Equimarginality and the Efficient Level of Emissions

David Possen
DIS Environmental Economics

Plan of this lecture

1. Review: MD and MAC curves
2. The efficient level of emissions
3. Costs of enforcement
4. The equimarginal principle
5. Policy implications

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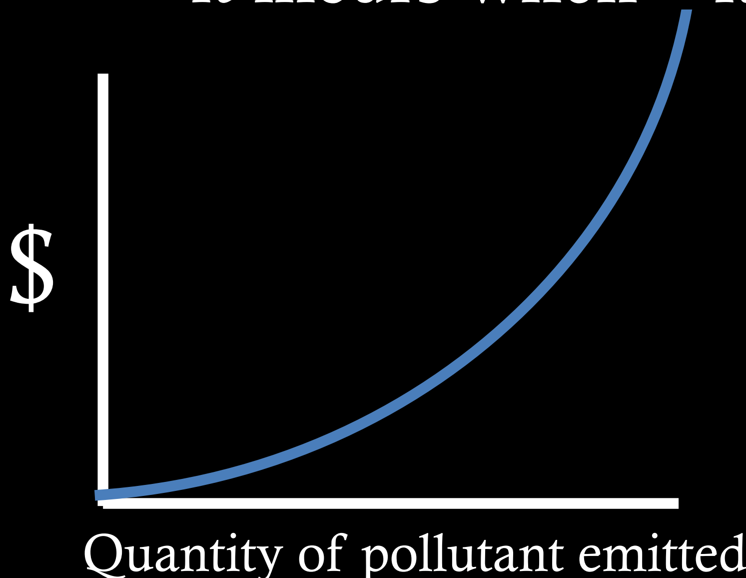
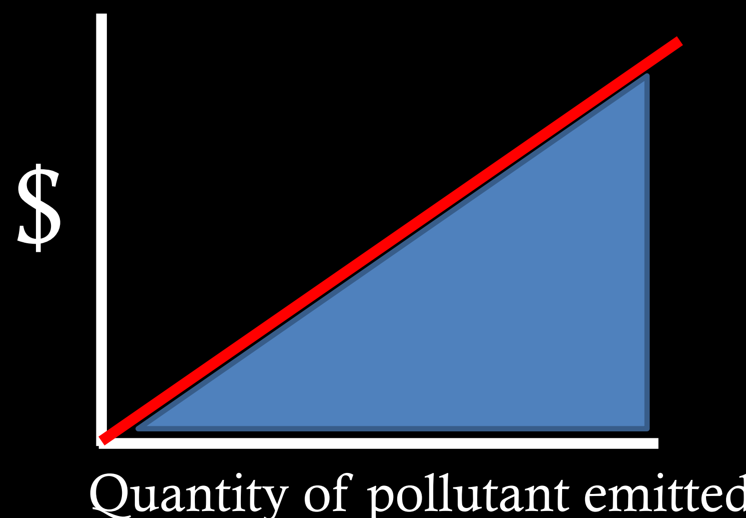
1. Review: MD and MAC curves

To understand the economics of pollution,
it helps to think of pollution
not in terms of the harms it causes,
but in terms of the services it provides
to particular firms operating
within particular communities,
who can offer those firms "pollution services."

1. Review: MD and MAC curves

The community's supply of pollution services is a function of the marginal damage costs it incurs when it lets the firm pollute more.





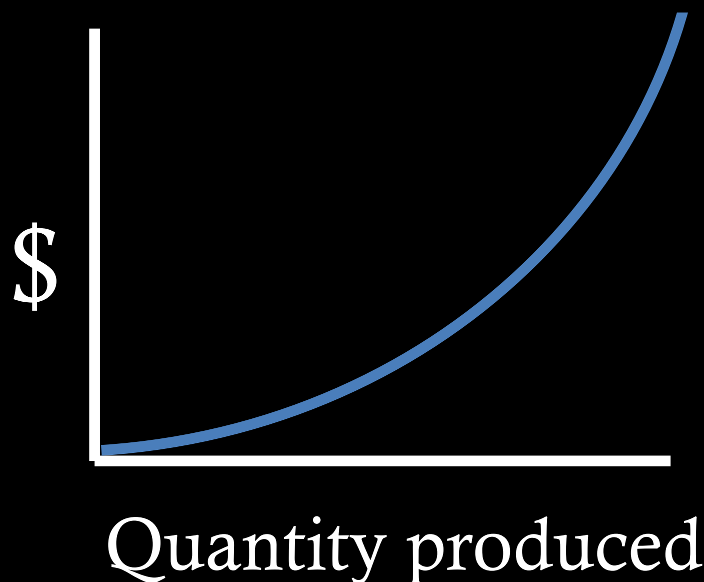
Supply of pollution services =

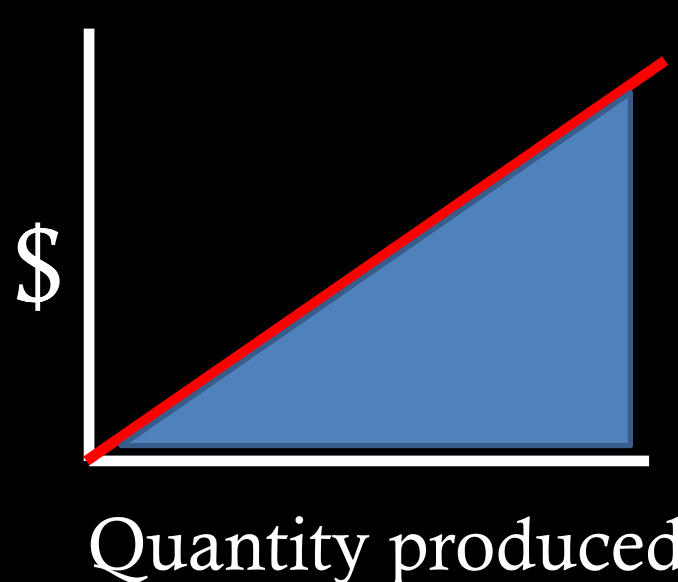
total damage cost

marginal damage cost

Flashback!

A supply curve is a marginal cost curve

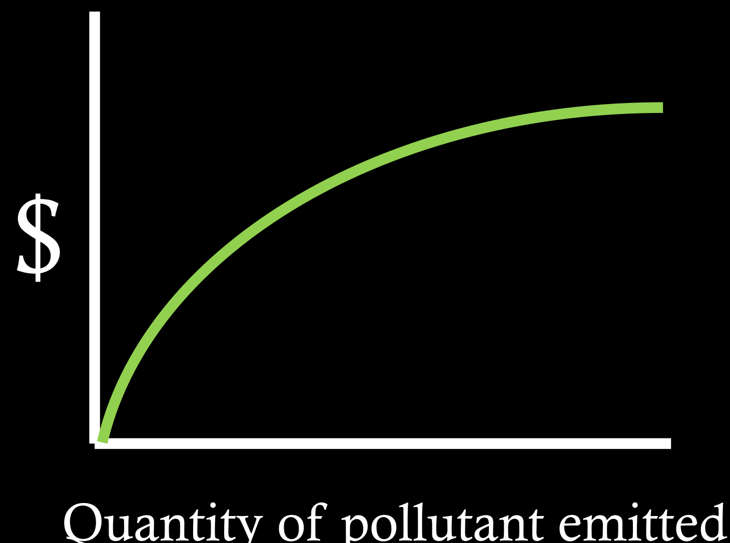




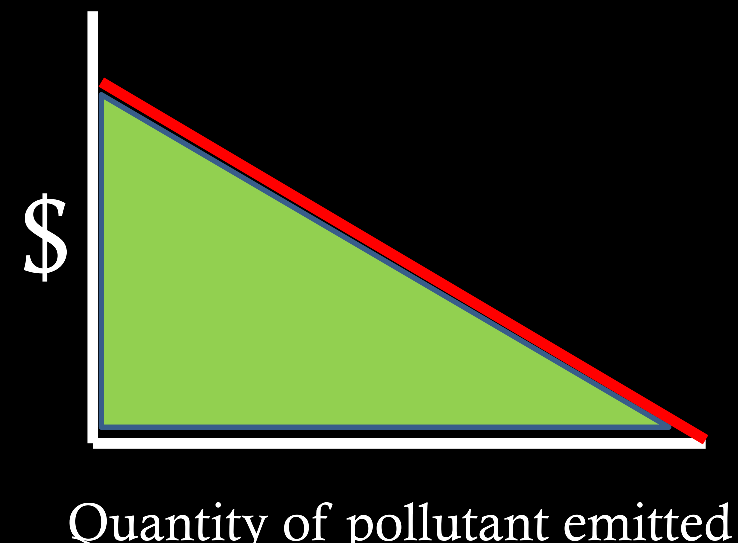
Total cost **Marginal cost**

1. Review: MD and MAC curves

The firm's demand for pollution services is a function of the marginal benefits that accrue to it when the community lets it pollute more.



total benefits from polluting

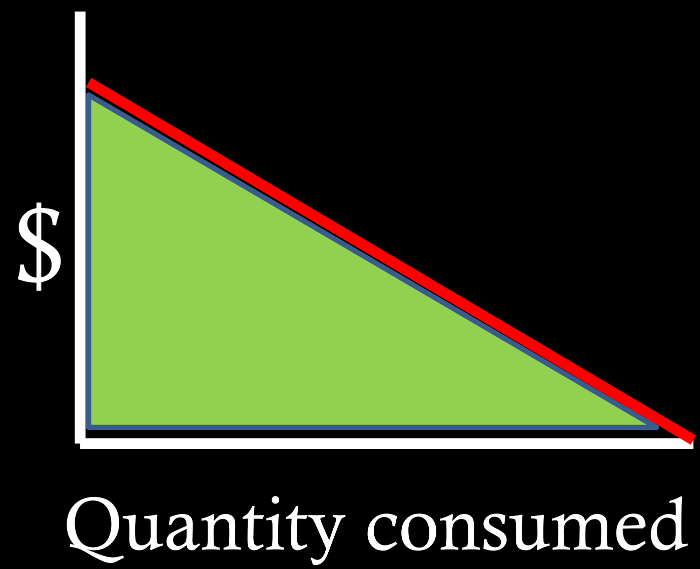


Demand for pollution services = marginal benefits from polluting

Flashback!

