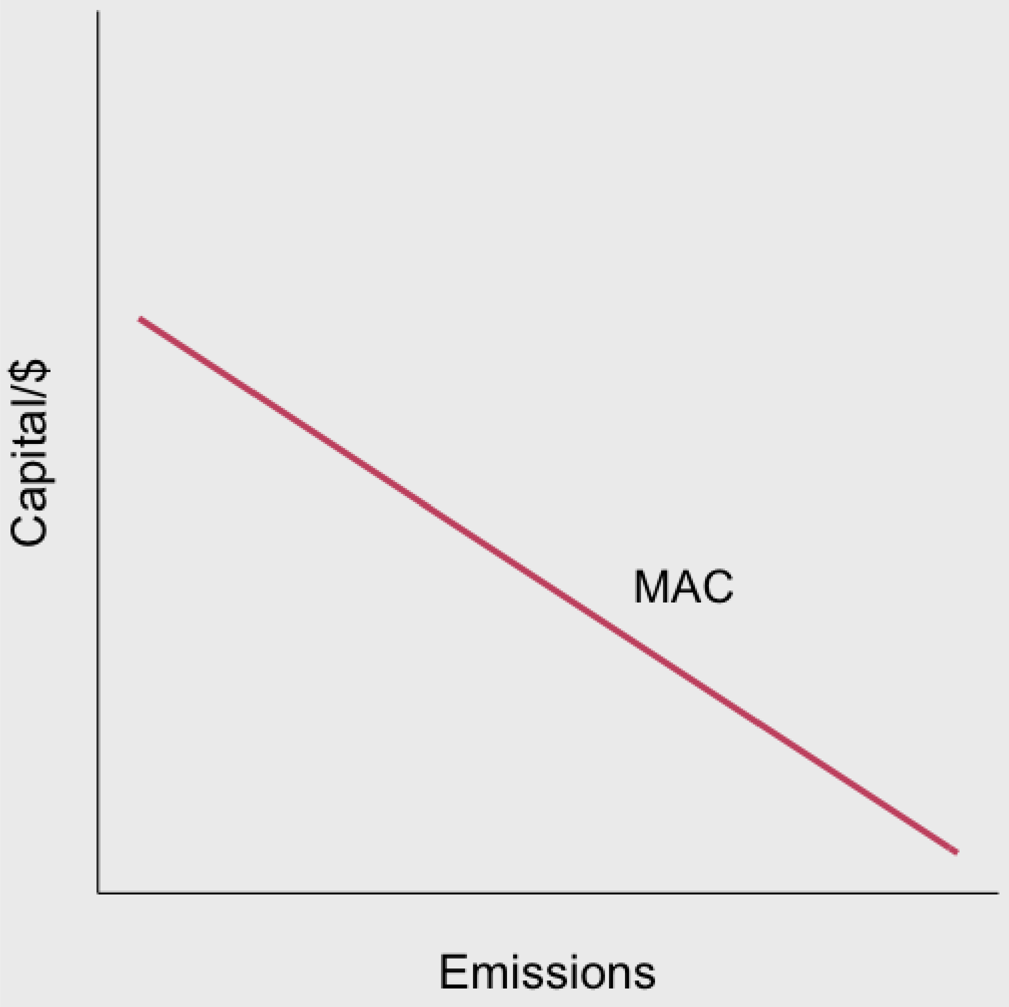


We will be working with graphs where we have cost as a function of emissions

First we have the **marginal abatement cost (MAC)** curve

This tells us the cost of abating the next unit of emissions

Setting up our model



The MAC curve is **decreasing** in emissions

This means its increasing in abatement: its costlier to reduce emissions as the level of emissions goes down

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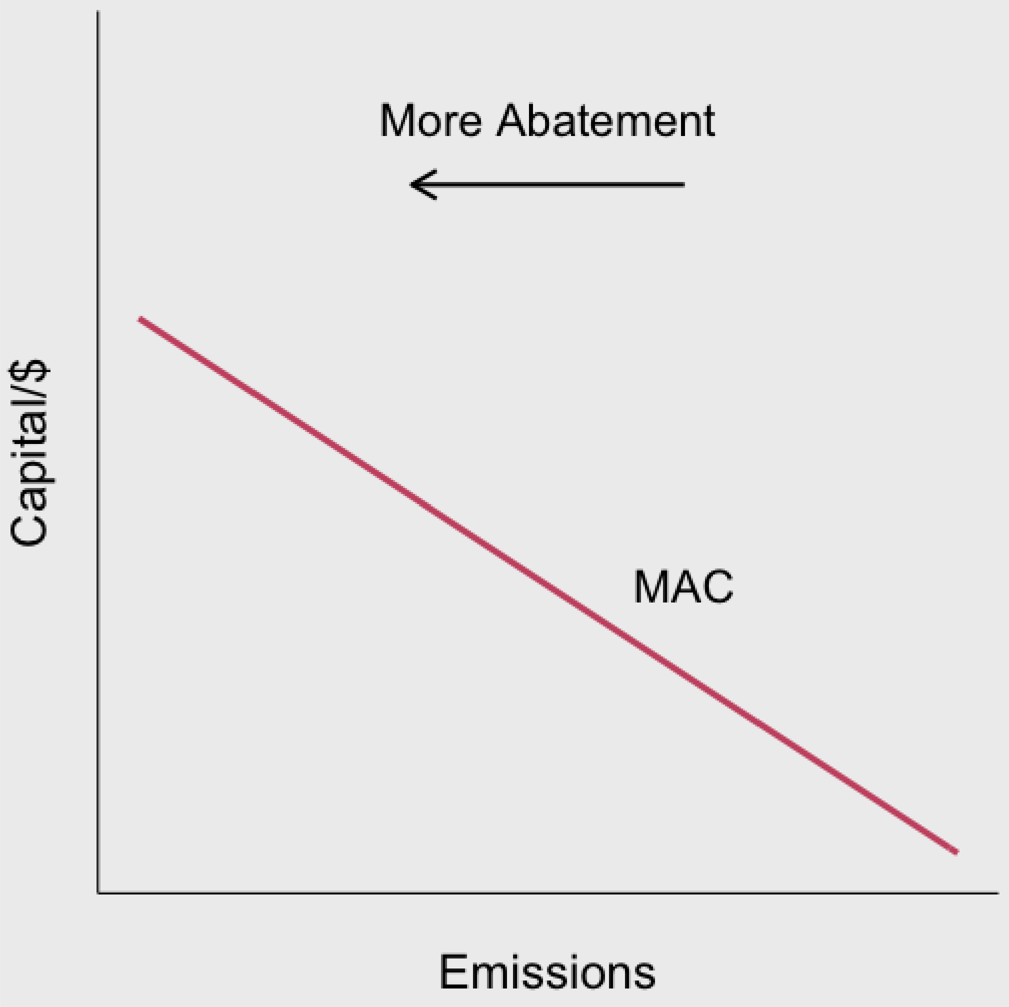
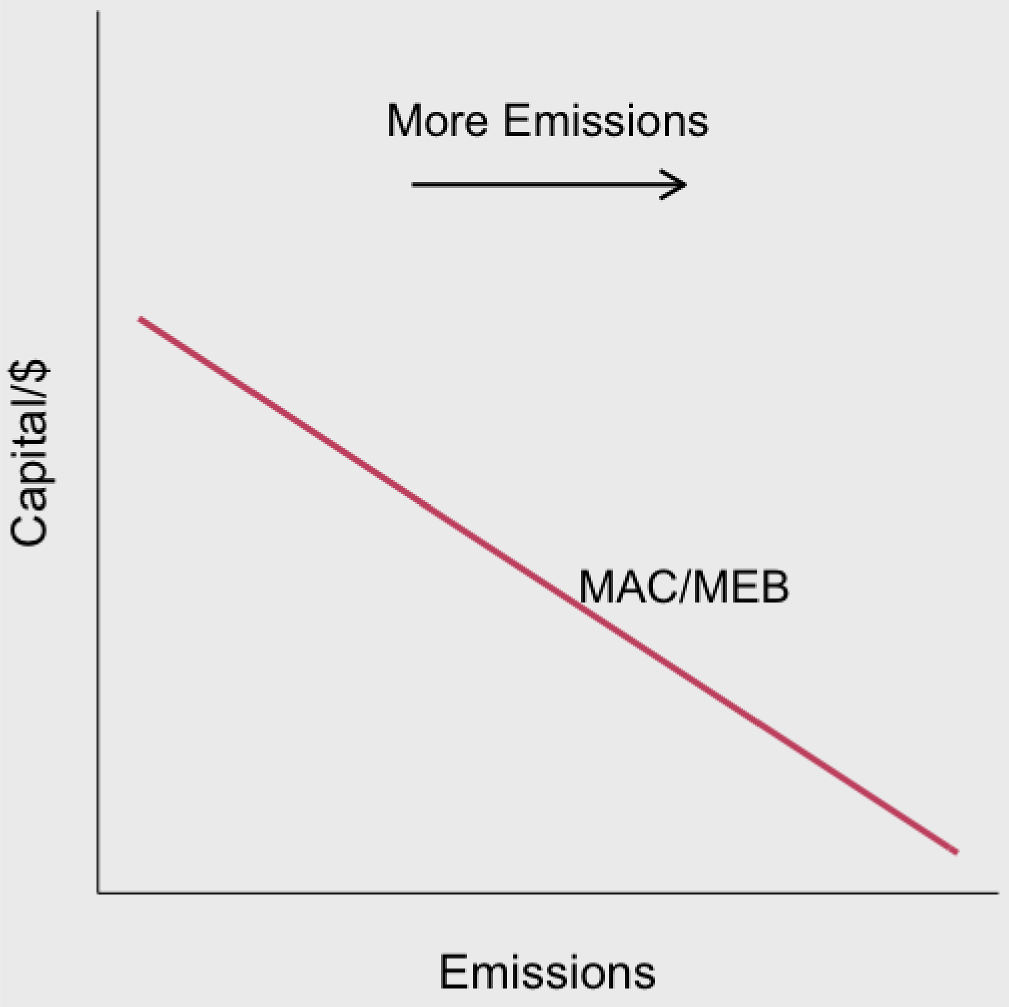


