Energy & Climate Economics

Externalities, pigovian taxes & ETS

Economics of pollution

1. Refresh free market economics basics
2. Introduce carbon emissions as an externality
3. Introduce 2 possible solutions
    1. Carbon Tax
    2. Emission Trading Scheme (ETS)
4. Overview carbon taxation & ETS in the world
5. ETS & substituting high-emission tech for low-emission tech.
6. What is better, carbon tax or ETS?

Economics of pollution

1. Refresh free market economics basics

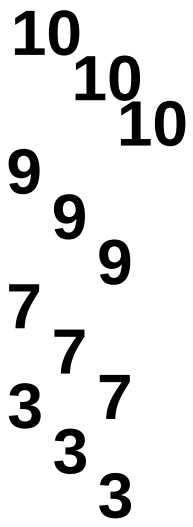
Any idea how many goods will be sold?

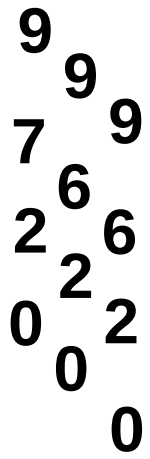
And at what price?

- Consumer:
- Maximum buying price

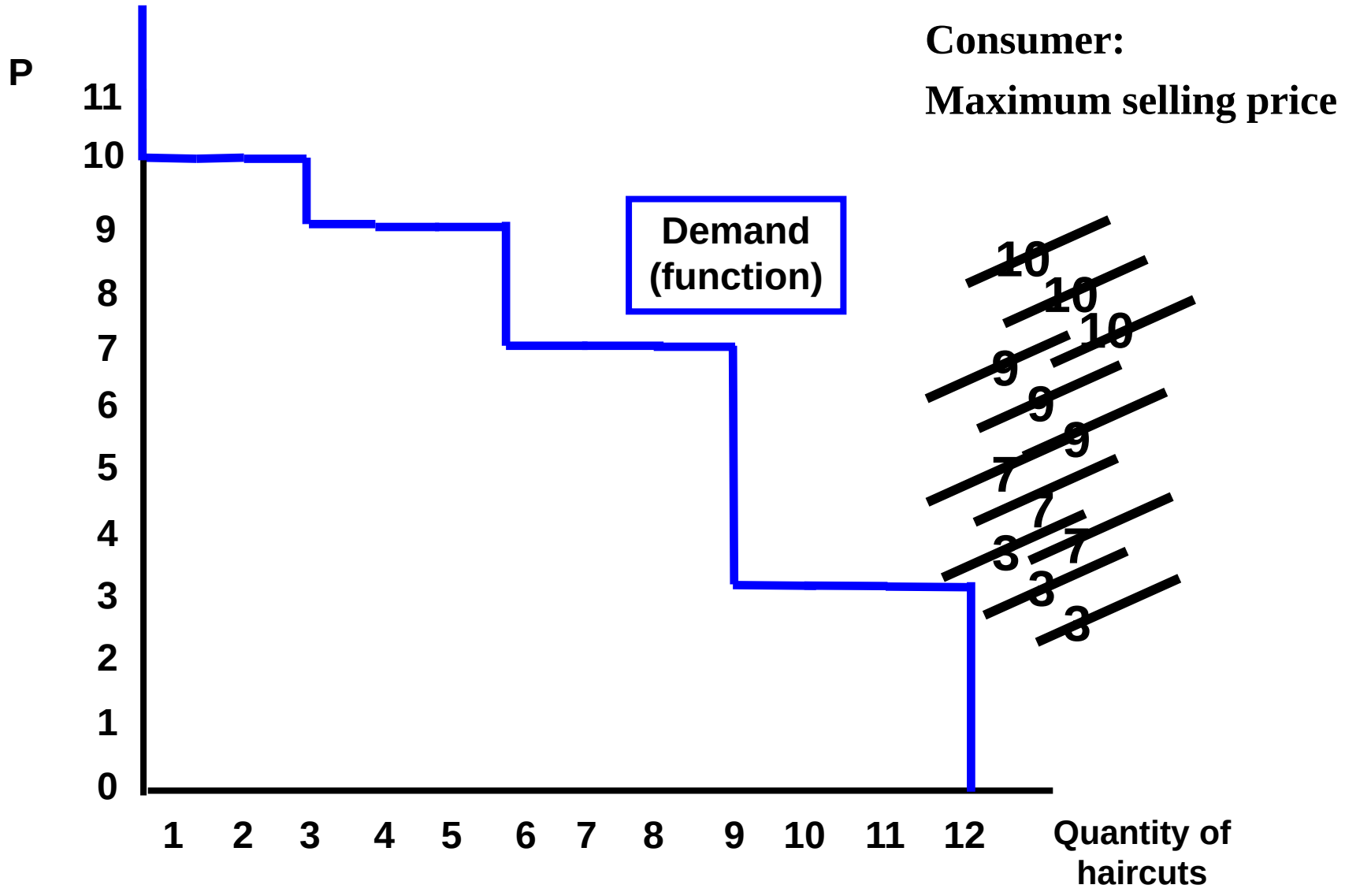
Producer:

Minimal selling price





Deriving a the equilibrium price



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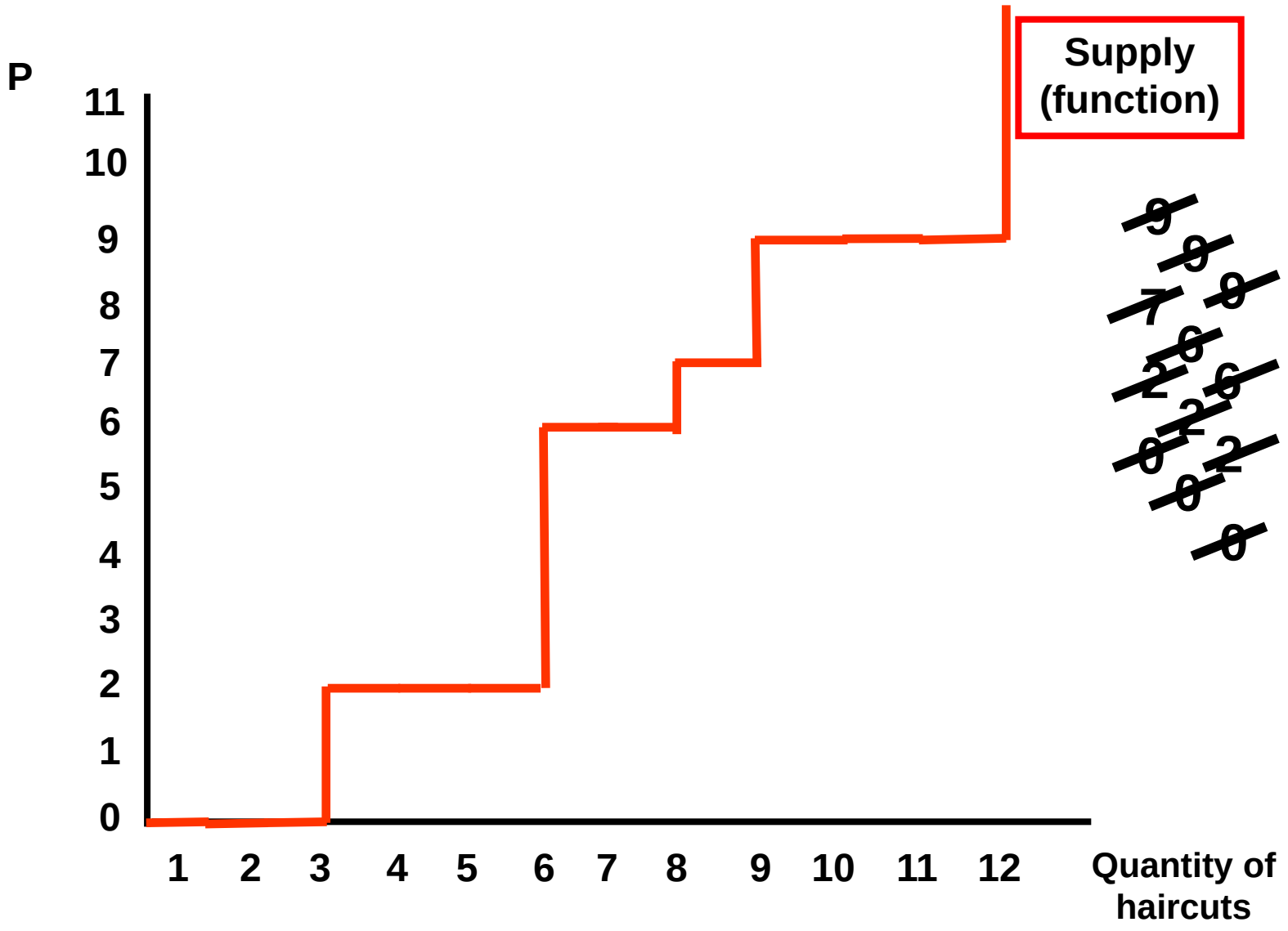
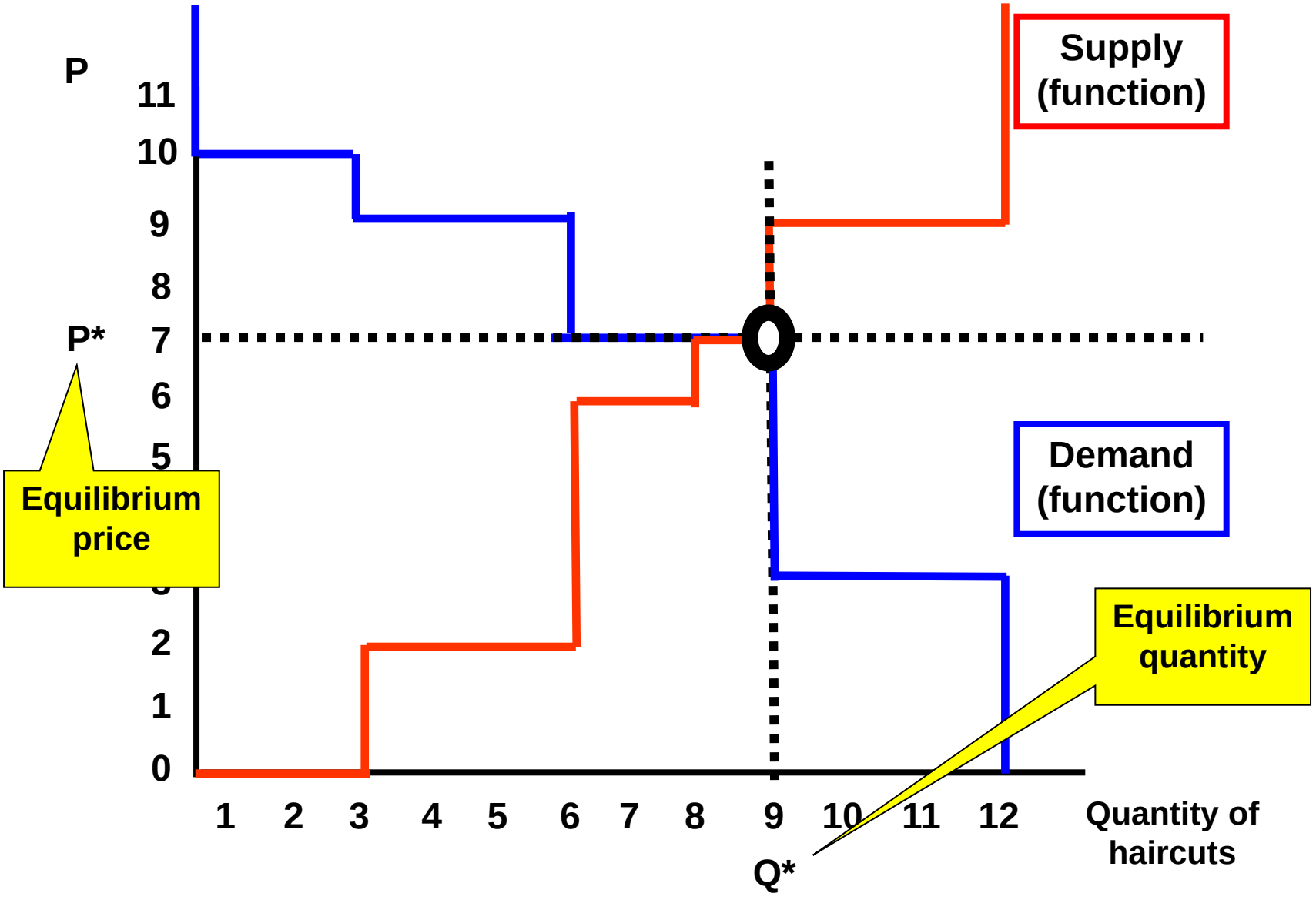
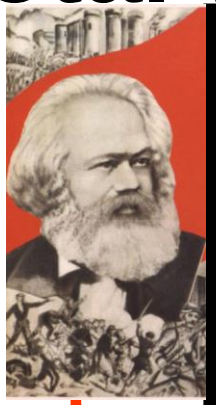


Deriving a the equilibrium price

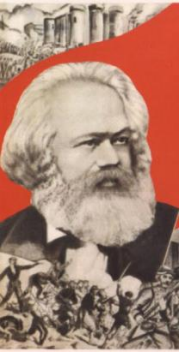


Looking at total welfare



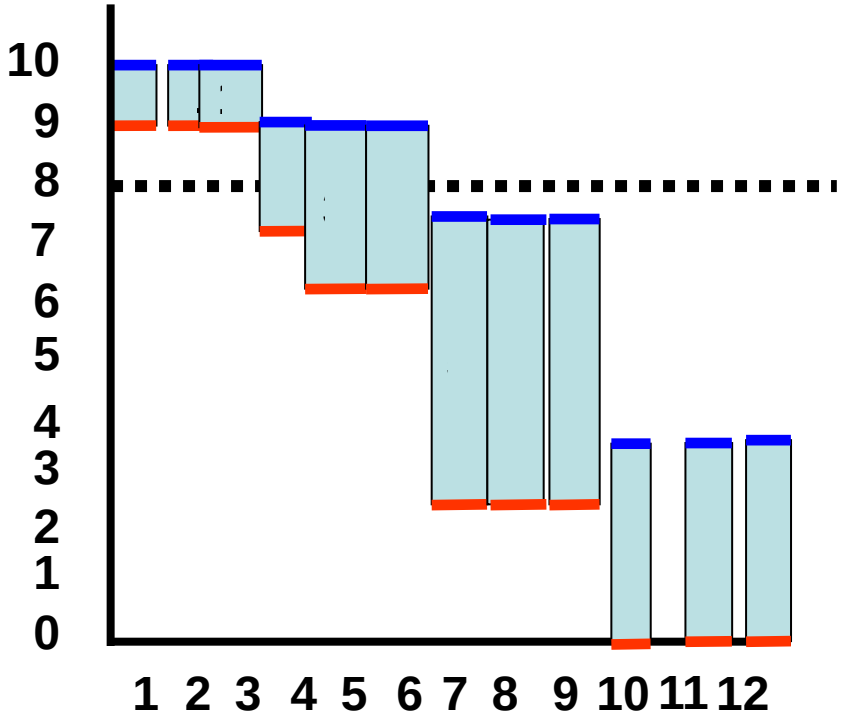
You do matching!

- Always pair the strongest buyer with the strongest seller.
- Until supply and demand intersect
- Isn't that unfair?
- Weakest guys are pushed from the market!

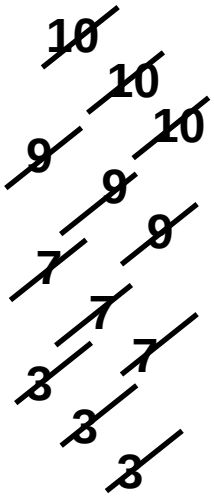


Other possible arrangements: Communist *"fair"* dictator

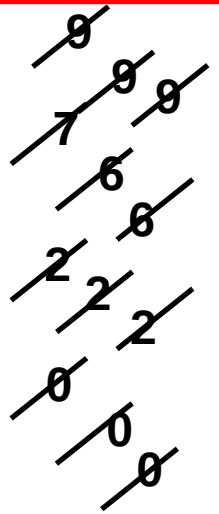
Could this be more efficient?