A demand curve is a marginal benefit curve

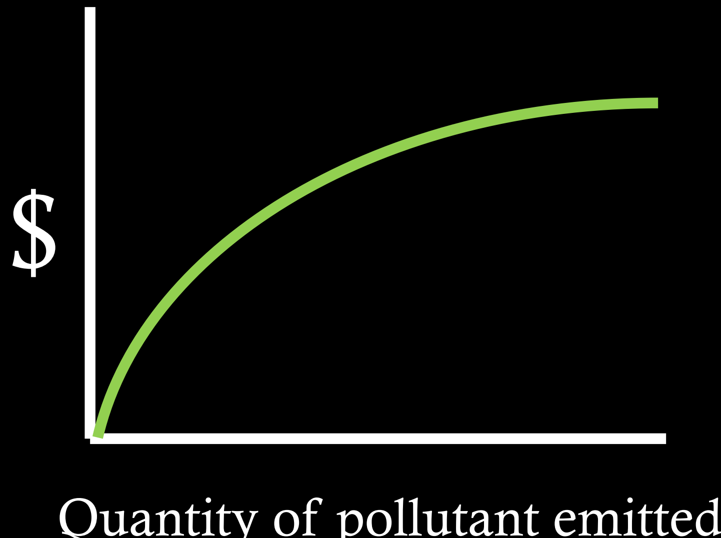
Total benefit

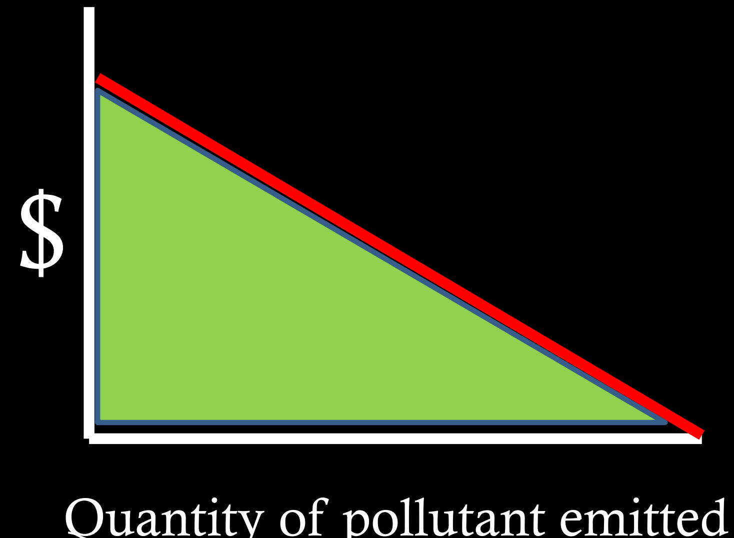


Marginal benefit

1. Review: MD and MAC curves

Now, there's also another way—besides this one—
of understanding the meaning
of a firm's demand for pollution services.



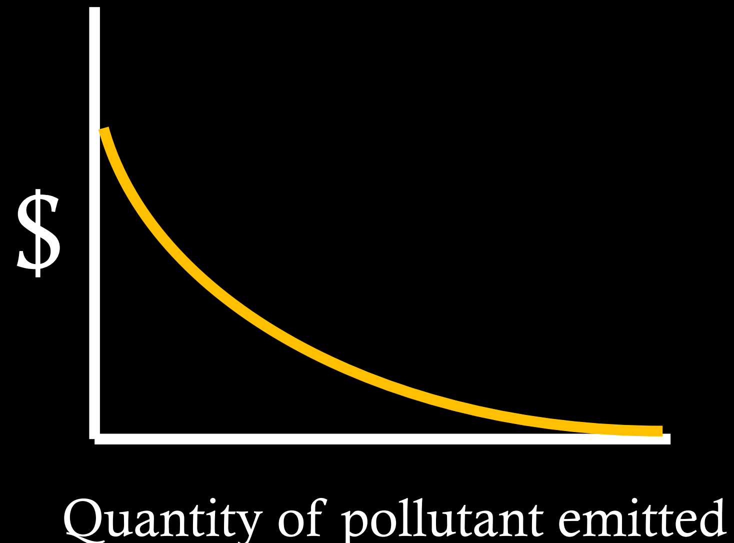


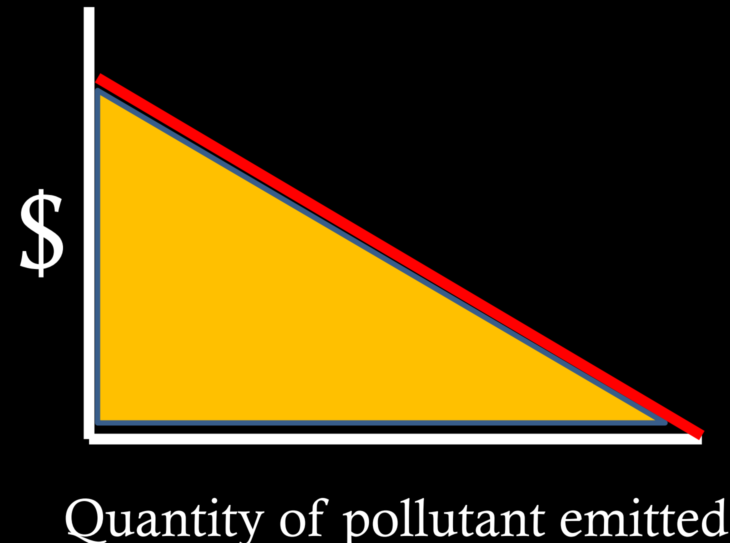
total benefits from polluting

Demand for pollution services = marginal benefits from polluting

1. Review: MD and MAC curves

Alternately: the firm's demand for pollution services is a function of the marginal abatement costs that it **avoids** when the community lets it pollute more.





total abatement cost from BAU maximum

Demand for pollution services = marginal abatement cost avoided

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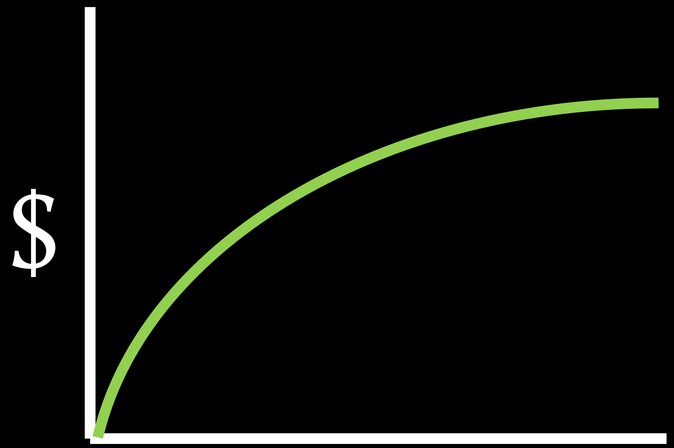
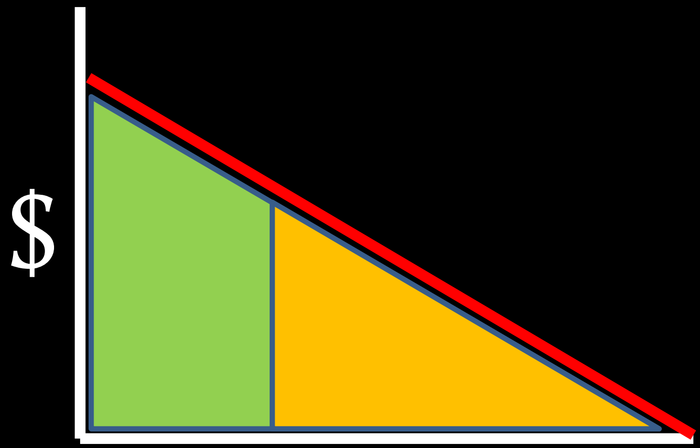


Quantity of pollutant emitted



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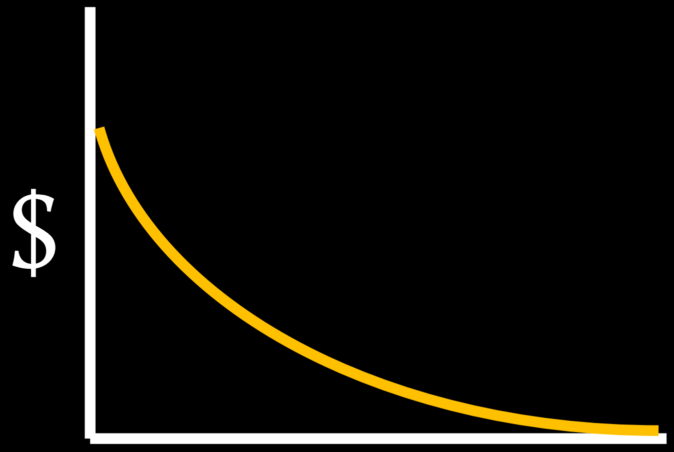