Abatement increases as you move to the left on the graph

This raises marginal abatement cost

Setting up our model

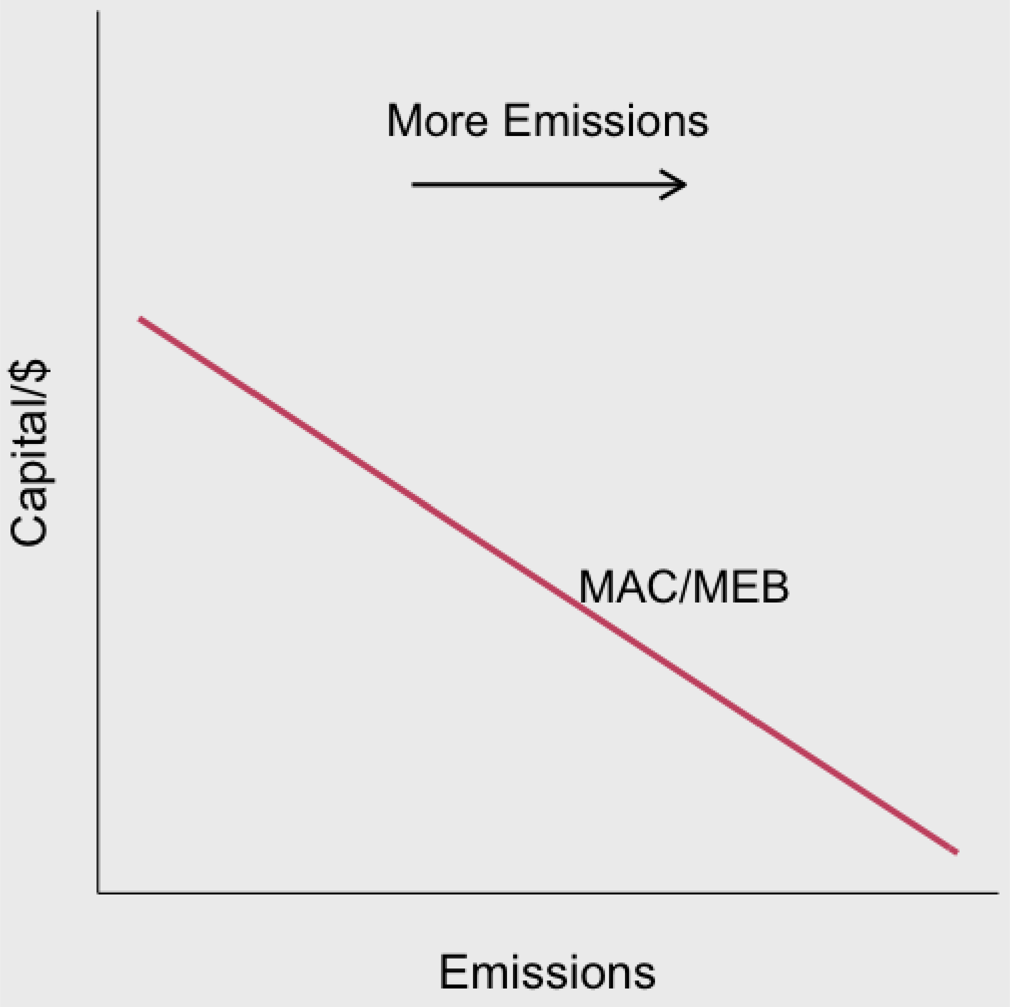


Abatement decreases (emissions increase) as you move to the right on the graph

This decreases marginal abatement cost

You can think of this as alternatively the **marginal emissions benefit (MEB)** from reduced abatement costs

Setting up our model

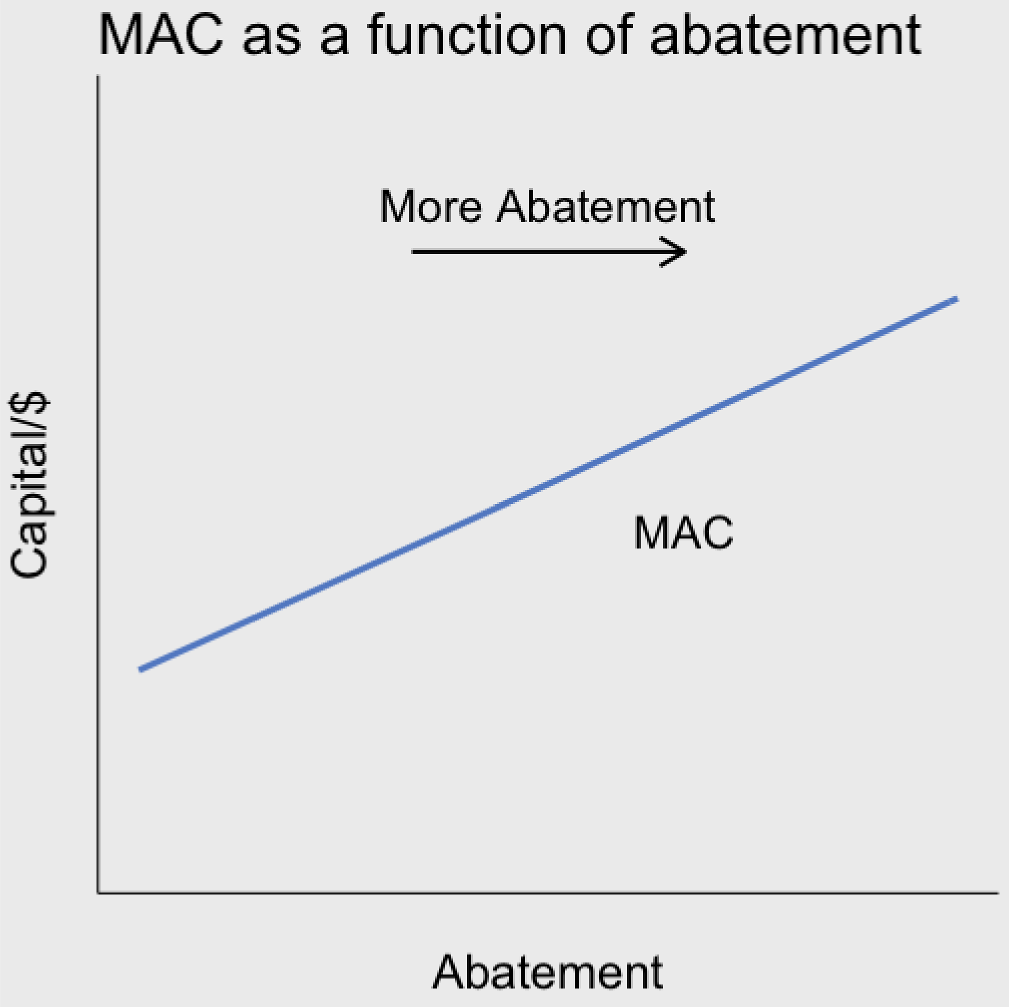


We can equivalently plot the MAC a different way

Now plot the MAC as a function of abatement

What will the MAC look like?