Consumer



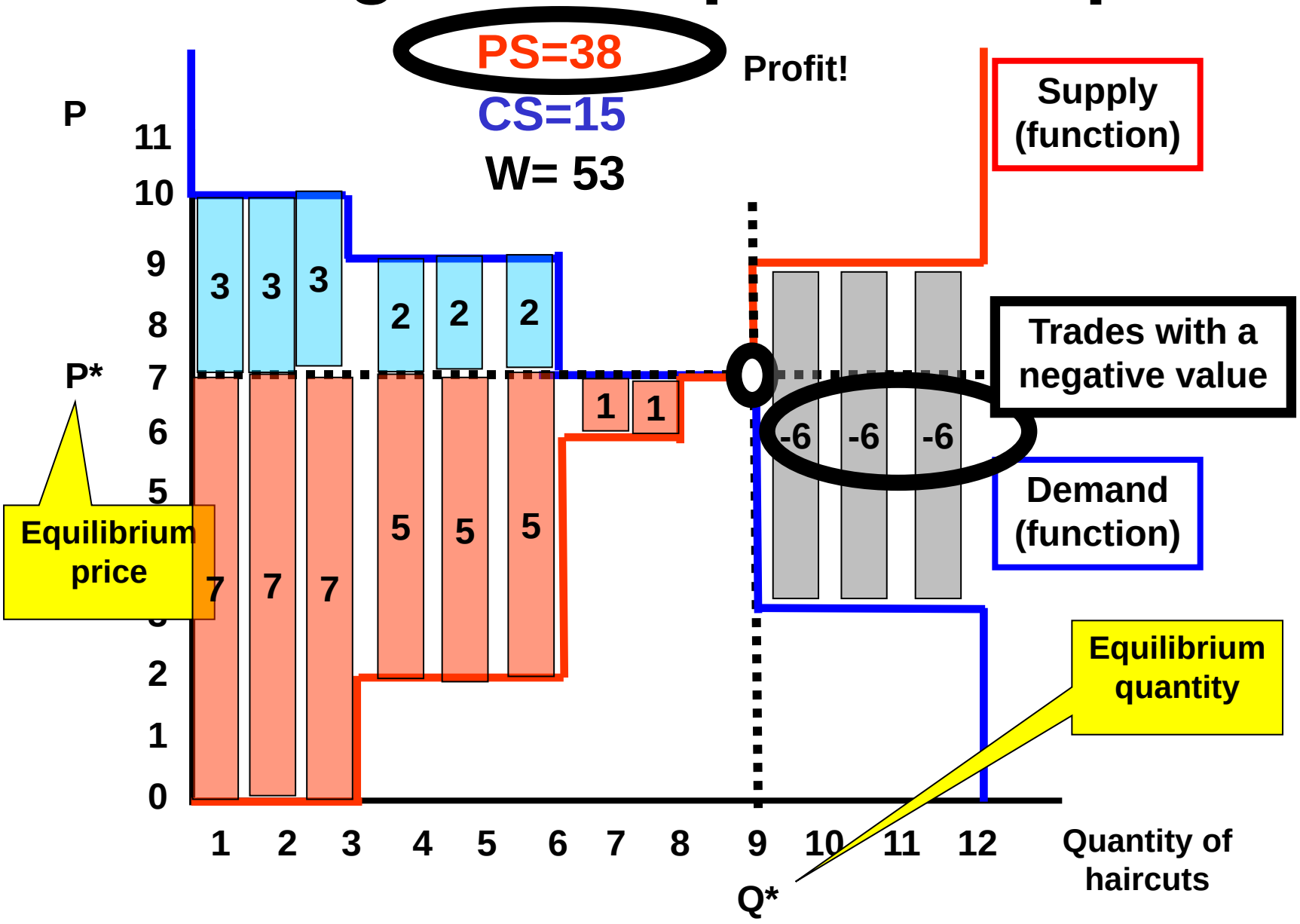
Producer



W= 35
W(Free market)=53
(difference =18)

Free market maximizes W=CS+PS

Deriving a the equilibrium price



- There is an optimum: the max welfare (52)
- There are different mechanisms to try to reach or approach this mechanism

2. Form of central planning
   - Easy to do suboptimal
   - Usually not self-enforcing (incentive-compatible)
1. Free market
   - Maximum welfare
   - Self-enforcing (ic)
   - But, only true when no **externalities**.

- Global warming is an externality problem

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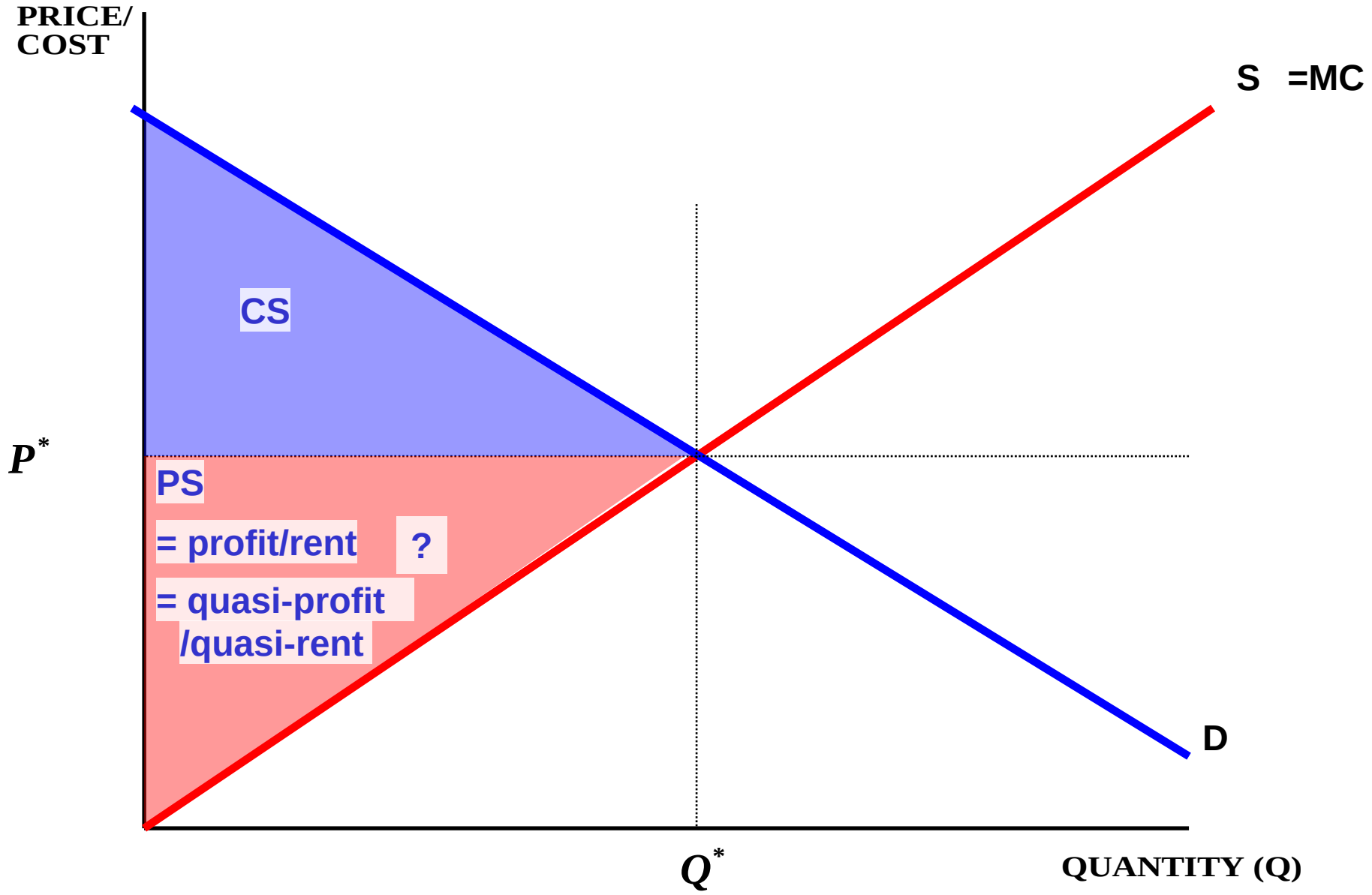
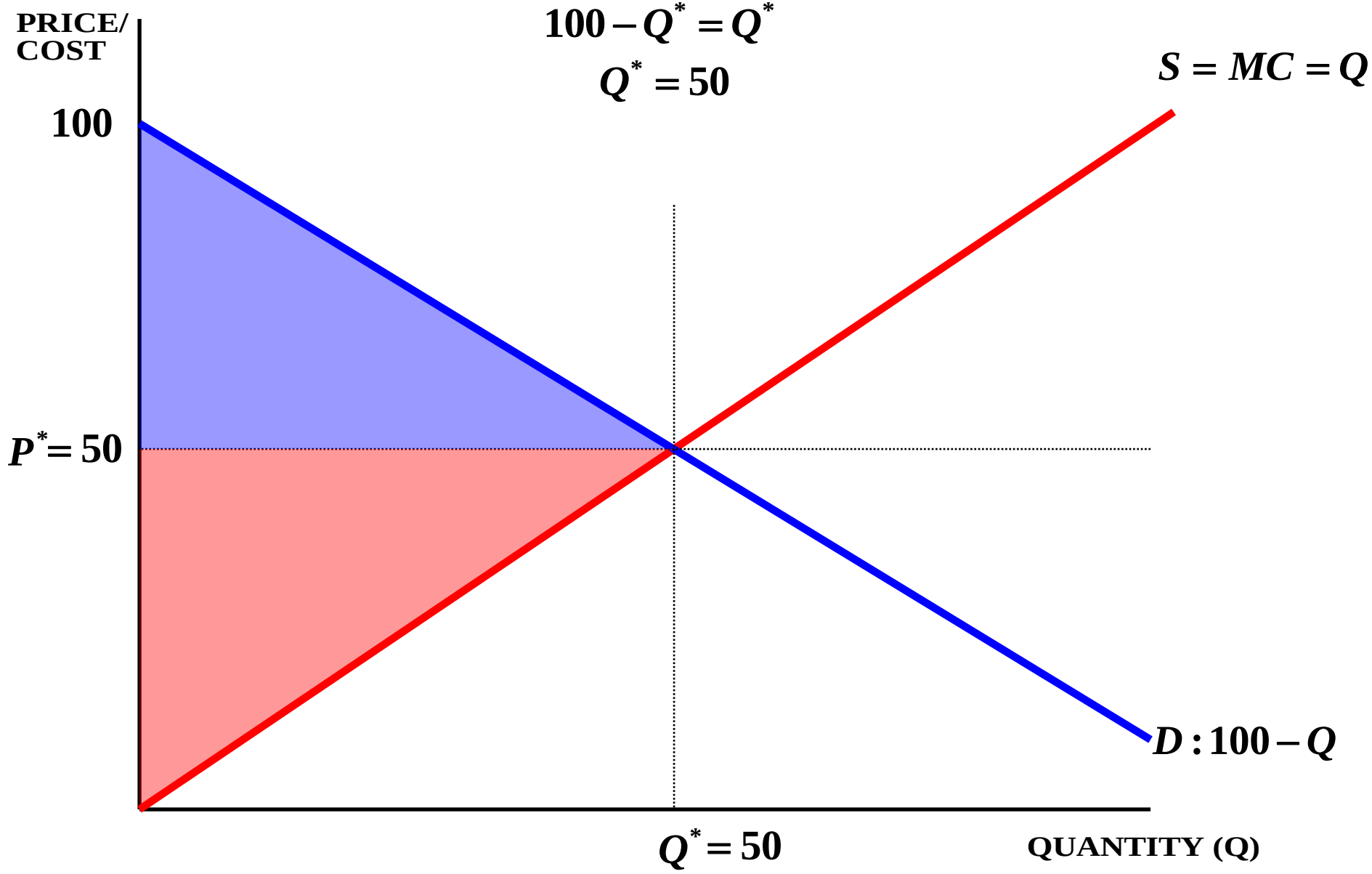