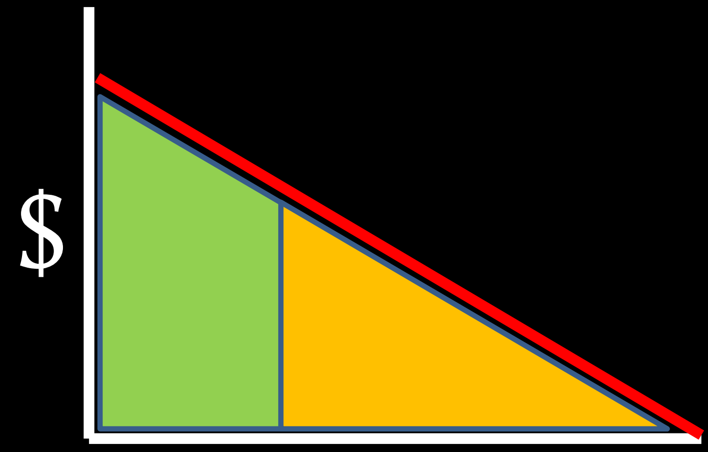

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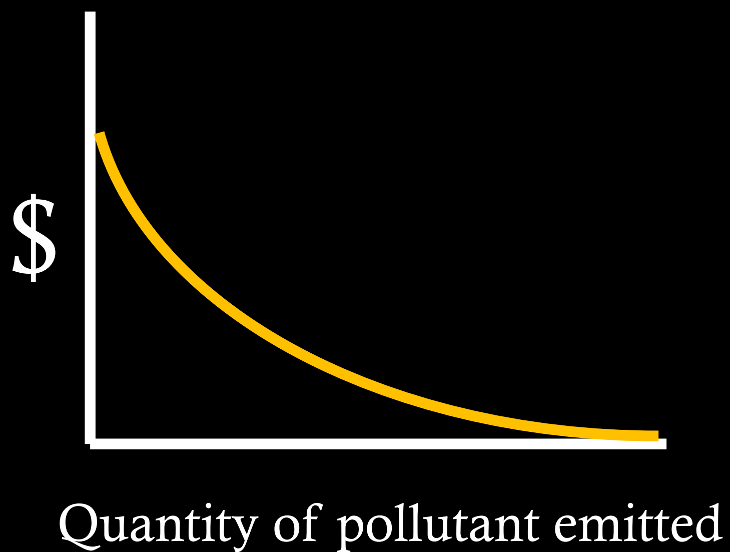
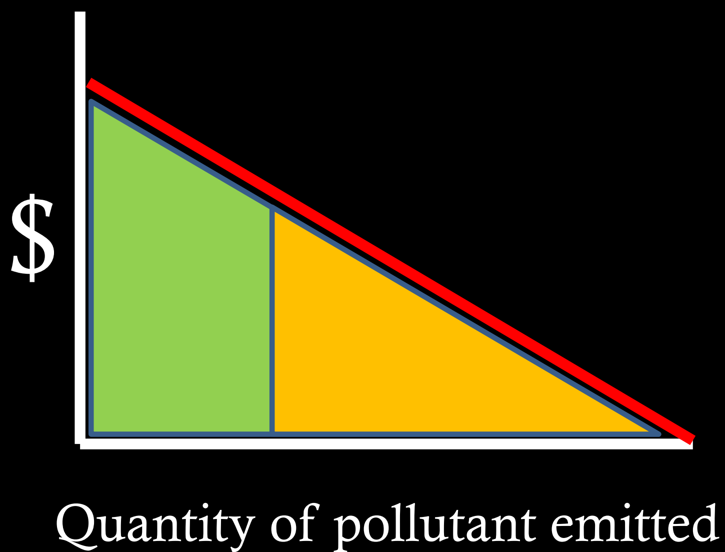
1. Review: MD and MAC curves

Hence a MAC (marginal abatement cost) curve is really a demand curve in disguise, reflecting the firm's demand for pollution services.





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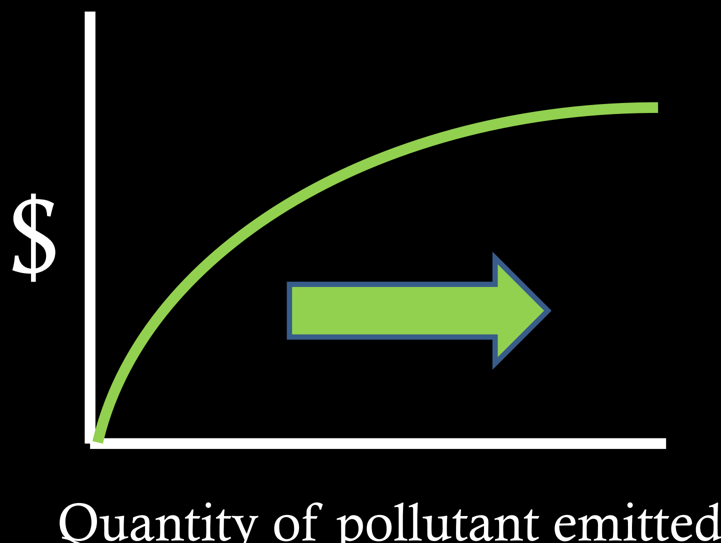
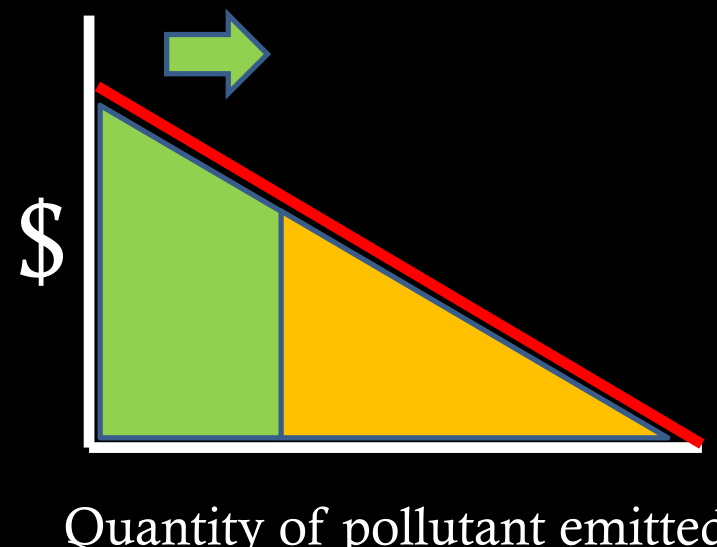
1. Review: MD and MAC curves

Just remember! Unlike standard demand curves,
MAC curves should be read **from right to left**
(as they describe abatement from the maximum).





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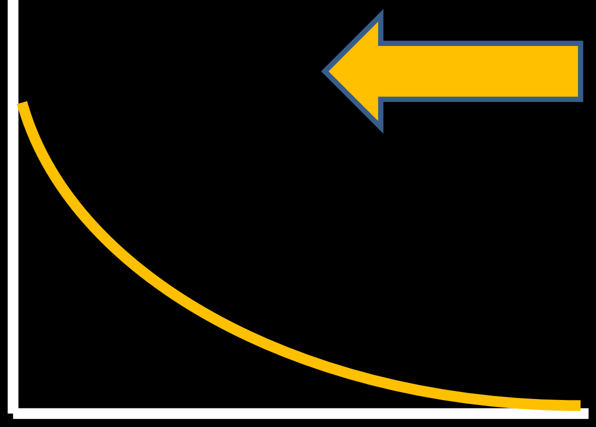

Quantity of pollutant emitted

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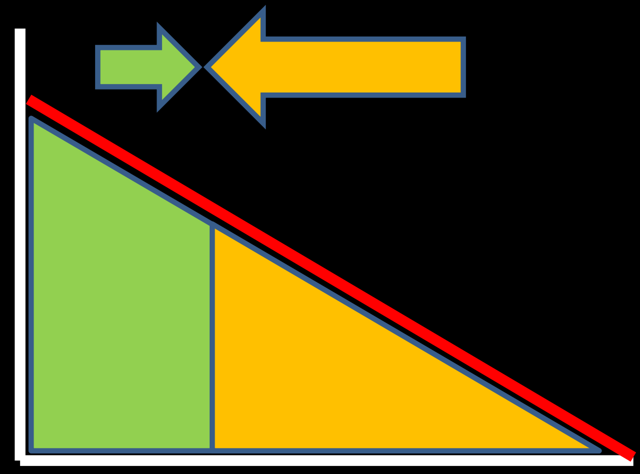

Quantity of pollutant emitted

Demand for pollution services = marginal abatement cost avoided

1. Review: MD and MAC curves

Typical features of MD curves

- At low emissions / ambient levels,
  marginal damages are small.
- There is commonly a threshold
  below which marginal damages are zero.
- MD curves typically have different slopes
  in urban vs. rural areas (which are higher?)
  and in areas with strong vs. weak winds
  (again, which would you guess are higher?)