Setting up our model

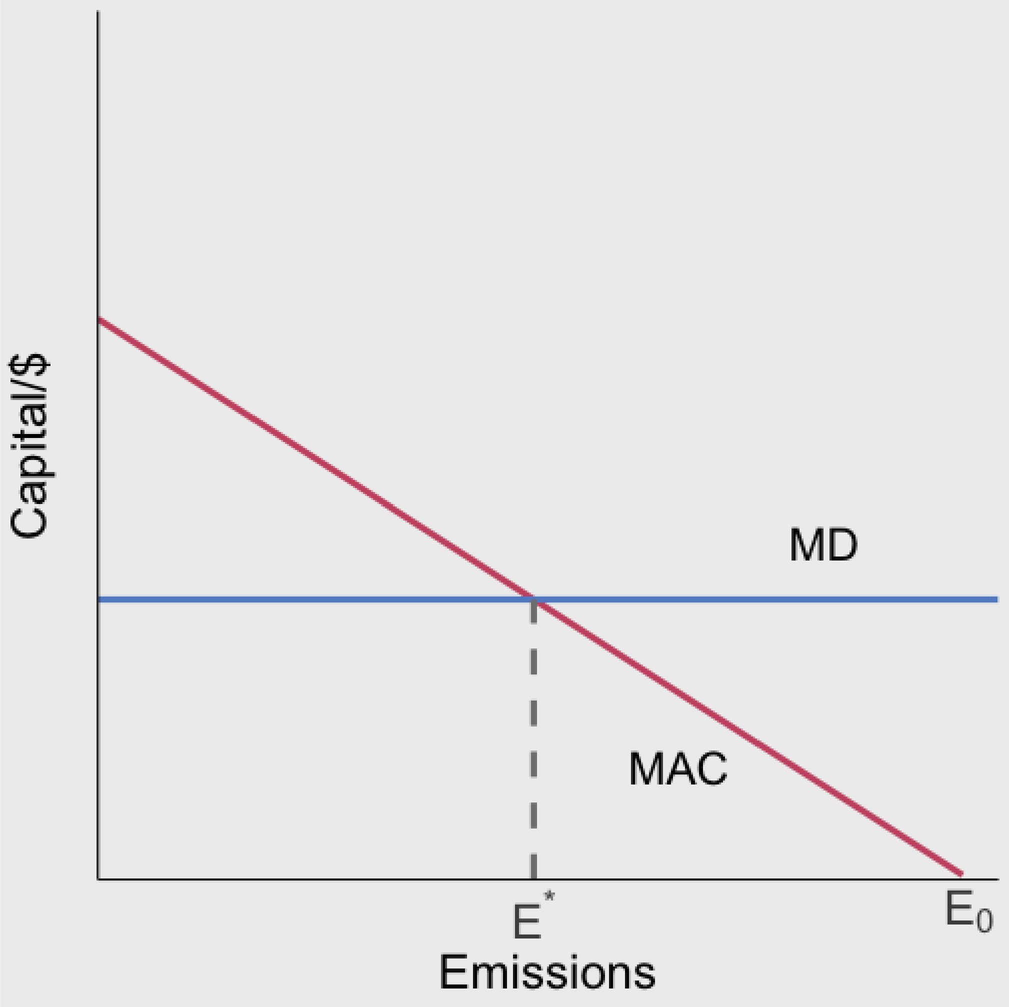


Abatement decreases (emissions increase) as you move to the right on the graph

This decreases marginal abatement cost

You should eventually be comfortable with either representation of MACs

Setting up our model

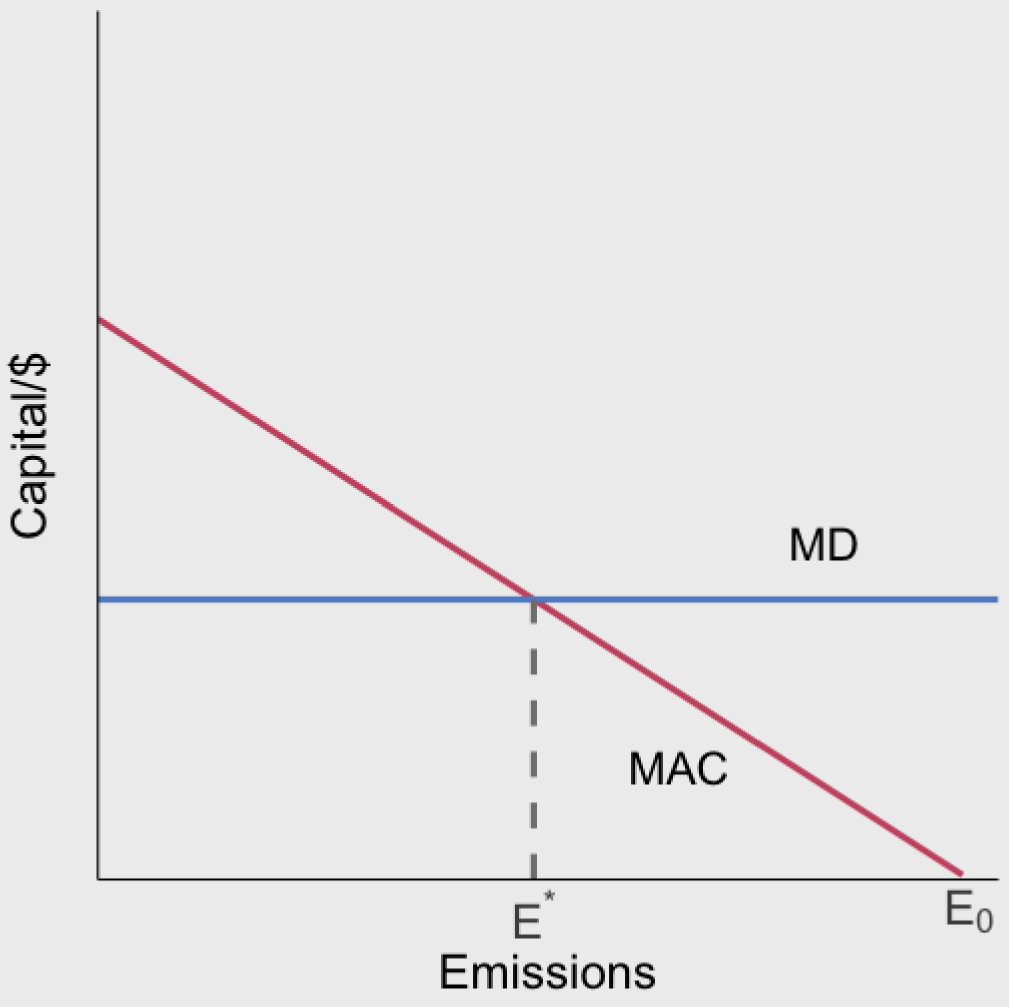


Next we have the **marginal damage (MD)** curve

This gives us the external cost of the next unit of emissions

It is also the social cost since we assume the private cost of emitting is zero

Setting up our model