PRICE/
COST
S =MC
CS
P*
PS
= profit/rent
?
= quasi-profit
/quasi-rent
D
Q*
QUANTITY (Q)

What is the numeric prediction?

$$D = S$$

$$100 - Q^* = Q^*$$

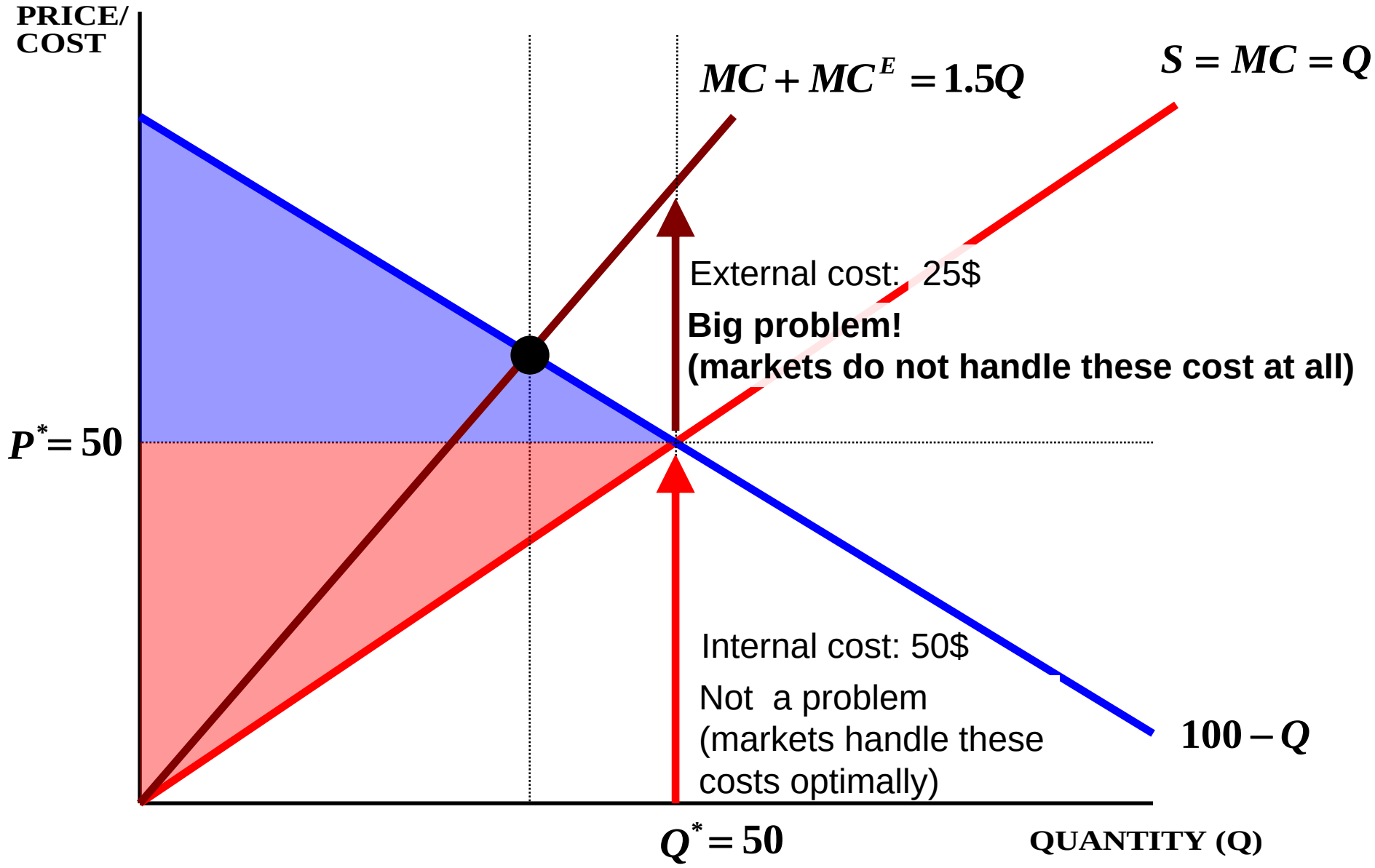
$$Q^* = 50$$



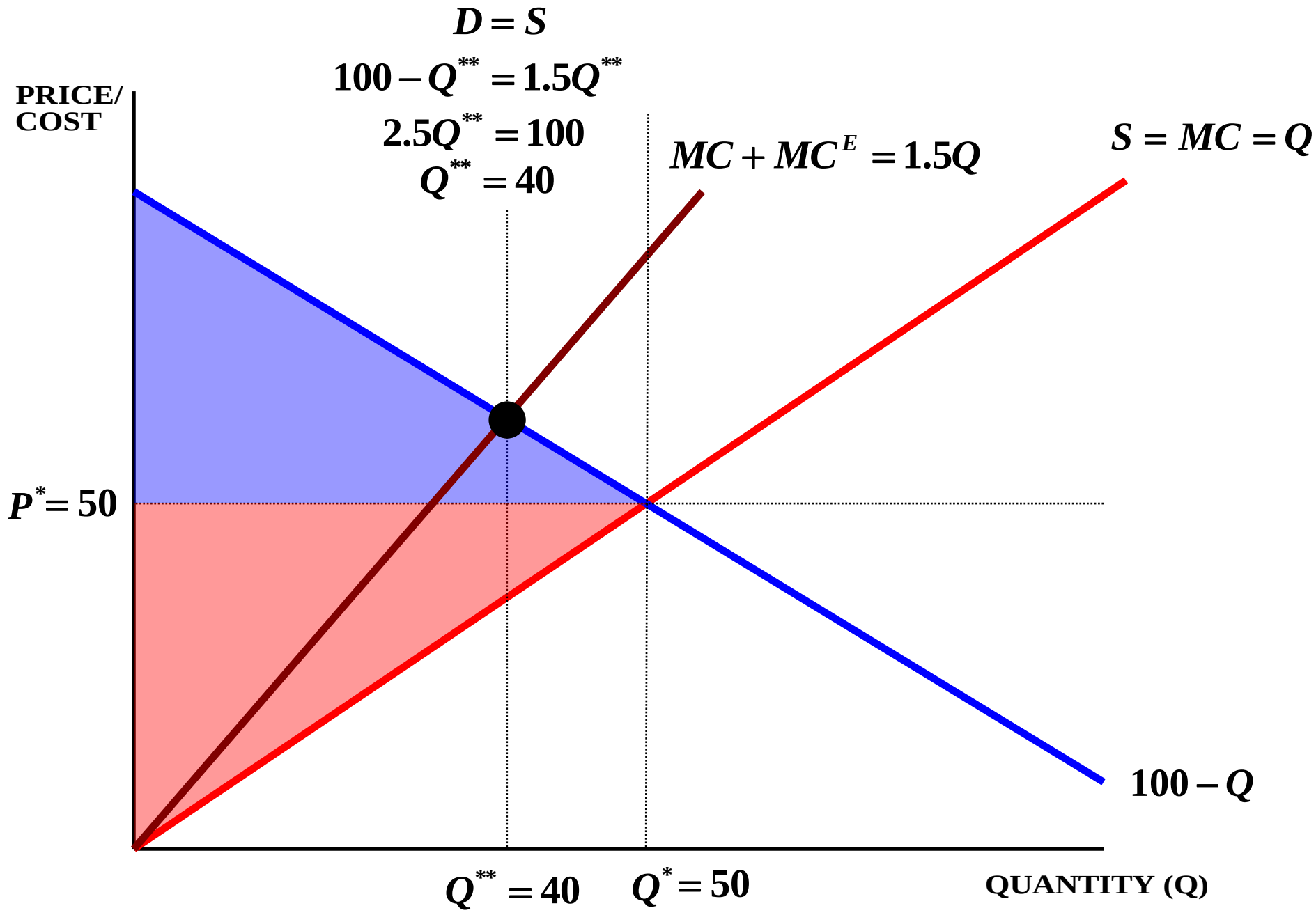
- We must look at the theory of **Externalities**
  - The price of a good does not reflect all of its costs
  - Markets are missing for these inputs