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Marginal abatement costs typically increase faster and faster as emissions are reduced (i.e., from right to left).

Why is this the case?

Different MAC curves can reflect

- different firms' technological starting points
- different stages in a single firm's technological development

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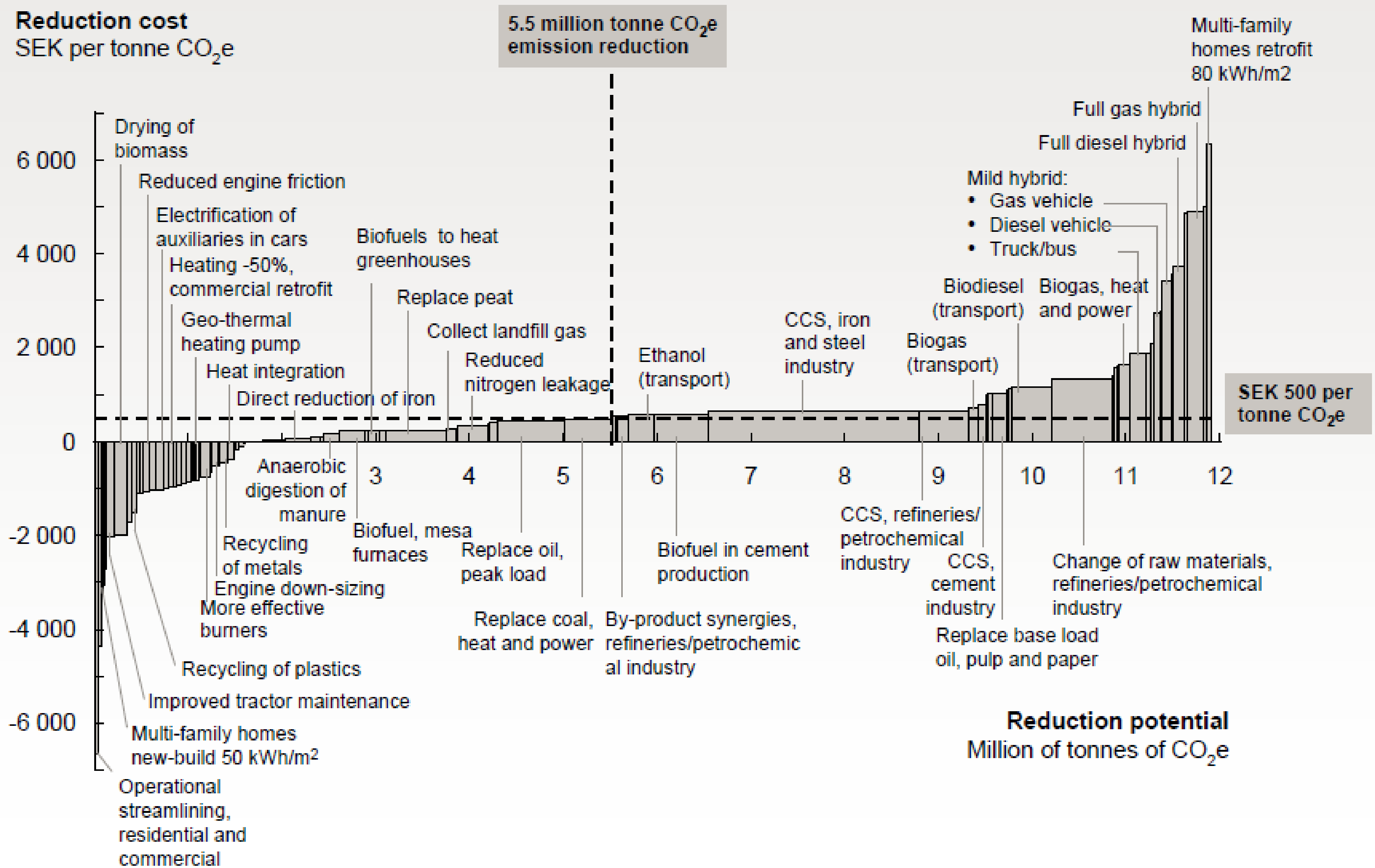
Measures in Sweden beyond the Reference scenario 2020



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1. Review: MD and MAC curves
2. The efficient level of emissions
3. Costs of enforcement
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2. The efficient level of emissions

Definition

"The efficient level of emissions is defined as that level at which marginal damages are equal to marginal abatement costs" (Field, p. 101).

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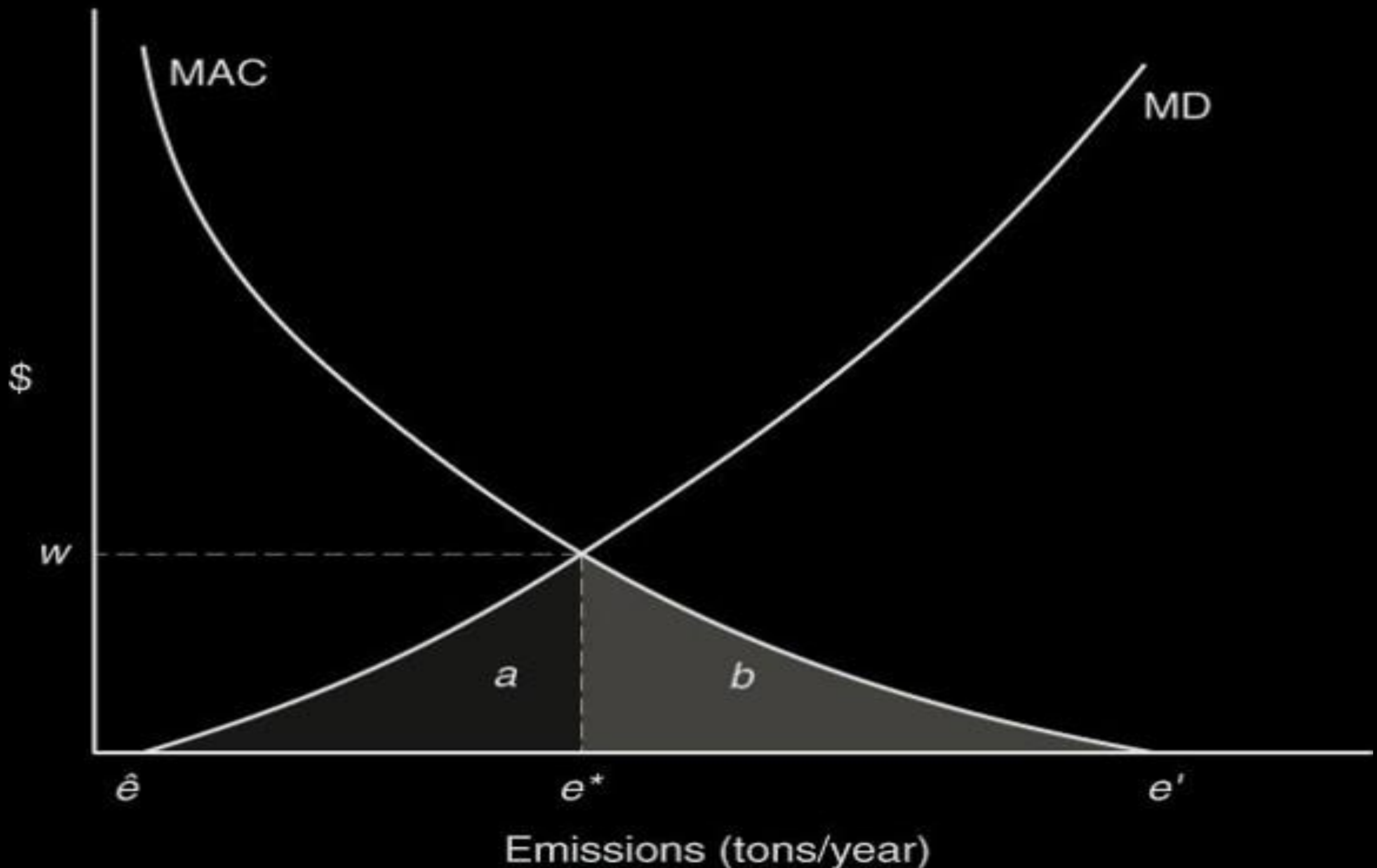
Why is this fair?