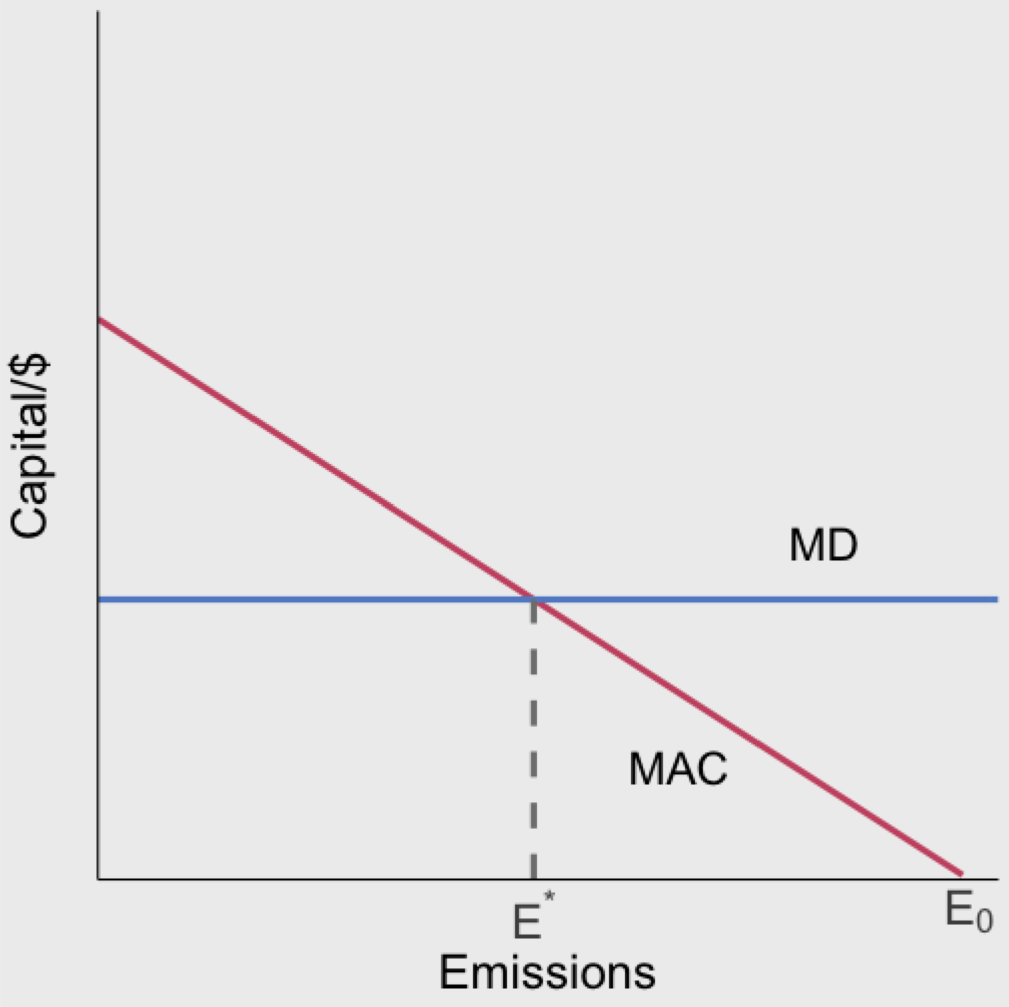


How do we think about this? One of two ways

1. MAC is the social marginal benefit of emissions, MD is the social marginal cost of emissions
2. MAC is the social marginal cost of abatement, MD is the social marginal benefit of abatement

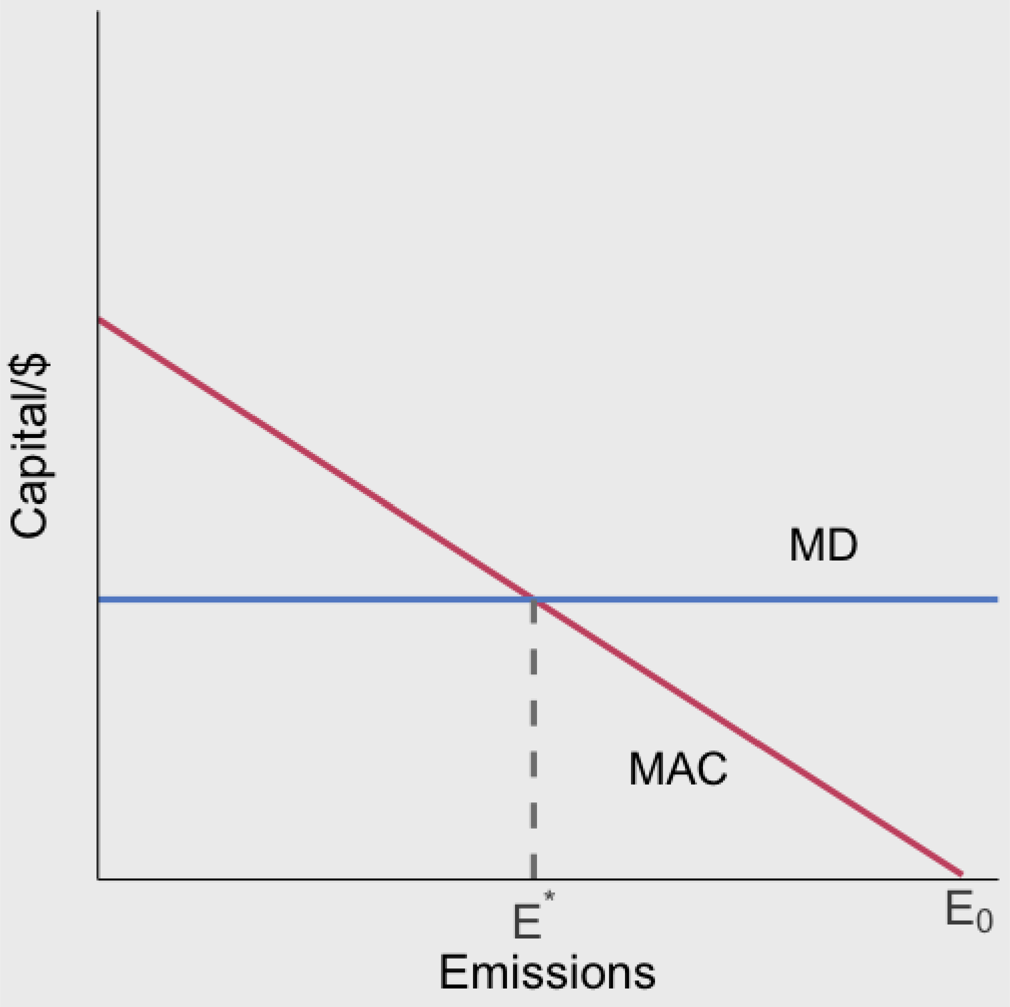
These are identical interpretations

The unregulated/free market



What is the unregulated / free market outcome?

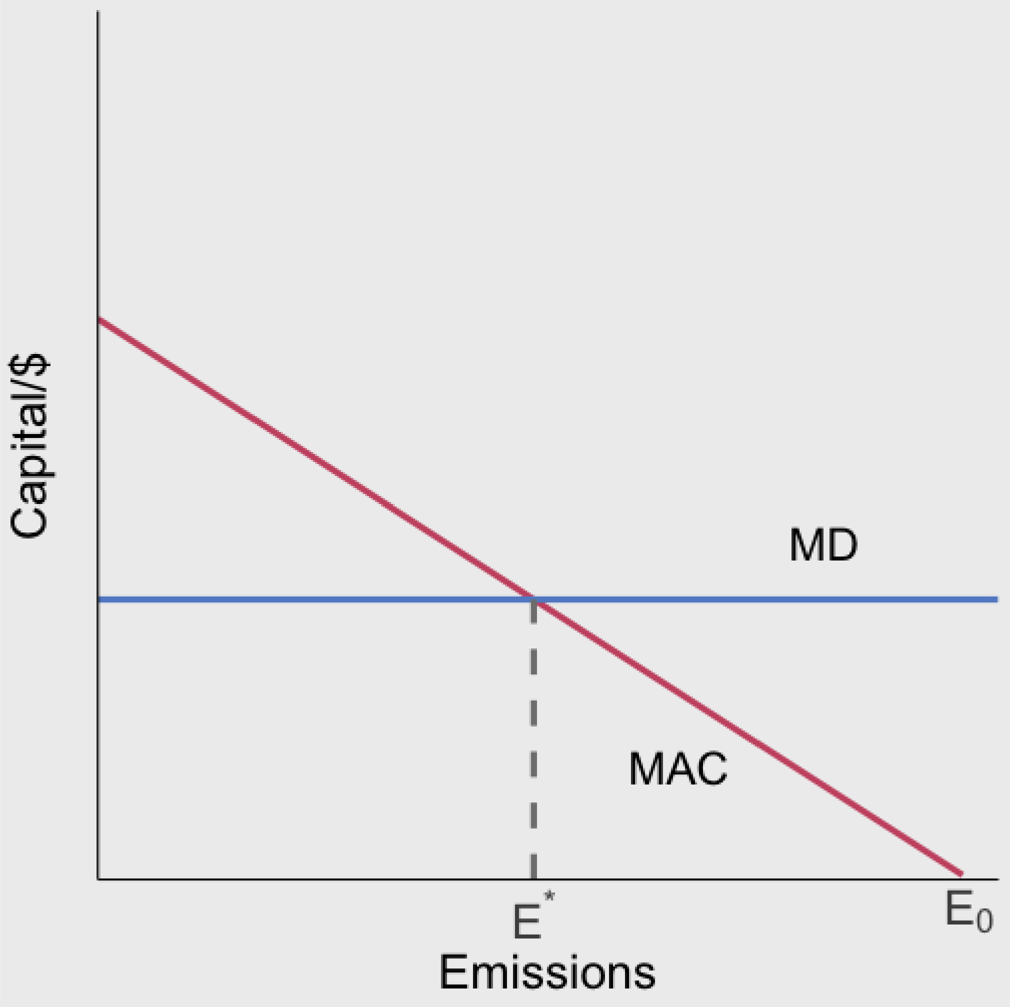
The unregulated/free market



What is the unregulated / free market outcome?