What is the externality?

Is Q* still the optimum? No.

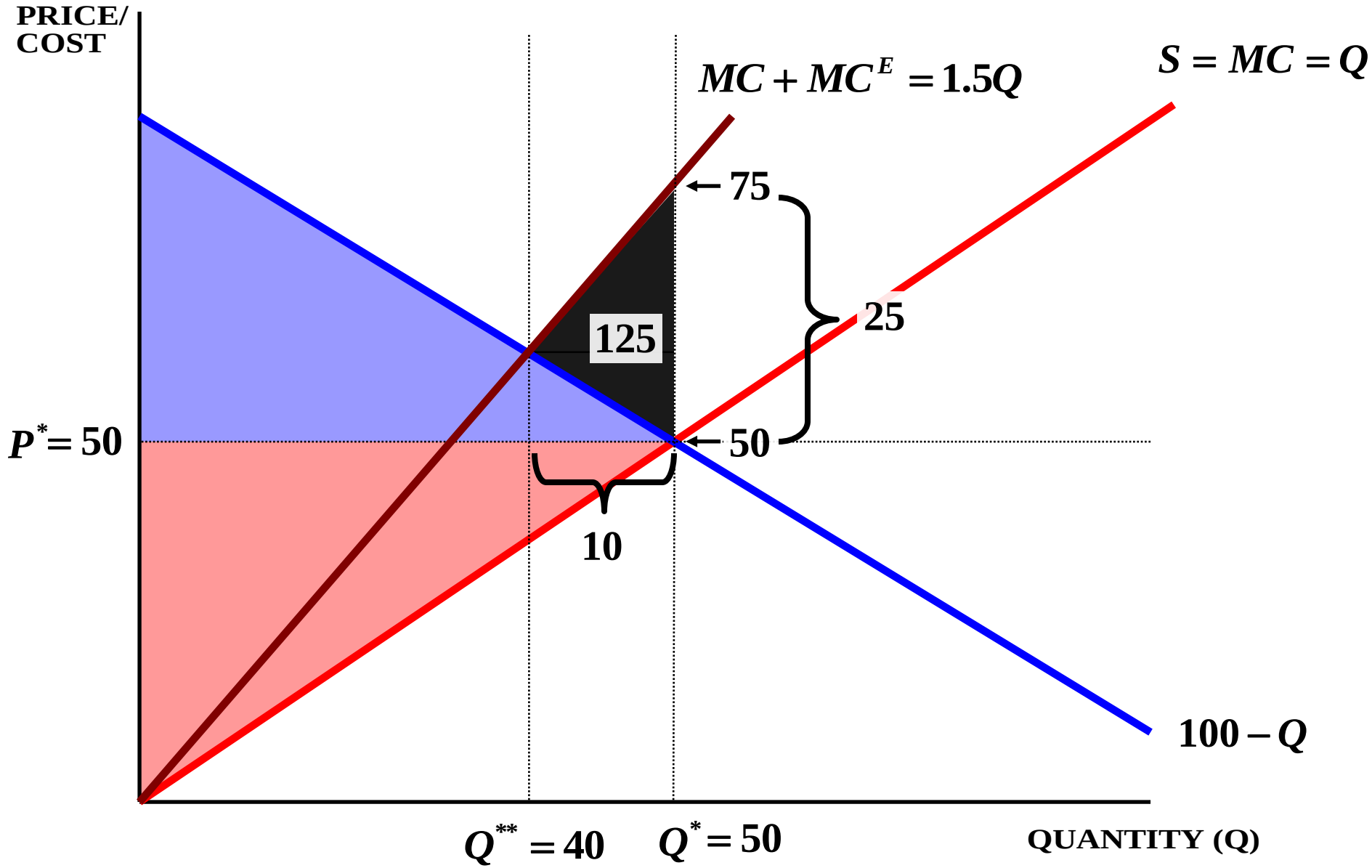


What is now the optimum?



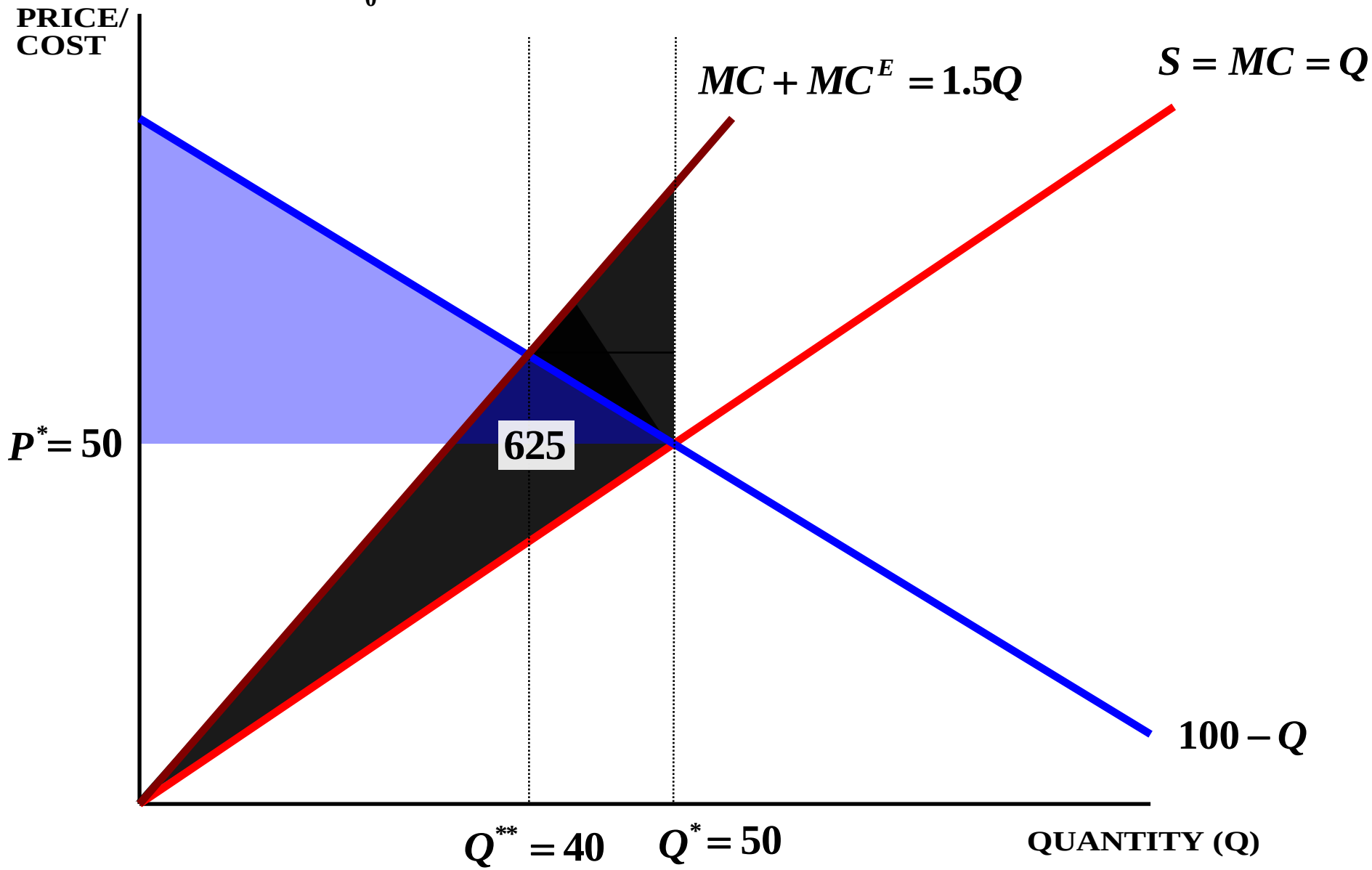
What is the damage to welfare of the externality?