FIGURE 5.6 The Efficient Level of Emissions



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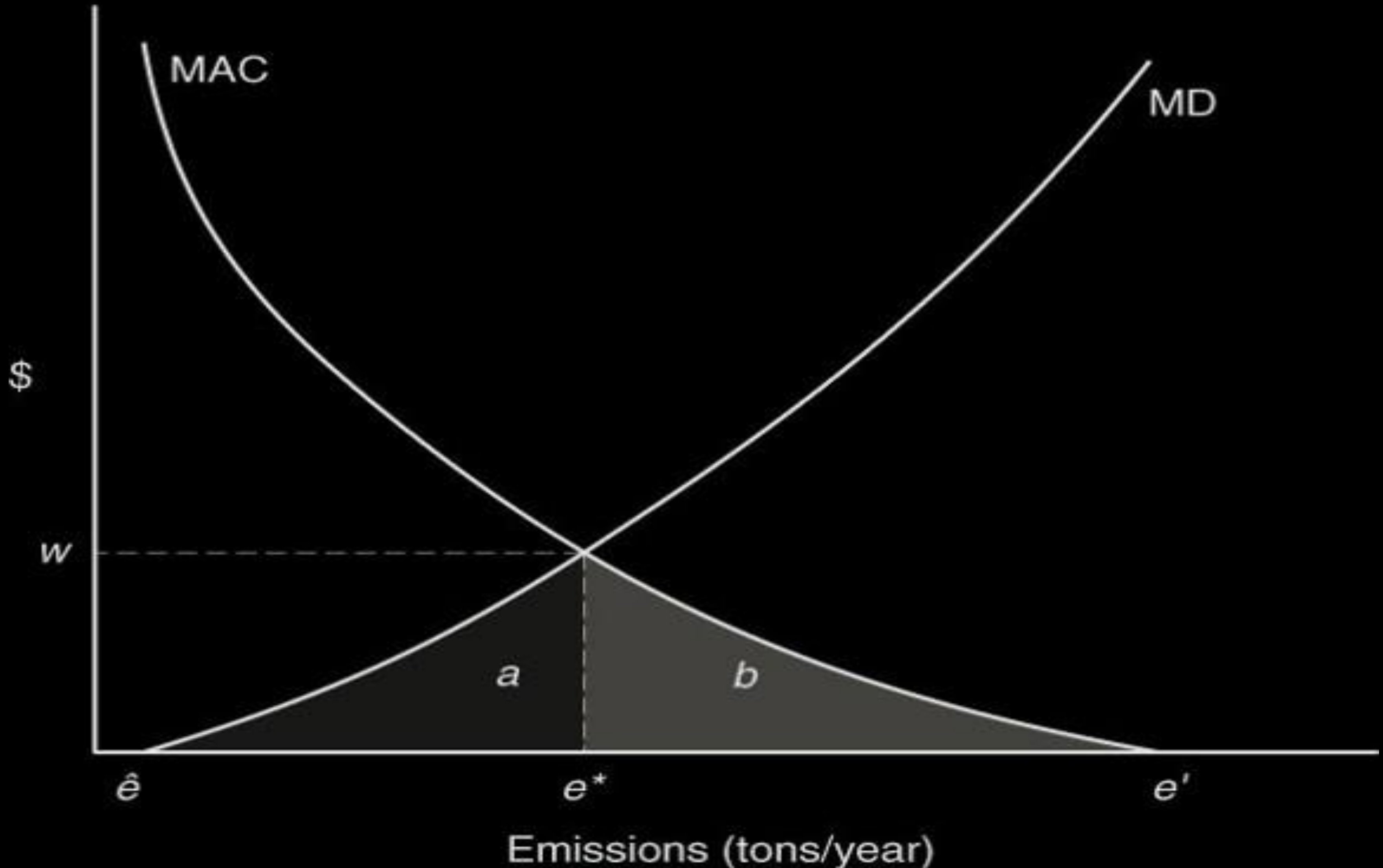

Why is this fair? Because it permits the best trade-off between pollution damages (*a*) and abatement costs (*b*).

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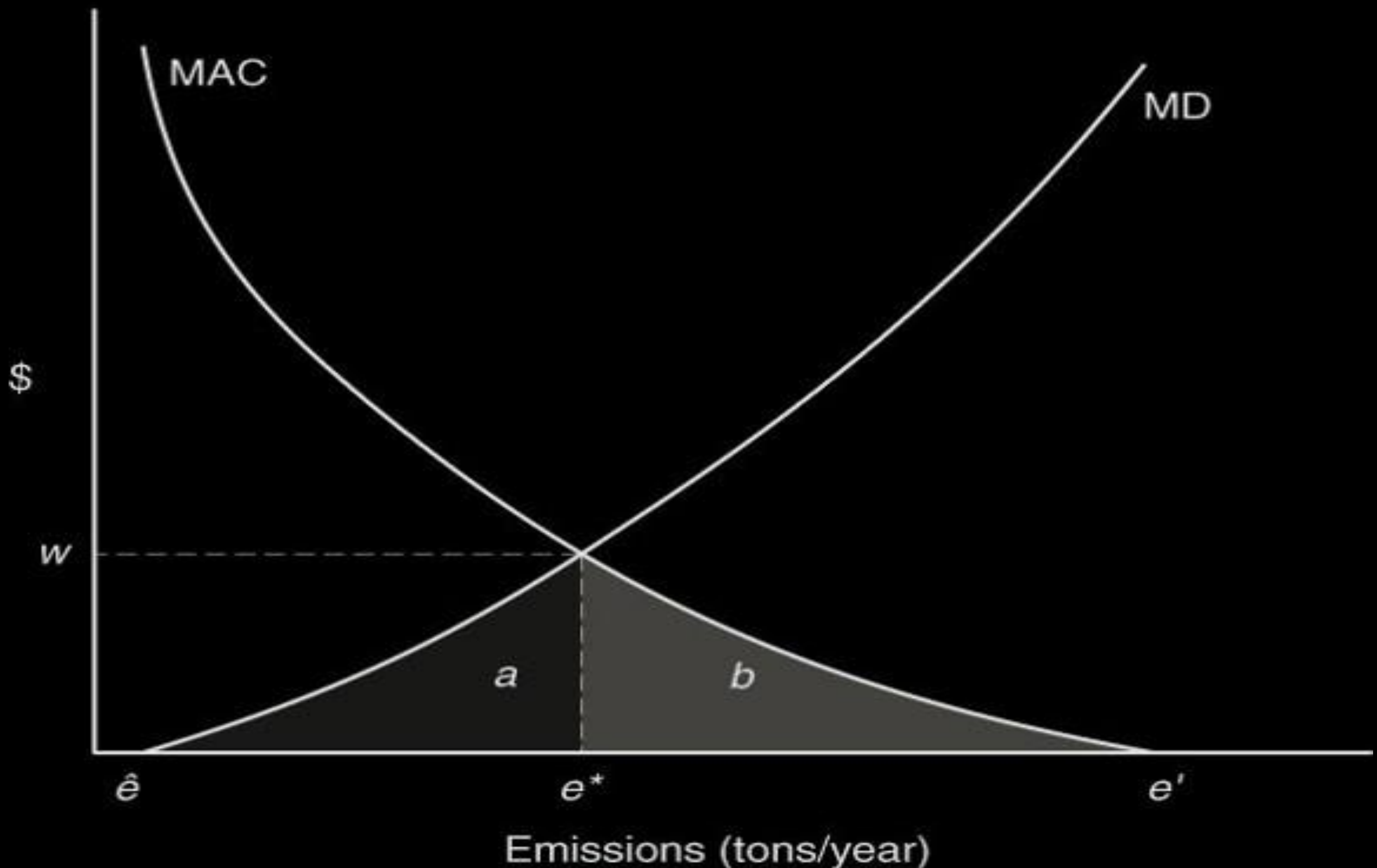
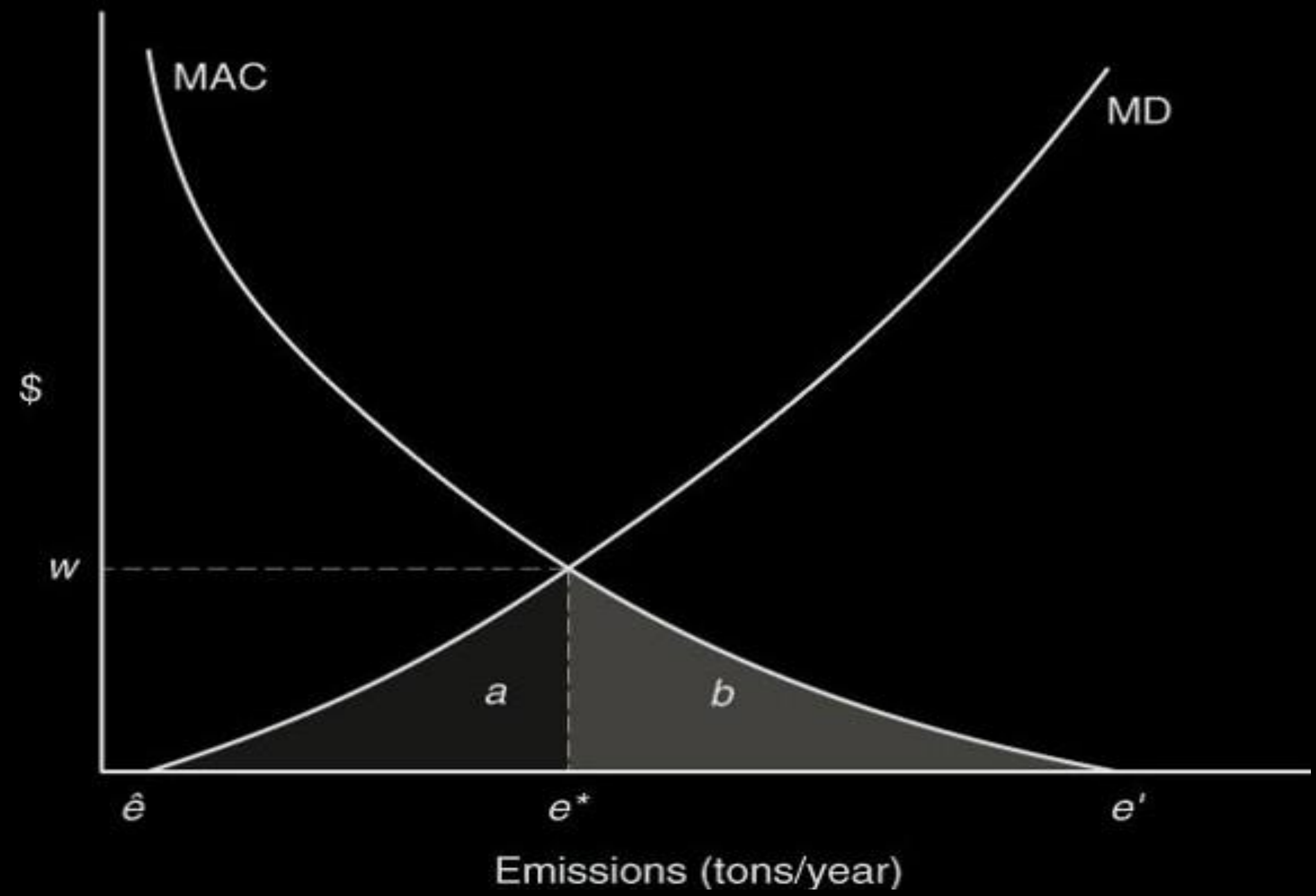


Challenge: **prove** that $a + b$ is lowest at emissions level e^*!