Think about the firm's problem in terms of the marginal benefits and costs of emissions

The unregulated/free market



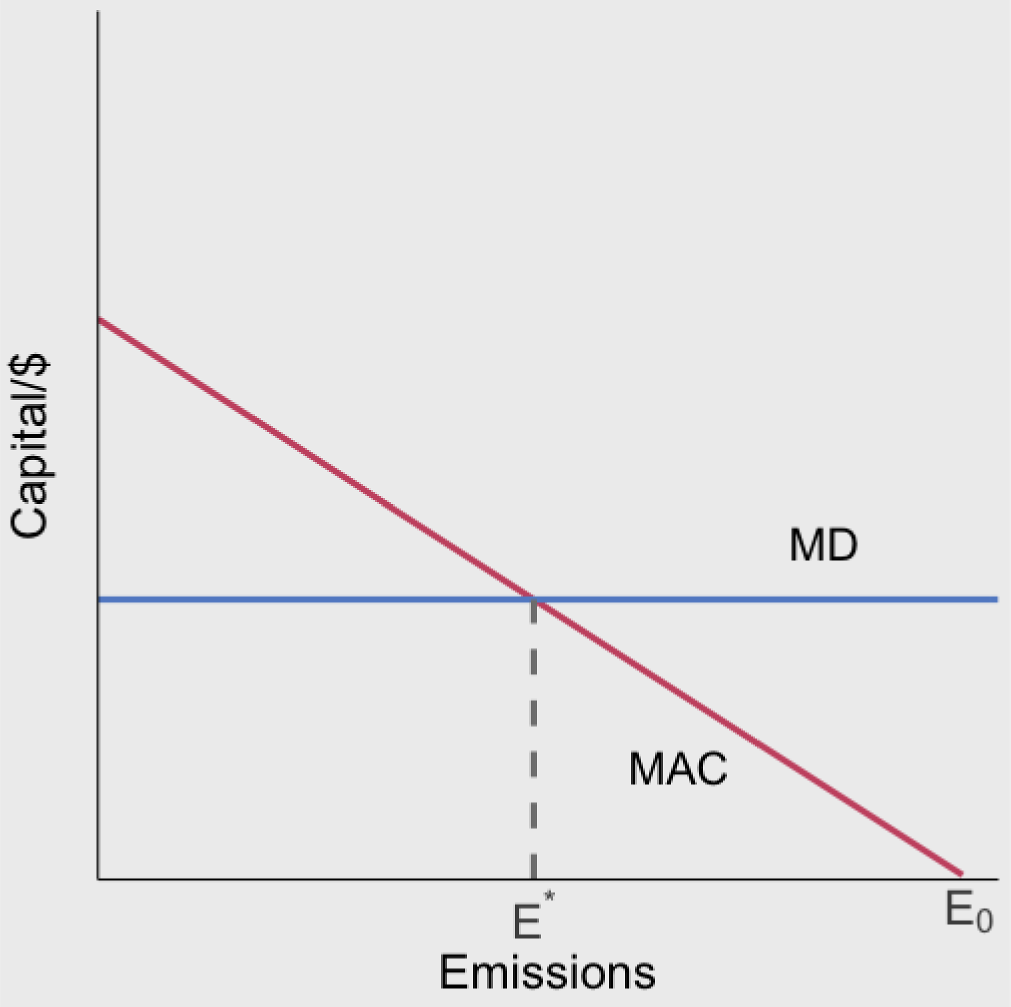
The PMB of emissions is given by the MAC (avoided abatement cost, an opportunity cost)

The PMC of emissions without regulation is....zero

So firms set emissions where: PMB=PMC $\rightarrow$ MAC = 0

Free market outcome is $E = E_0$

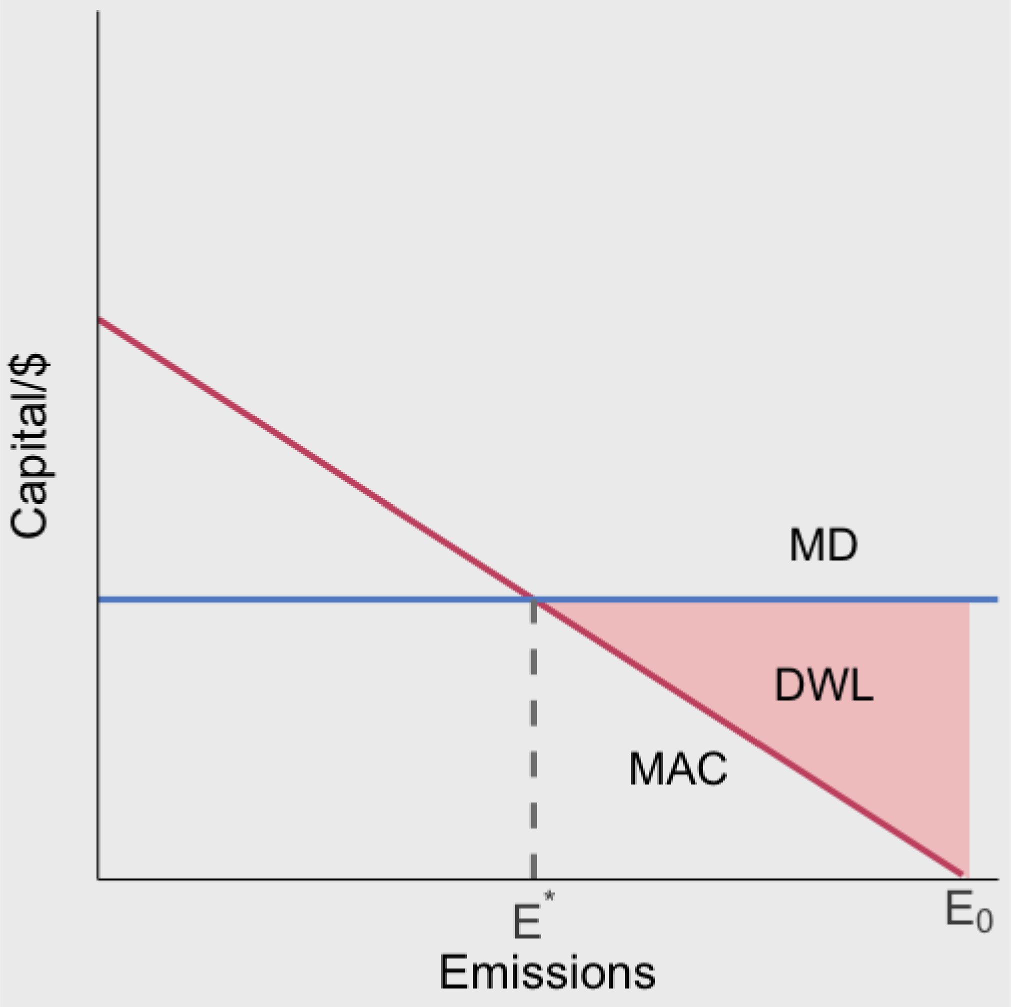
The unregulated/free market



But, if we could get all the victims of pollution together, they are willing to pay up to MD in order to get the firm to abate the pollution

The MAC for eliminating the first unit of emissions is ≈ 0

The cost of no regulation



People are willing to pay to eliminate emissions until $E = E^*$

If we add up all of these potential surpluses from Pareto improving trades, we get our DWL from the externality

Command and control

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Called “command and control” because a government agency (e.g. the EPA) imposes (e.g. commands) a common control technology standard on all firms

Command and control

> > Thirty Years ago, the economists at Resources for the Future were pushing the idea of pollution taxes. We lawyers at the NRDC (Natural Resources Defense Council) thought they were nuts, and feared that they would derail command-and-control measures like the Clean Air Act, so we opposed them. Looking back, I'd have to say this was the single biggest failure in environmental management – not getting the prices right…"
>
> Gus Speth, 2002. Dean, Yale School of Forestry and Environmental Studies. Former head of World Resources Institute and co-founder of NRDC

Brief aside

If you're interested in doing cool real world policy work on the environment, RFF hires paid interns every summer and RAs on a 1-2 year basis, RA positions there are basically a stepping stone into top graduate programs

Half of the environmental economists at Dyson have current/prior affiliations with RFF

Summer Research Intern (PAID): Control of Industrial Greenhouse Gas Emissions

Job Details

Level	Entry
Job Location	RFF - WASHINGTON, DC
Position Type	Internship

Summer Research Intern (PAID): Control of Industrial Greenho

Do you want to begin a career in academic or policy research? Are you interested in contributing to impactful, balanced research that is aimed at improving environmental, energy and natural resource decisions? A summer research internship with Resources for the Future (RFF) might be right for you. The RFF summer internship program provides an opportunity for students to prepare for careers that engage in academic and policy-relevant research. Interns are essential members of the Resources for the Future (RFF) Research and Policy Engagement team. They are responsible for providing technical support that, under the direction of RFF Fellows, allows for the production of compelling and impactful research that aligns with RFF's mission of improving environmental, energy and natural resource decisions through impartial economic research and policy engagement.