$$\text{damage} = 25 \cdot 10 \cdot \tfrac{1}{2} = 125$$



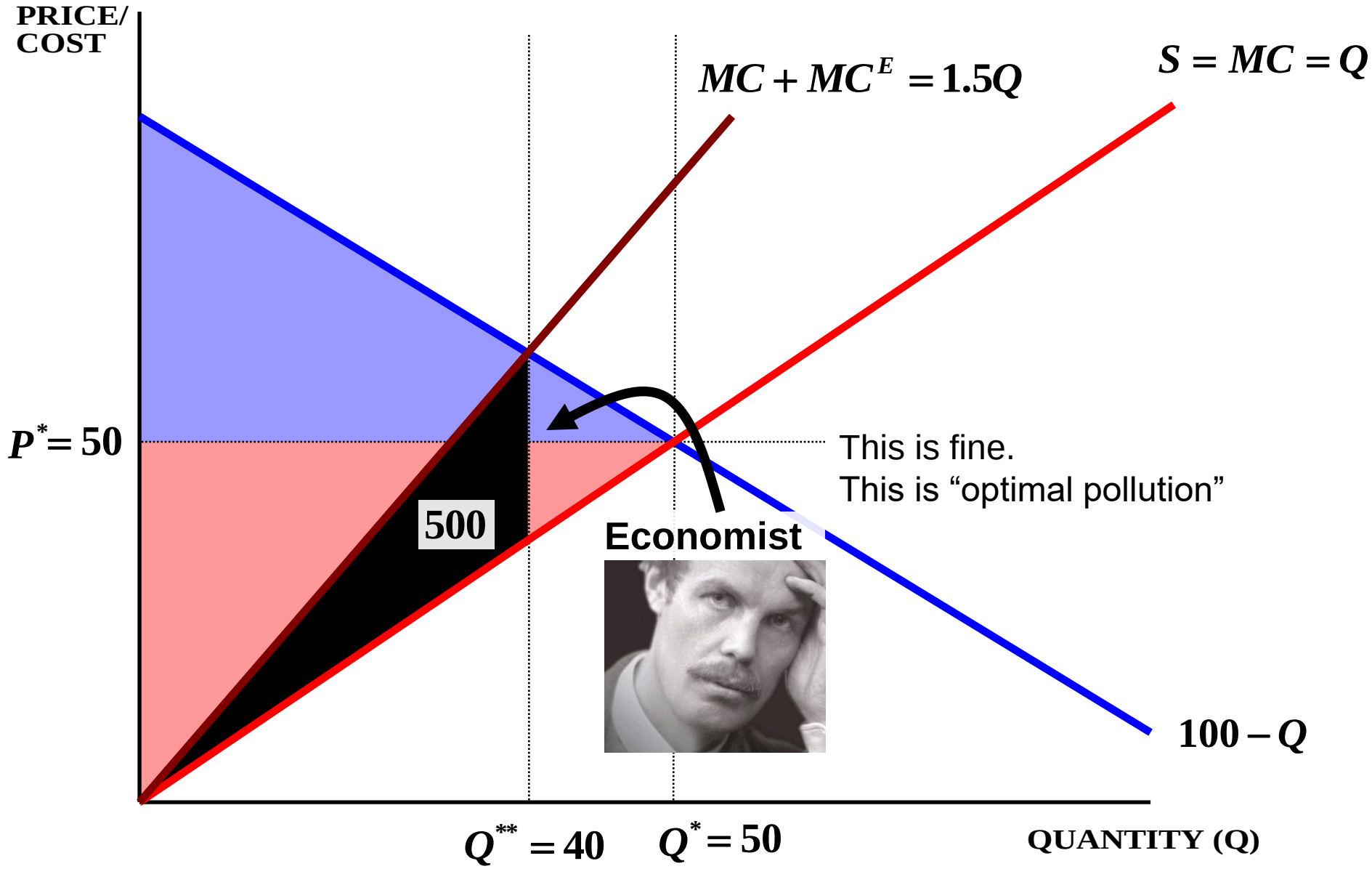
What is the total damage of the externality?

$$\text{damage} = \int_0^{50} (1.5q - q)dq = [.25q^2]_0^{50} = 2500/4 = 625$$



Why do (some) environmentalists hate economics?

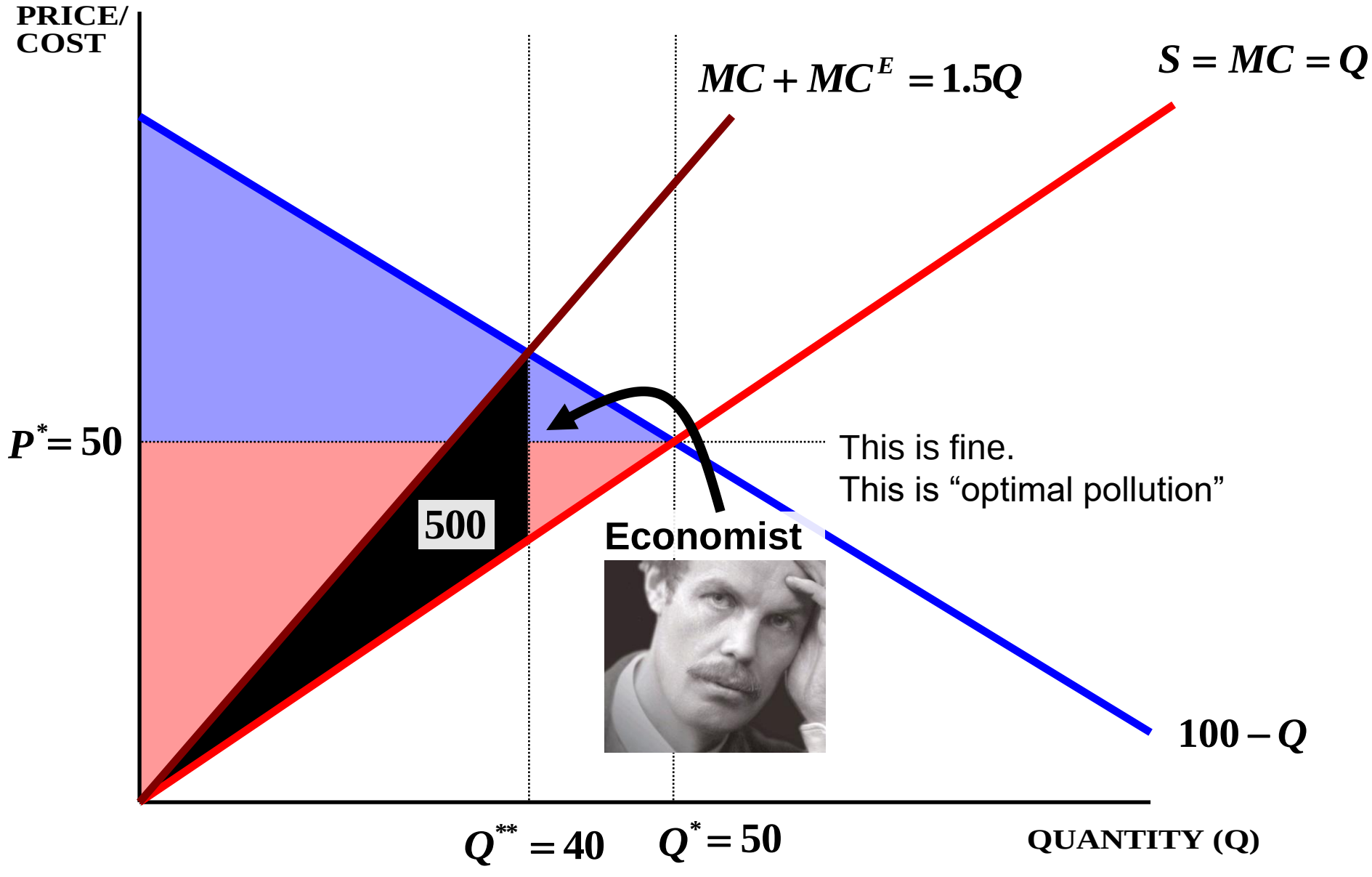
What is the optimal pollution?