2. The efficient level of emissions

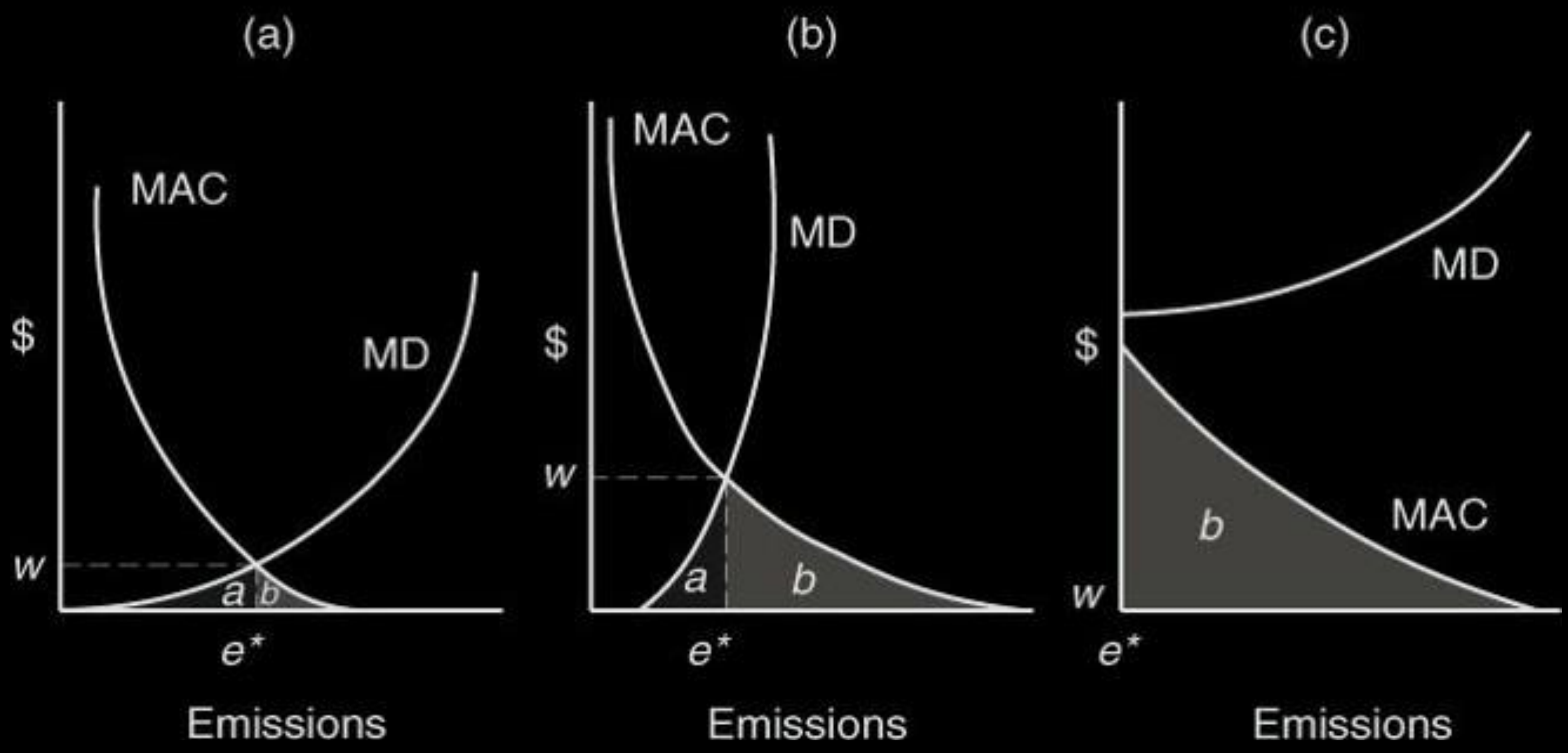
Does accepting *e** mean putting up with lots of pollution?



2. The efficient level of emissions

Does accepting e^* mean putting up with lots of pollution?

<u>**Not necessarily. Consider:**</u>



2. The efficient level of emissions

Remember that *e^** rarely stays the same for long…

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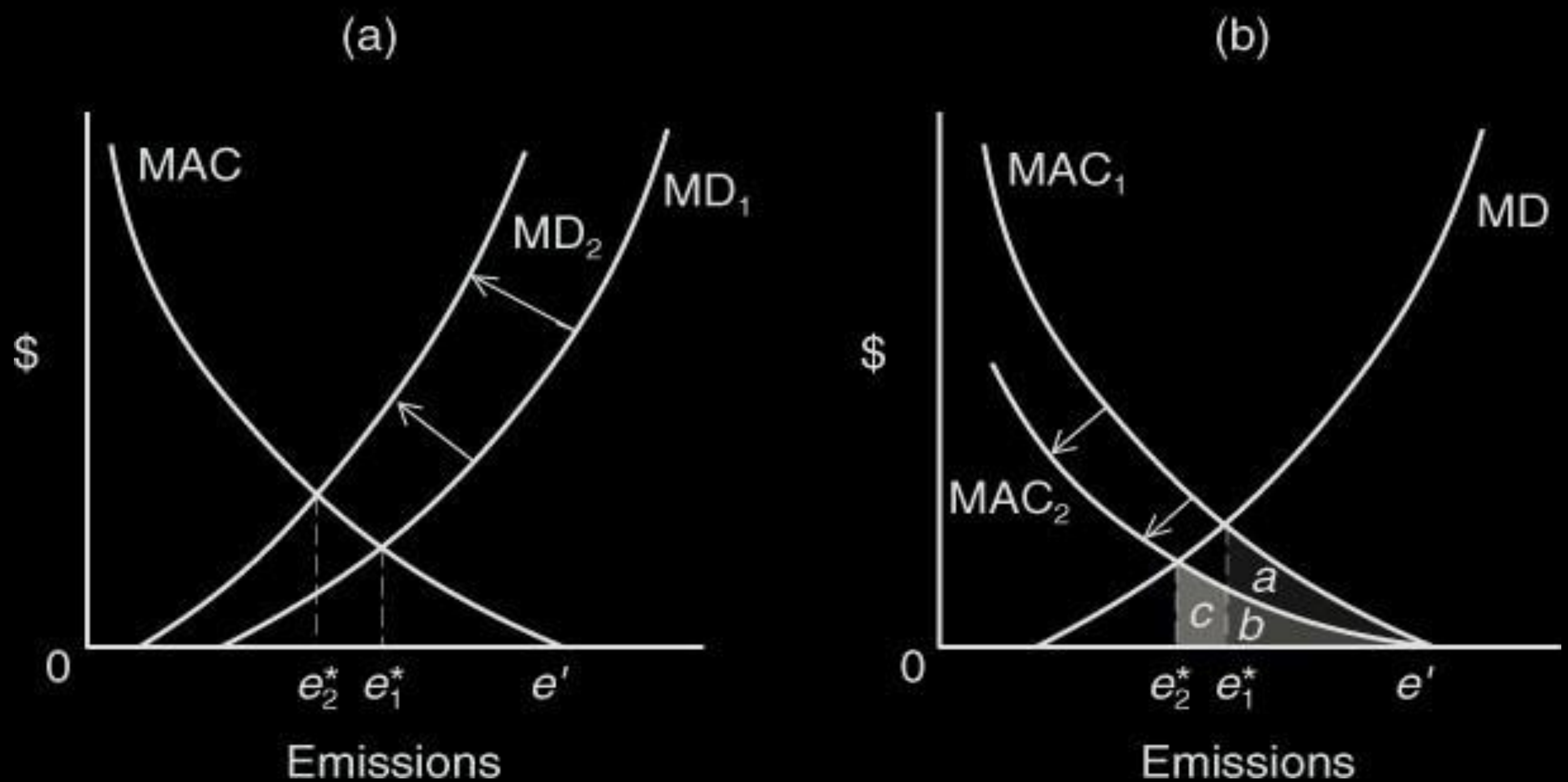
FIGURE 5.8 Changes in e*, the Efficient Level of Emissions