Our research internships are a 10-week program paid at $15 an hour for up to 35 hours a week. They will be conducted virtually unless otherwise noted. Internships will run from June 7, 2021 to August 13, 2021. Start or end dates can be changed with an approved exception.

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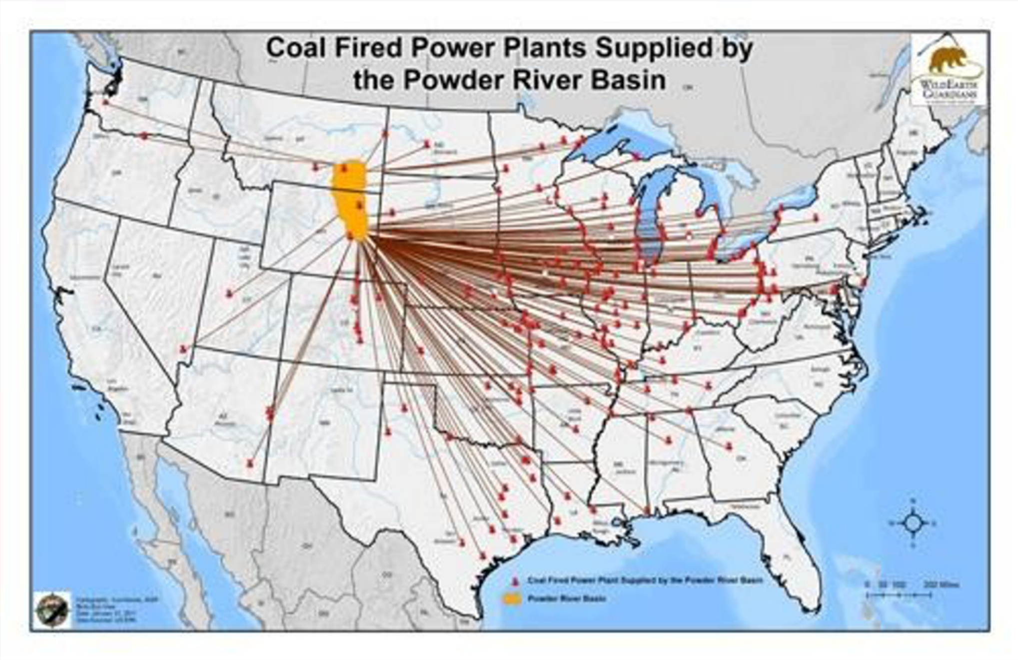
2. In the 1970s the US mandated catalytic converters in cars
3. The Clean Air Act mandates that the 'Best Available Control Technology' be used by emission sources (often not clearly defined)

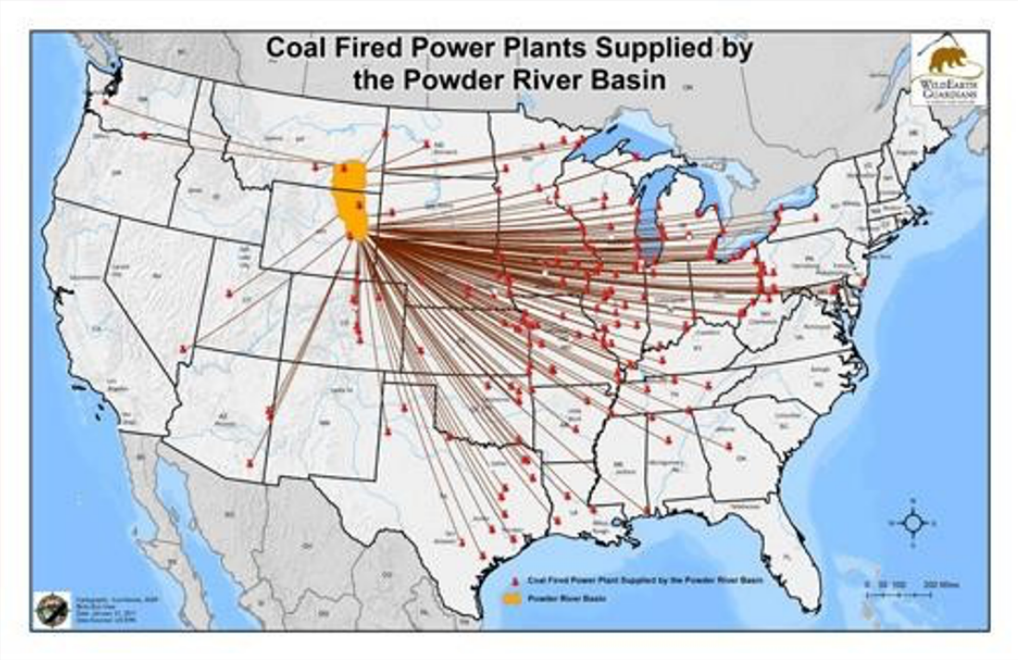
Command and control



CC policies are nice because they have low administrative costs (do you have this technology installed or not?)

They also have significant costs in that they lead to distortions

Command and control



Coal from WY has much lower sulfur content than coal from WV

Ideally, if we want to reduce sulfur dioxide emissions, we would like coal plants to use more low-sulfur WY coal

Command and control

Byrd, who had single-handedly blocked clean air legislation while majority leader, joined an unlikely assemblage at a news conference announcing the compromise worked out in 22 days of negotiating by the "Group of 15," led by Senate Majority Leader George J. Mitchell (D-Maine), Minority Leader Robert J. Dole (R-Kan.) and White House domestic policy adviser Roger Porter.

Senator Byrd from WV single-handledly blocked legislation for sulfur regulations and pushed for scrubber mandates so that high-sulfur WV coal could compete with low-sulfur WY coal

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What other drawbacks are there to CC policies?

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The government is picking winners and losers in technology

Current firms can “capture” regulatory board and require technologies that are easy to implement, or may serve as a barrier-to-entry to new competition

Emission standards

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You can think about it as a bubble over multiple plants/emission sources owned by each firm, the firm can decide how to allocate emissions across plants not mandate a specific technology

> On March 16, 2011 EPA proposes Mercury and Air Toxic Standards, the first nationwide limits on coal-fired power plant emissions of mercury. Specifically, the proposal aims to reduce emissions from new and existing coal and oil-fired EGUs by 91% from current levels through national quantity-based, numerical emission limits on mercury releases.

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Let $C(E)$ be abatement cost of emissions level E and $D(E)$ be damages at E

We assume that: $C'(E) < 0 \leftrightarrow \underbrace{-C'(E)}_{\text{MAC}} > 0$ and $\underbrace{D'(E)}_{\text{MD}} > 0$

Emission standards

$-C'(E)$ is the MAC because we are decreasing emissions by 1, $\frac{dE}{dA} = -1$:

$$\underbrace{\frac{dC(E)}{dA}}_{\text{MAC}} = \frac{dC(E)}{dE}\frac{dE}{dA} = -\frac{dC(E)}{dE} = -C'(E)$$

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Emission standards: firm

The firm problem: minimize the cost of satisfying the policy:

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Next we have the regulator's problem

Emission standards: regulator

The regulator's problem is to minimize the social cost of emissions

$$\min_{\bar{E}} \{C(E) + D(E)\} \quad \text{subject to:} \quad \underbrace{E = \bar{E}}_{\text{firm's choice}}$$