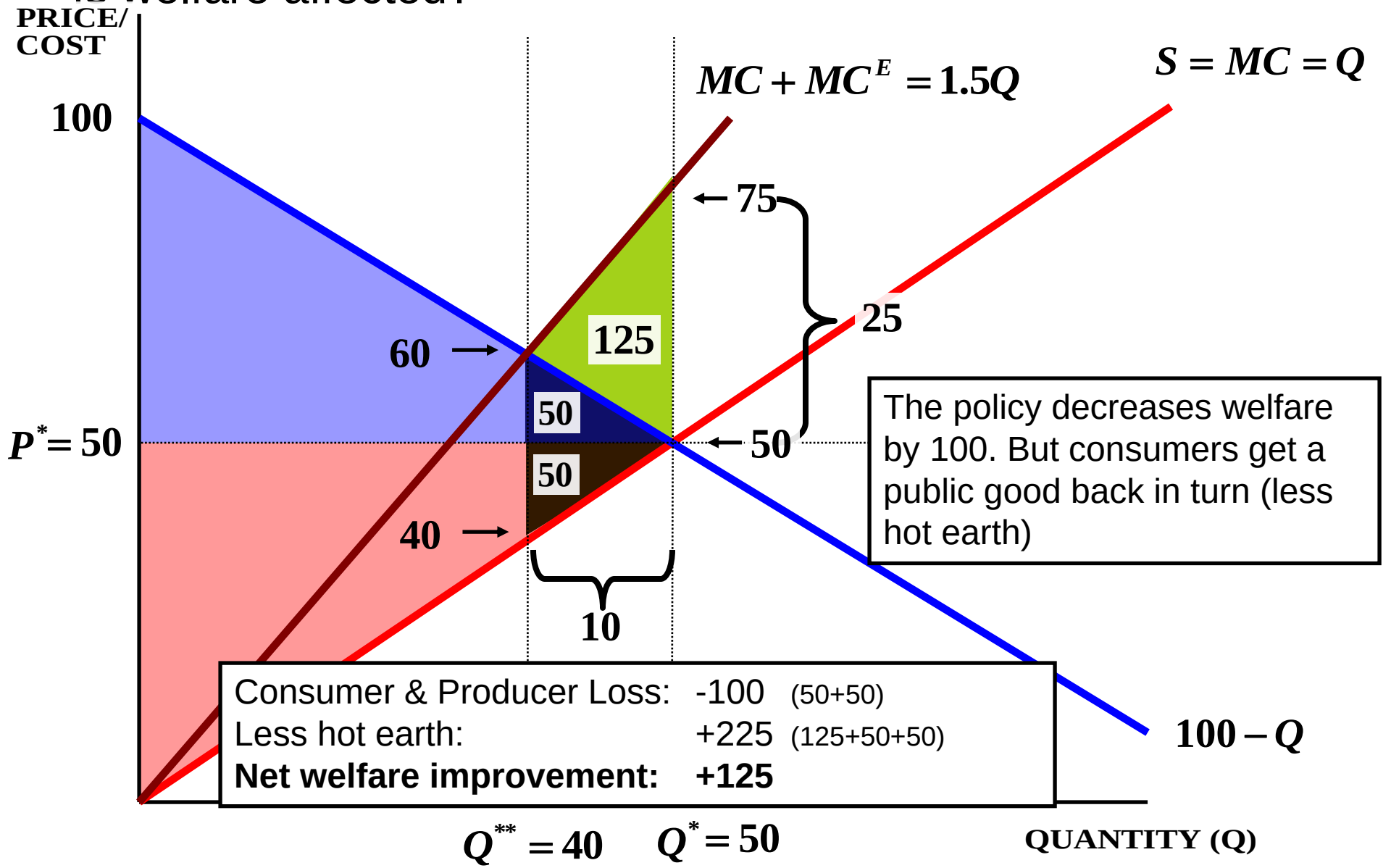
Lettuce contains arsenic (a tiny bit)

Why do (some) environmentalists hate economists?

What is the optimal pollution?



Assume we implemented a policy that moved us to the optimal outcome.
Is welfare affected?



- We must look at the theory of **Externalities**
  - The price of a good does not reflect all of its costs
  - Markets are missing for these inputs

- What to do?
- Need regulation
- First-best regulation:
  1. Tax (Pigovian tax)
  2. Cap-and-trade (ETS)

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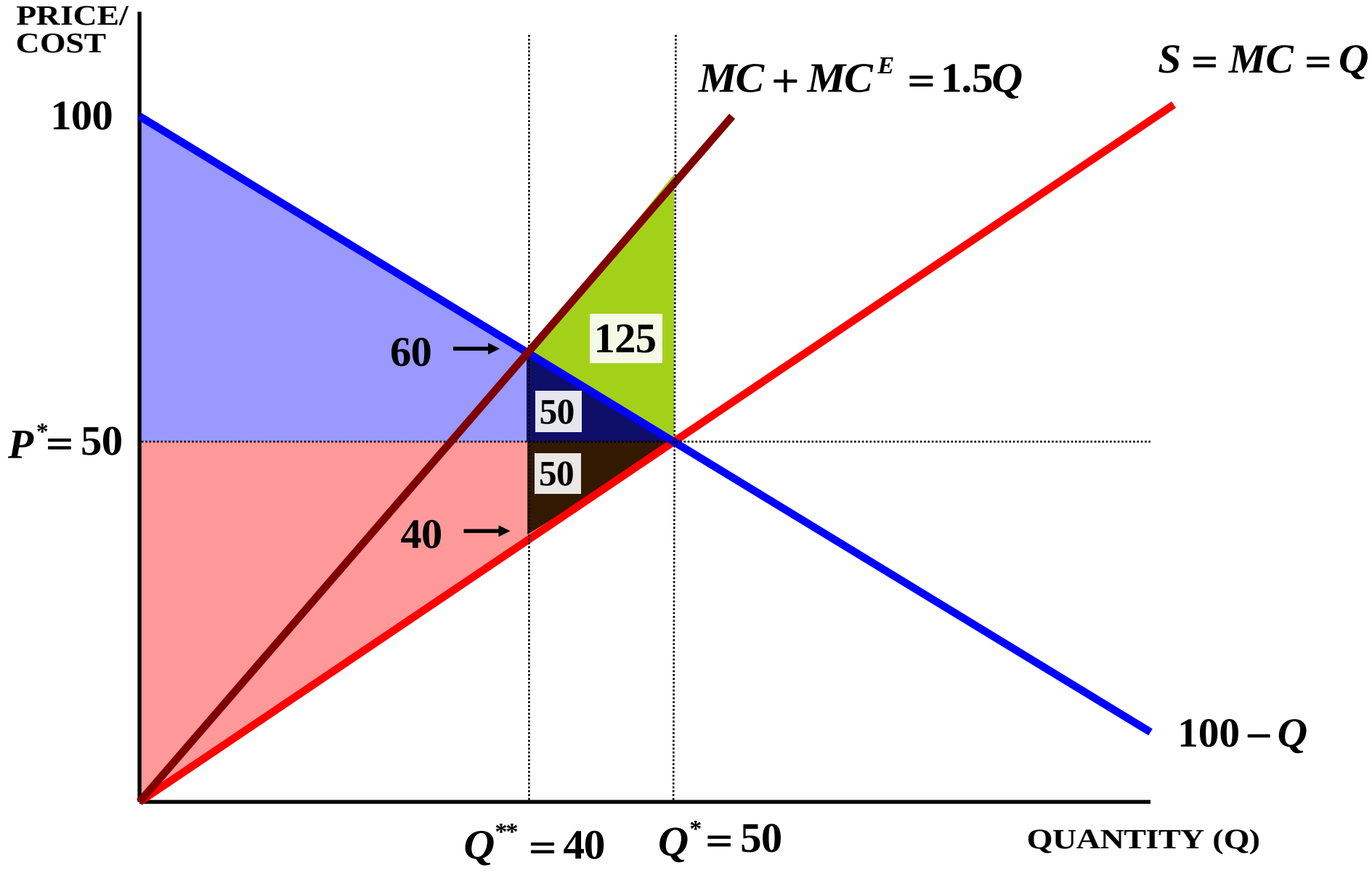
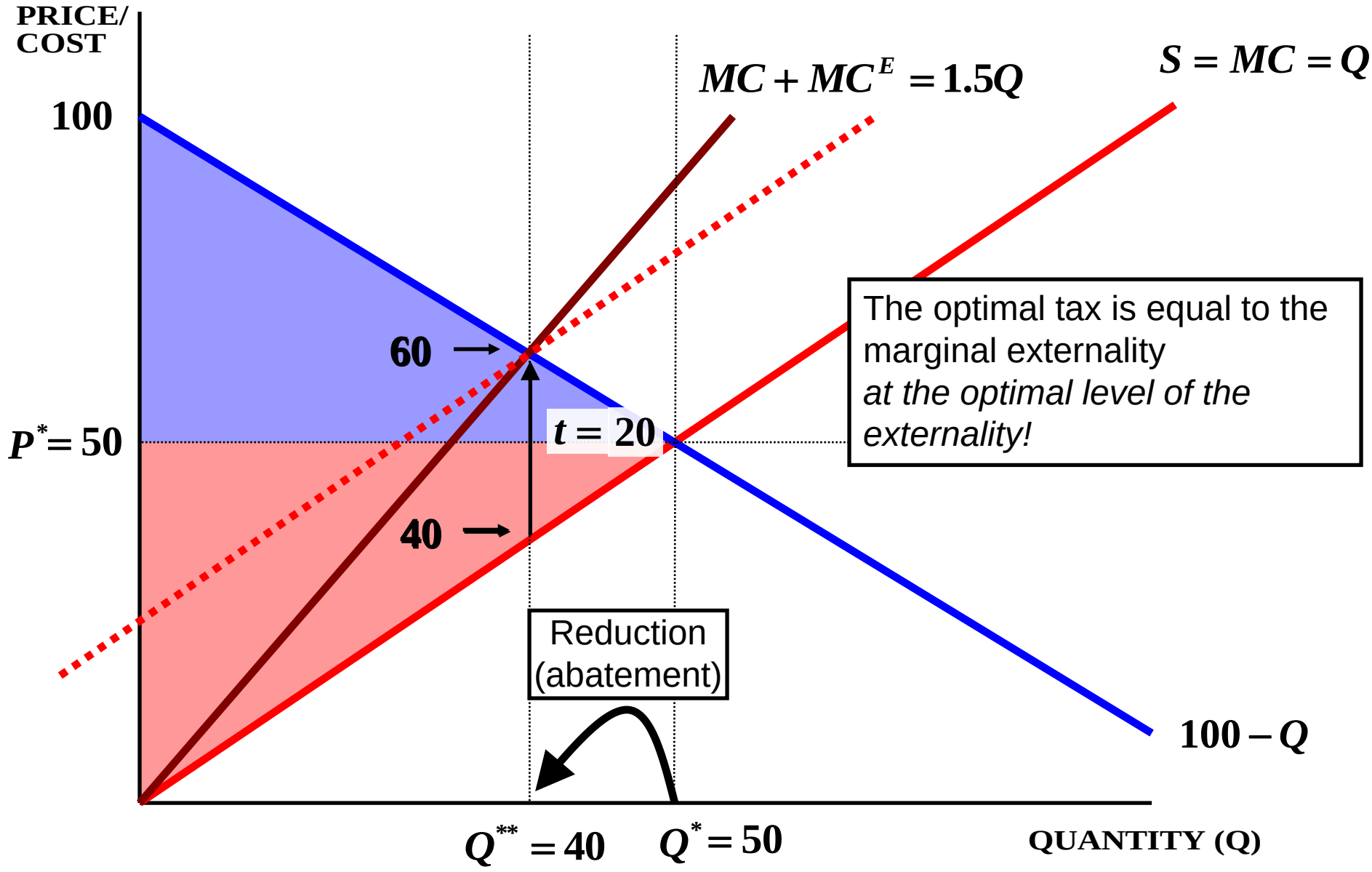
Carbon Taxing