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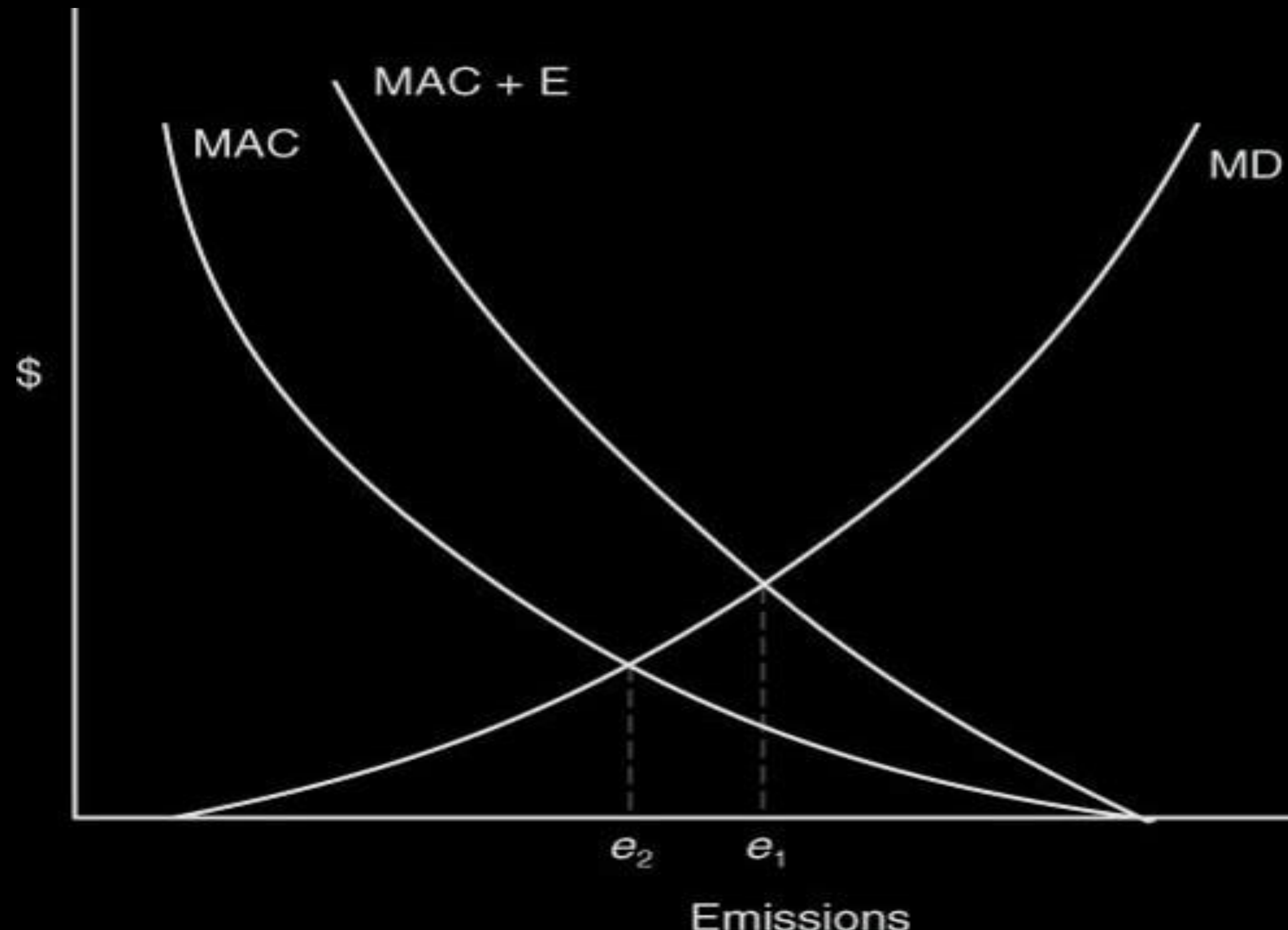
The result looks like this:

3. Costs of enforcement



3. Costs of enforcement

Upshot for policy:

"This shows the vital importance
of having good enforcement technology,
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decreasing the efficient emissions level."

(Field, p. 104)

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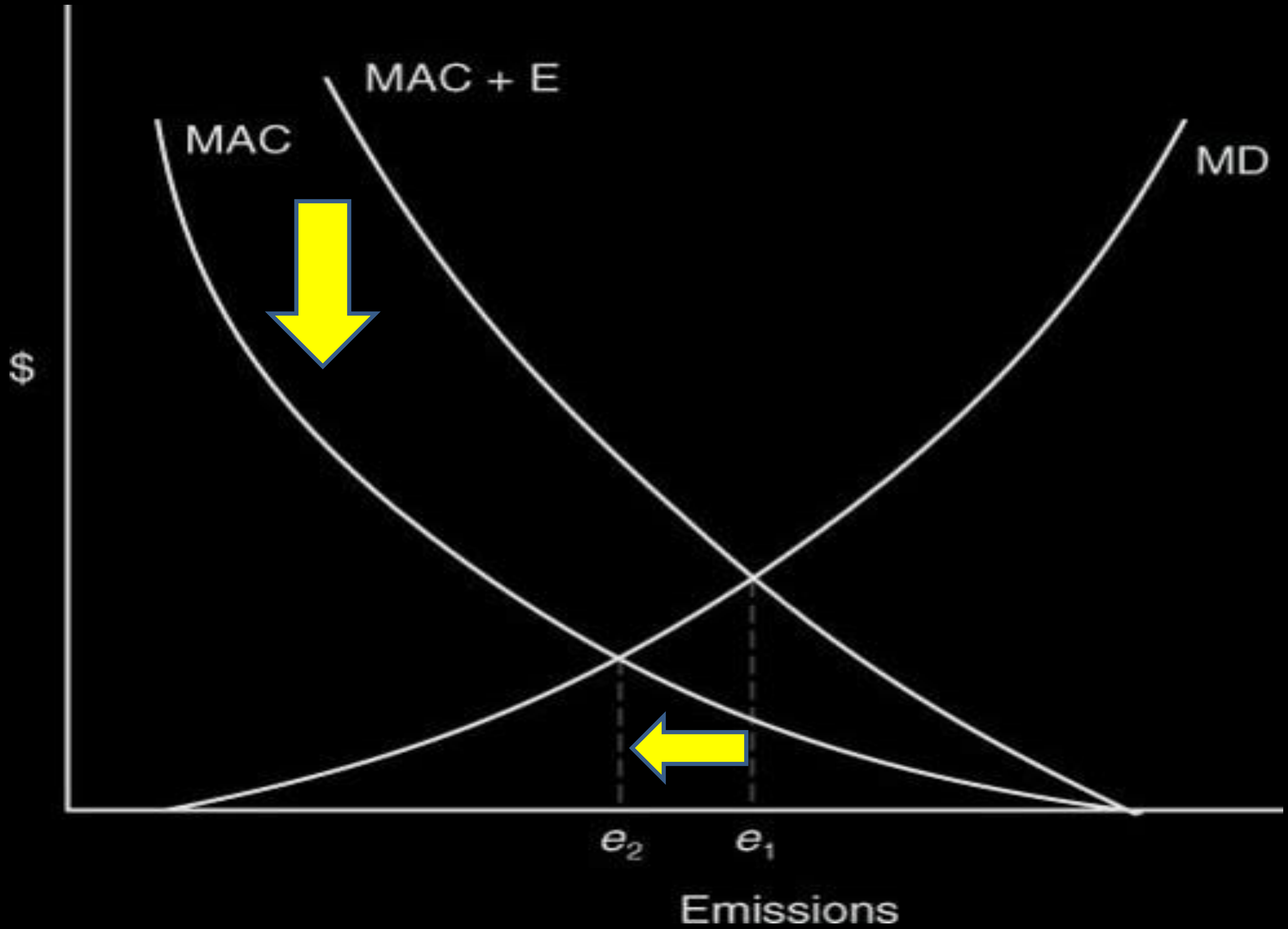

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4. The equimarginal principle

To aggregate multiple MAC curves,
add them **horizontally**:

4. The equimarginal principle

To aggregate multiple MAC curves,
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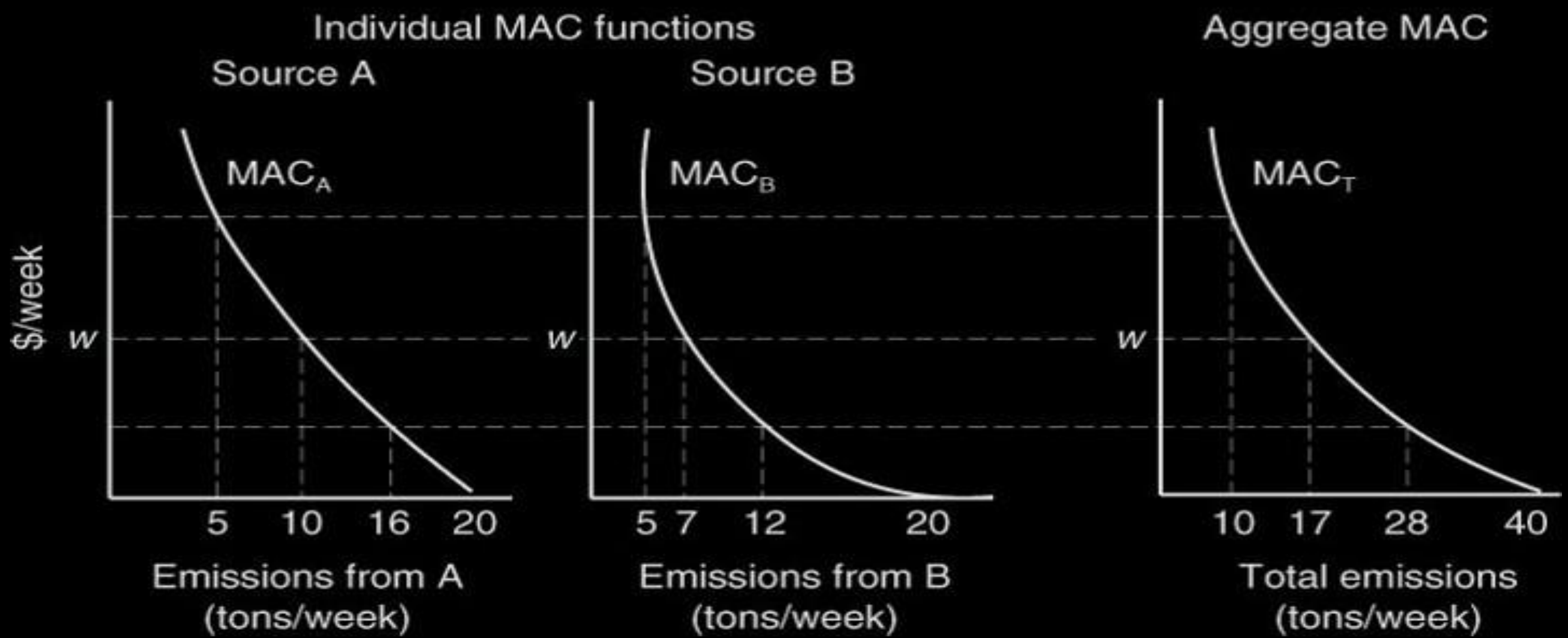
FIGURE 5.5 Aggregate Abatement Costs

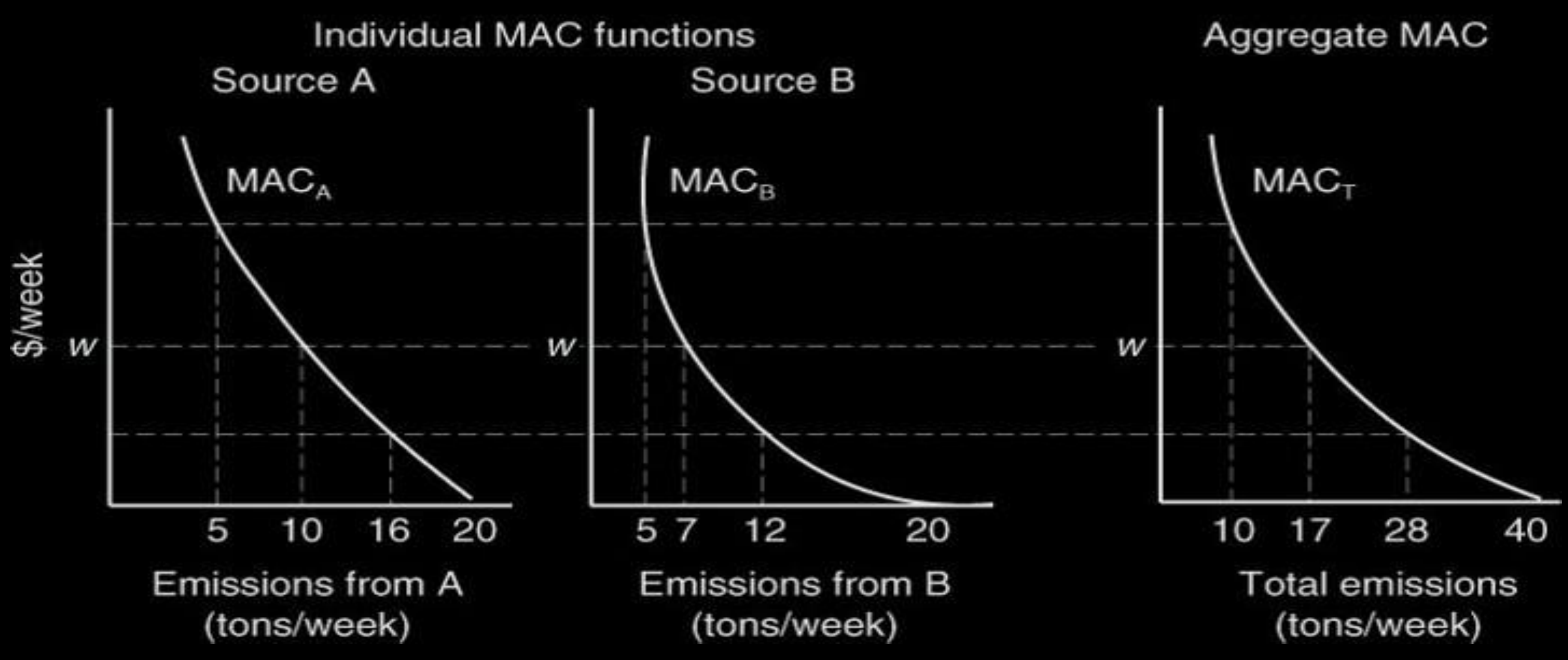


4. The equimarginal principle

To aggregate multiple MAC curves,

add them **horizontally**: Why not vertically?

FIGURE 5.5 Aggregate Abatement Costs



4. The equimarginal principle

The secret to why we aggregate MAC curves
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is the equimarginal principle:

"To get the **minimum** aggregate MAC curve,
the aggregate level of emissions must be distributed
among the different sources in such a way
that they all have the same marginal abatement costs."

(Field, p. 100)

4. The equimarginal principle

The example in Field, p. 106:

	Marginal Abatement Costs ($1,000/week)	
Emissions (tons/week)	Source A	Source B
12	0	0
11	1	2
10	2	4
9	3	6
8	4	10
7	5	14
6	6	20
5	8	25
4	10	31
3	14	38
2	24	58
1	38	94
0	70	160

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Total abatement cost:

A	B
$ 1,000	$ 2,000
$ 2,000	$ 4,000
$ 3,000	$ 6,000
$ 4,000	$ 10,000
$ 5,000	**$ 22,000**
$ 6,000	
$ 8,000	
$ 10,000	
$ 39,000	

A + B = $ 61,000

Let's assume that the socially efficient level of emissions is 12 tons/week

4. The equimarginal principle

*Would **equiproportionate abatement** be fairer?*

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If A and B have to abate the same amount:

total abatement cost:

A	B
$ 1,000	$ 2,000
$ 2,000	$ 4,000
$ 3,000	$ 6,000
$ 4,000	$ 10,000
$ 5,000	$ 14,000
$ 6,000	$ 20,000
$ 21,000	**$ 56,000**

A + B = $ 77,000

Let’s assume that the socially efficient level of emissions is 12 tons/week

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But from society's point of view, the best aggregate MAC curve is the lowest (cheapest) one, and that is secured by applying the equimarginal principle:

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"To get the **minimum** aggregate MAC curve,
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Table 1. Current emissions (except projected emissions for Medupi), from Eskom study plan. Values highlighted in blue are taken from the December 2013 Atmospheric Impact Reports, as different values were reported.

Emission source				Emissions, t/a			Currently achievable emission limits, mg/Nm3 @10%O2		
Power station	Stack	Lat	Lon	NOx	SO2	PM10	NOx	SO2	PM10
Arnot	Stack 1	-25.94	29.79	25692	38637	1495	1200	2500	50
Arnot	Stack 2	-25.94	29.79	25691	38637	1495	1200	2500	50
Camden	Stack 1	-26.62	24.09	10345	21325	1041	1700	4000	75
Camden	Stack 2	-26.62	24.09	10345	21325	1041	1700	4000	75
Camden	Stack 3	-26.62	24.09	10345	21325	1041	1700	4000	75
Camden	Stack 4	-26.62	24.09	10345	21325	1041	1700	4000	75
Duvha U1-3	Stack 1	-25.96	29.34	39638	68618	4548	1100	2600	200
Duvha U4-6	Stack 2	-25.96	29.34	39638	68618	4548	1100	2600	350
Grootvlei	Stack 1	-26.77	28.50	12376	23929	4084	1200	3800	350
Grootvlei	Stack 2	-26.77	28.50	12376	23929	4084	1200	3800	340

From Greenpeace's 2014 report on power plants in South Africa

5. Policy implications

Chan et al., "The Impact of Trading on the Costs and Benefits of the Acid Rain Program," p. 23:

"… if marginal damages and marginal abatement costs are positively correlated, market-based instruments may not increase net benefits relative to command-and-control policies. In the present context, marginal damages are primarily a function of population density: power plants in the (more populous) eastern U.S. tend to have **higher marginal damages** than facilities in the west. On the cost side, one of the most cost-effective sulfur abatement strategies is the use of low-sulfur coal. Most low sulfur coal is mined in western states. Hence, **marginal [abatement] costs are higher** in the east because of the high cost of transporting low-sulfur coal. →

5. Policy implications

Chan et al., "The Impact of Trading on the Costs and Benefits of the Acid Rain Program," p. 23:

→ "Putting these patterns together, **marginal damage and marginal costs are both higher in the eastern U.S., and, therefore, positively correlated.** This implies that facilities that are likely to purchase additional allowances (those with higher than average marginal costs) are also likely to have high marginal damages. Thus, emissions migrate to high damage facilities and, on net, damages increase. Had it been the case that damages and costs were negatively correlated at the margin, trading would have reduced damages, reinforcing abatement cost savings reported above."