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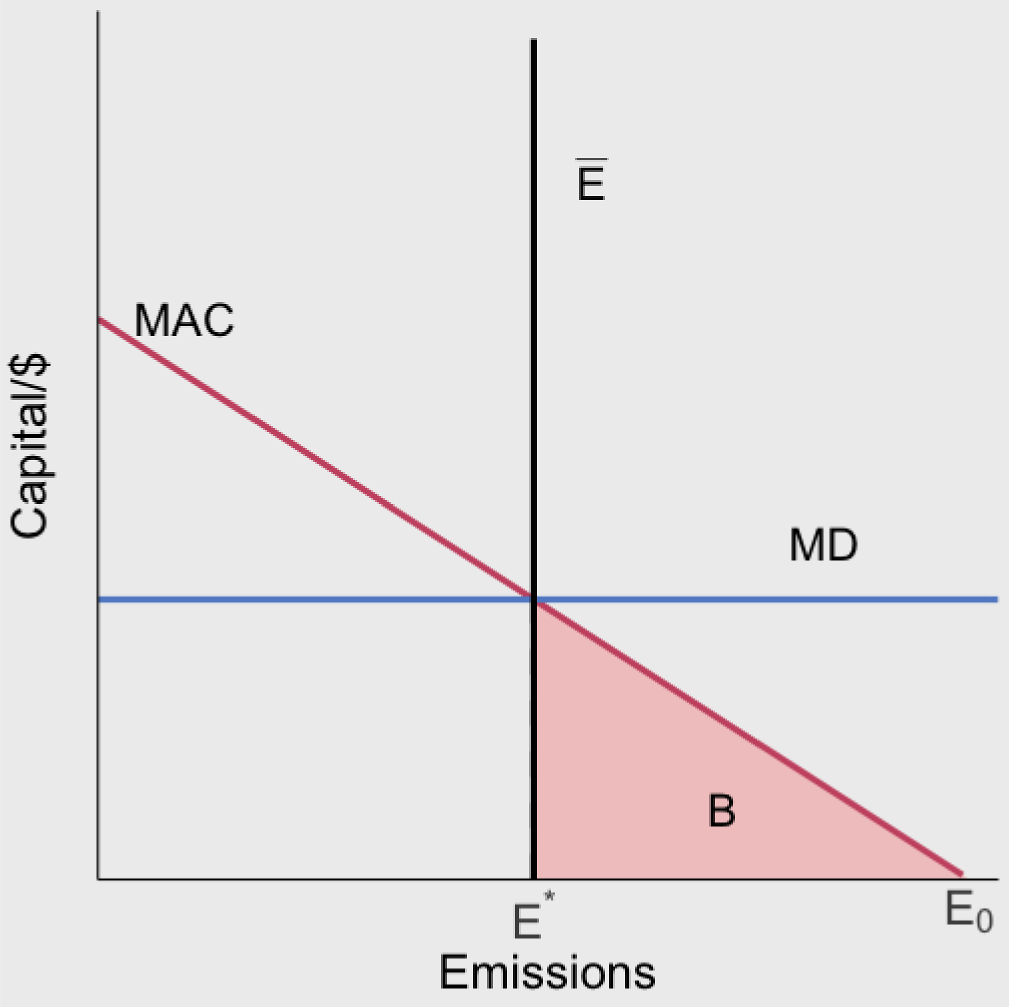
The optimal choice of $\bar{E}$ is governed by the first-order condition:

$$-C'(\bar{E}) = D'(\bar{E})$$

The regulator chooses $\bar{E}$ to be the emission level where MAC = MD: $\bar{E} = E^*$

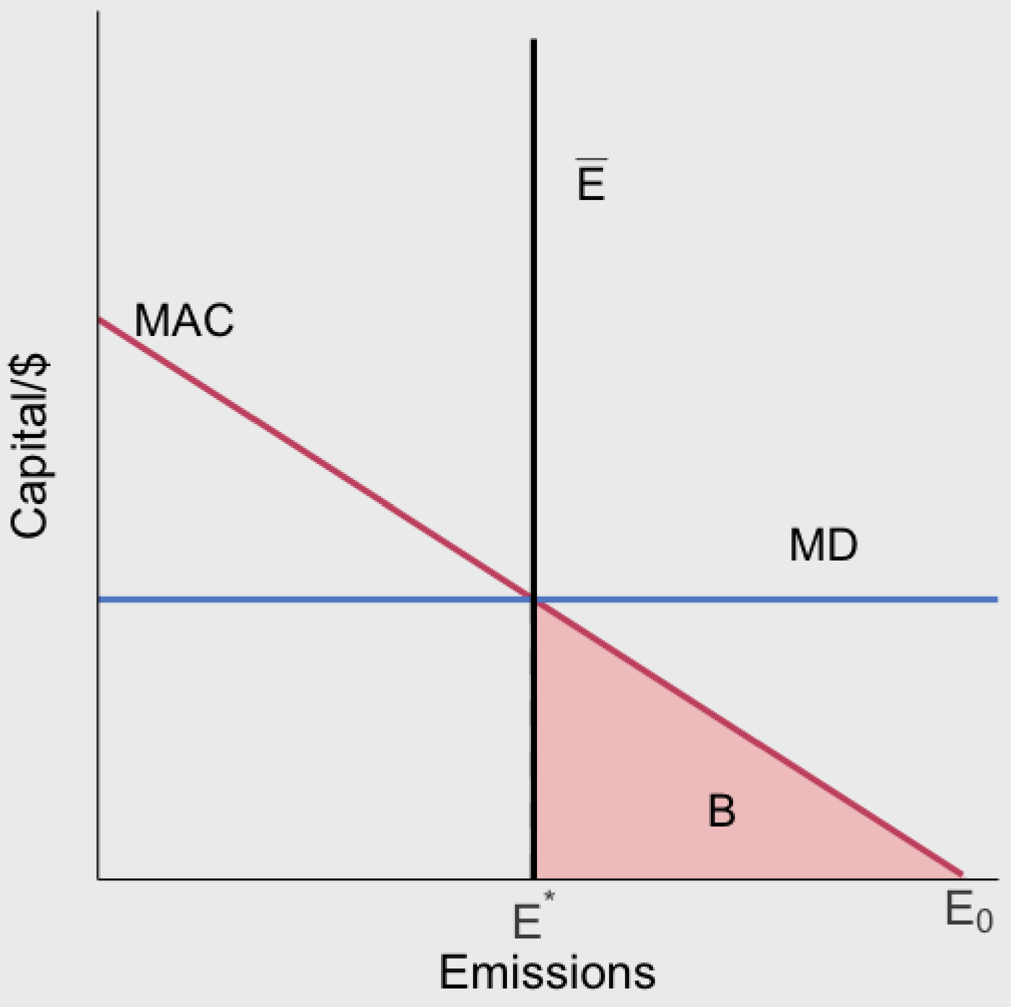
Emission standards: graphical



The optimal standard restricts emissions to be $\bar{E} = E^*$

You can think of this as the regulator setting a tax equal to 0 on the first $\bar{E}$ units of emissions, and a tax of ∞ on each unit after

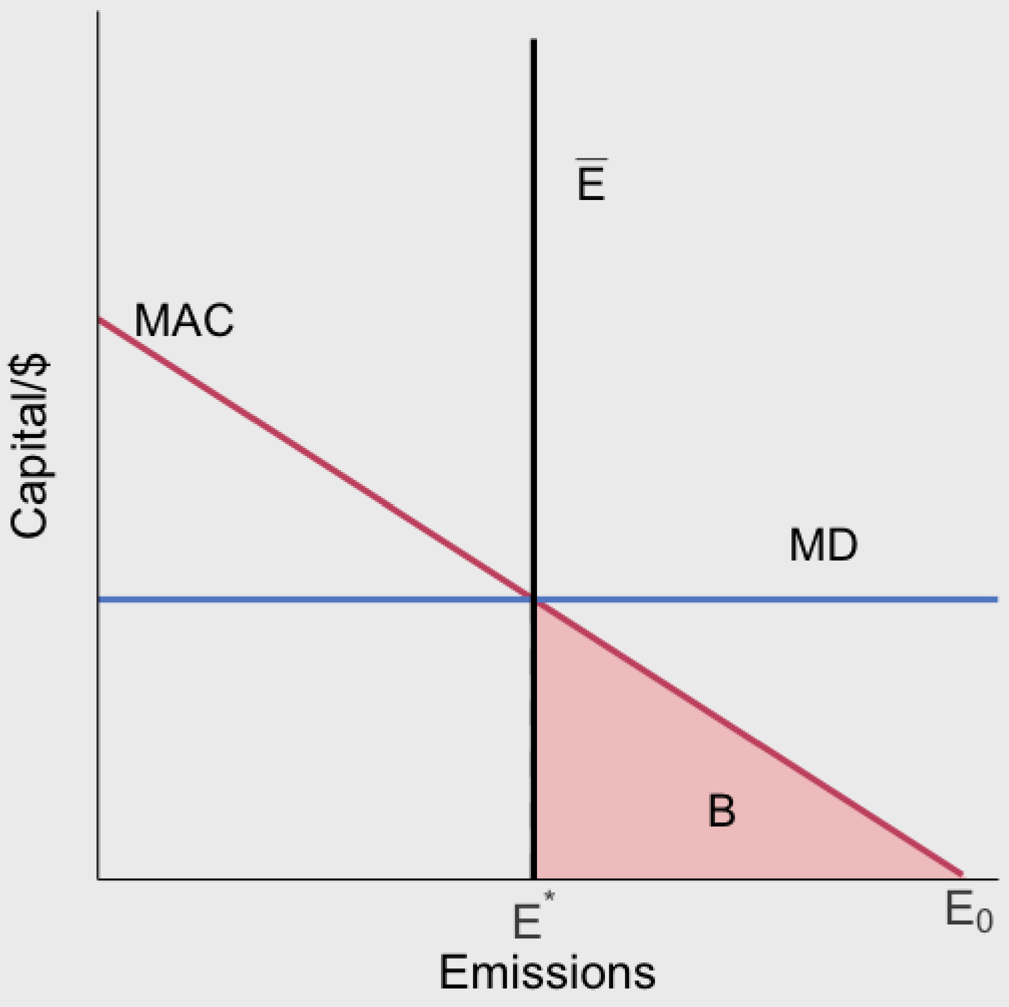
Emission standards: graphical



Firms will then only emit $\bar{E}$ since emitting any more has infinite cost, emitting any less incurs extra abatement cost

Firms total abatement cost under the standard is equal to the red area (B)

Emission standards: graphical



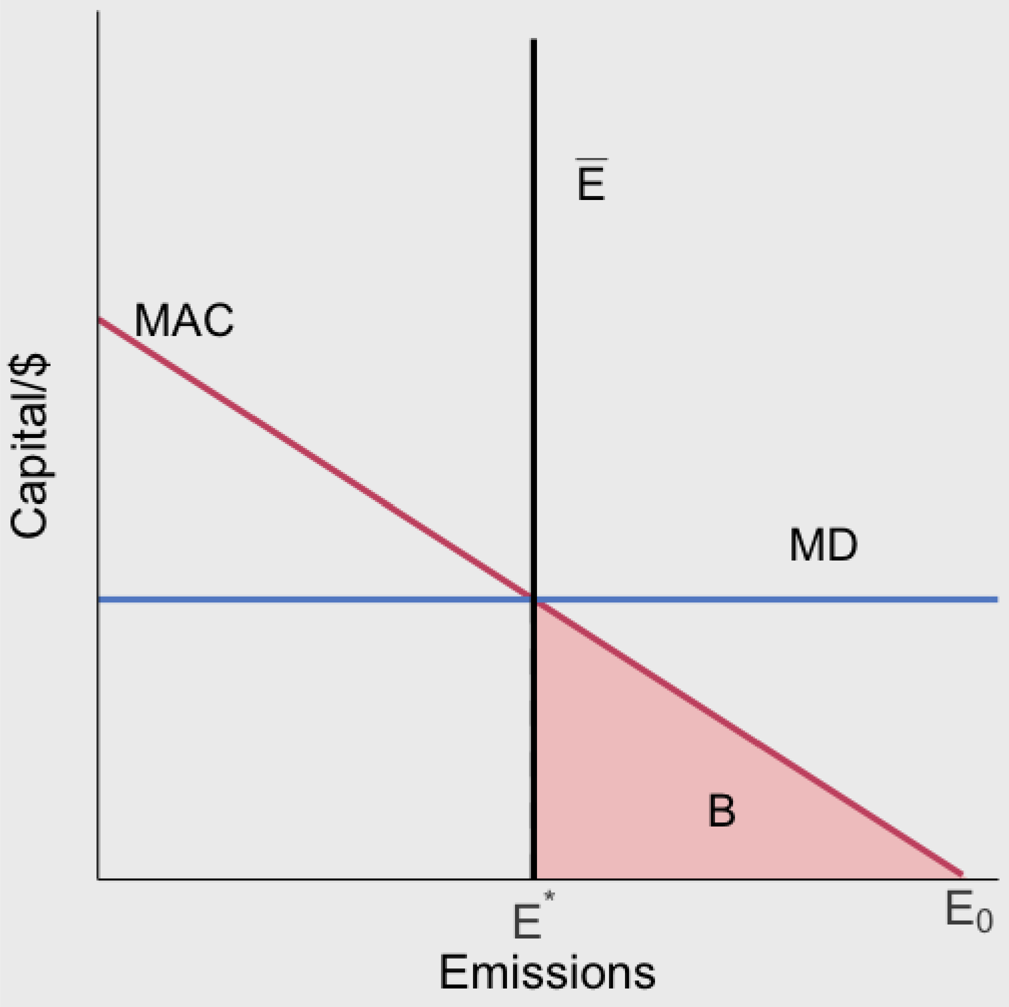
The previous example assumed firms couldn't lie/cheat and **not** abate at all

Suppose that they can, but they are inspected with probability p

If they are caught cheating, they pay a fine F

What determines whether the firm cheats?

Emission standards: graphical



Firm cheats if the benefits are greater than the expected costs

Benefits: B

Expected costs: pF

Cheat if $B \geq pF$

This tells us how big of a fine or how often inspections need to be to stop cheating

Tailpipe emission standards

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CAA was amended in 1990, and new emission standards (in grams/mile) were set for four additional smog pollutants

- Non-methane organic gases (NMOG)
- Carbon monoxide (CO)
- Particulate matter (PM)
- Formaldehyde (HCHO)

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Currently, Tier 3 standards are being phased in

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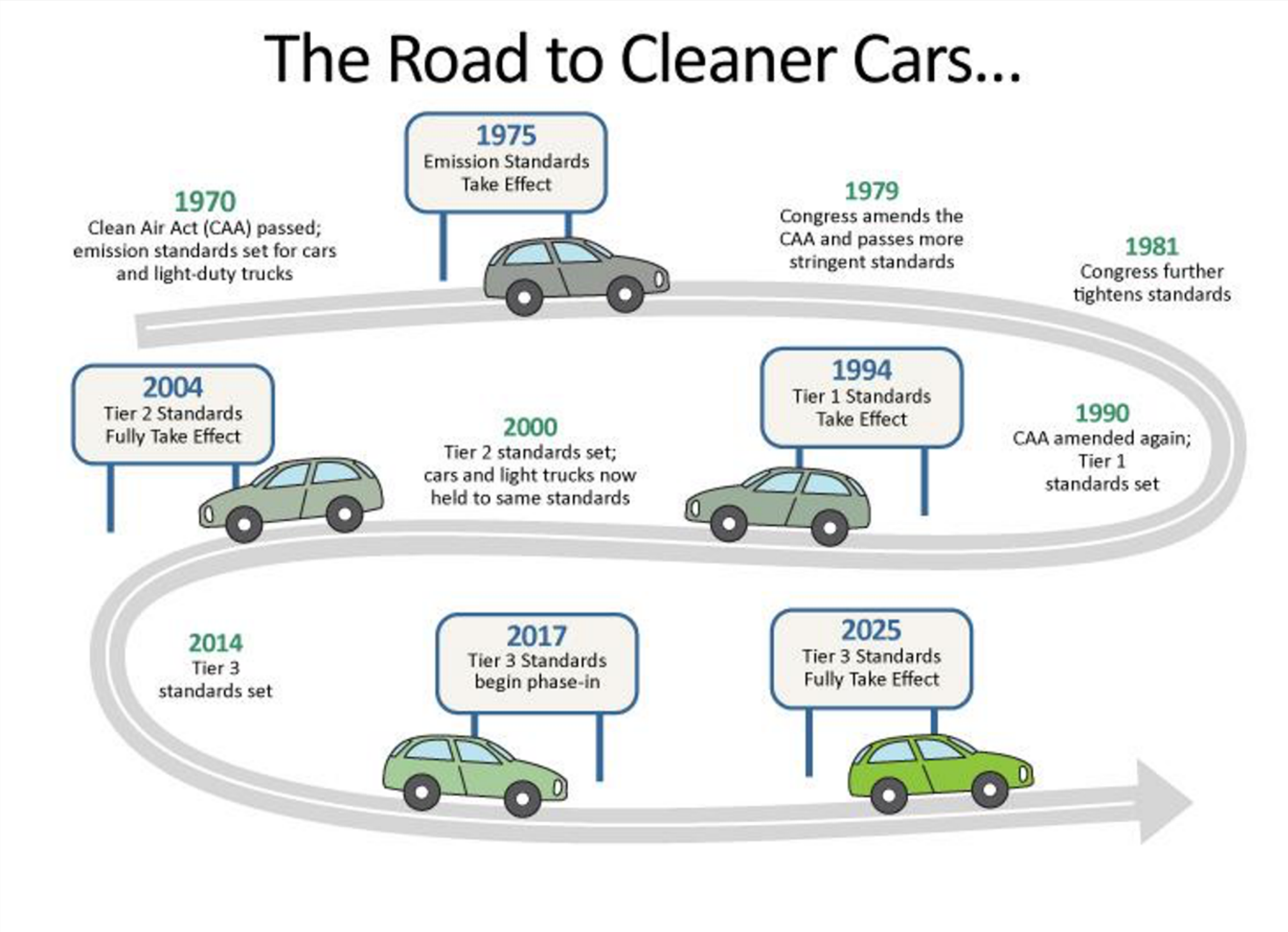

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