3. Introduce carbon tax

How can we make the outcome optimal.



How can we use a tax to moved us to the optimal outcome?



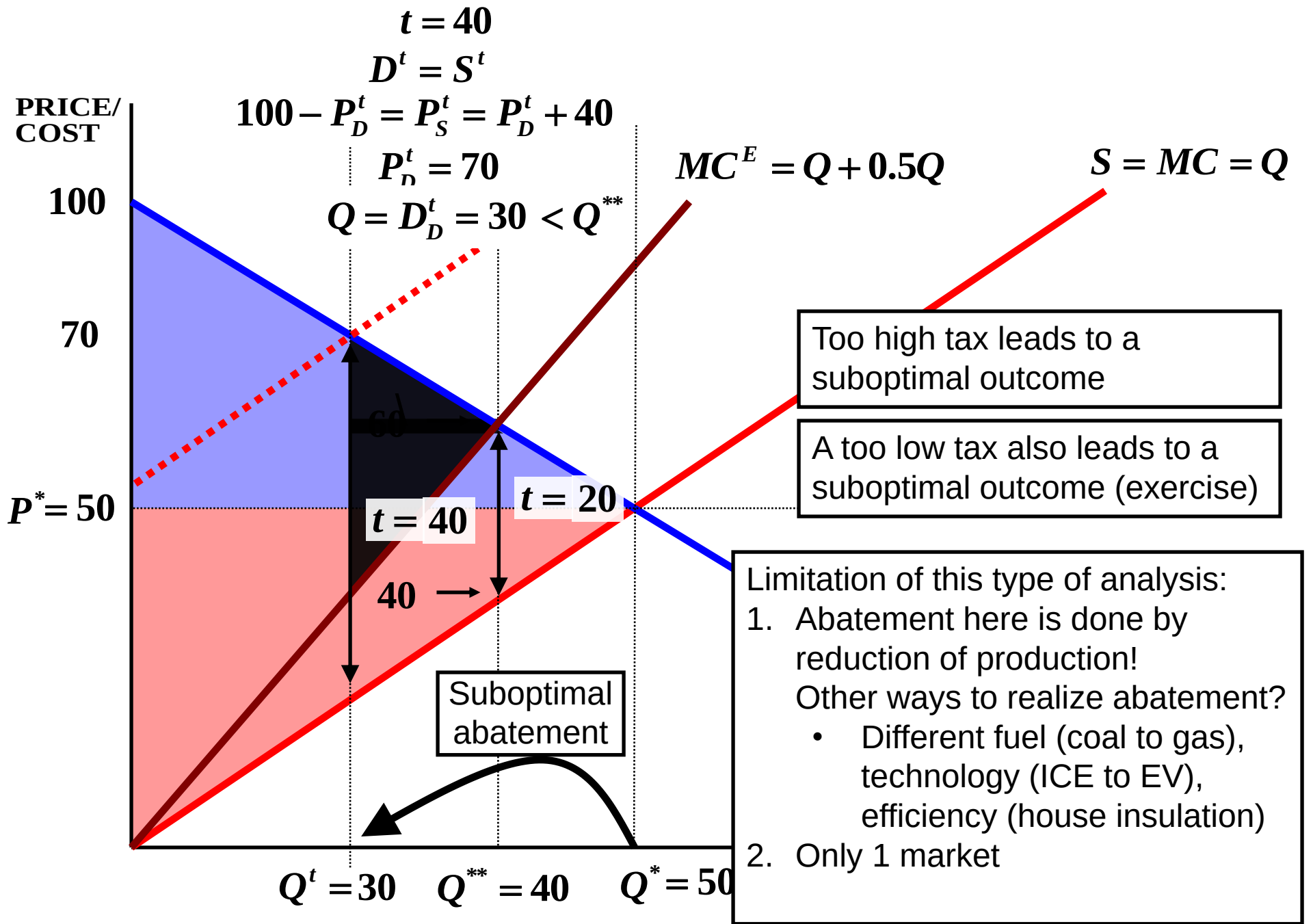
- A tax is a signal, not a punishment! /price

  Marcel Boiteux, testimony to the French National Assembly

- enables fine-tuned coordination
- Impossible to replicate by command & control
  - See failure of communist economics

  Hayek, F. A. (1945). The use of knowledge in society. The American economic review, 35(4), 519-530.

What if we make a mistake in estimating the externality?



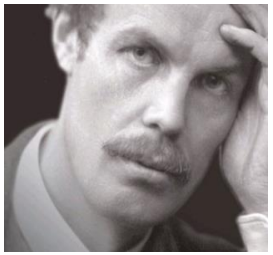
Too high tax leads to a suboptimal outcome

A too low tax also leads to a suboptimal outcome (exercise)

Limitation of this type of analysis:

1. Abatement here is done by reduction of production!
   Other ways to realize abatement?
   - Different fuel (coal to gas), technology (ICE to EV), efficiency (house insulation)
2. Only 1 market

Carbon Taxation

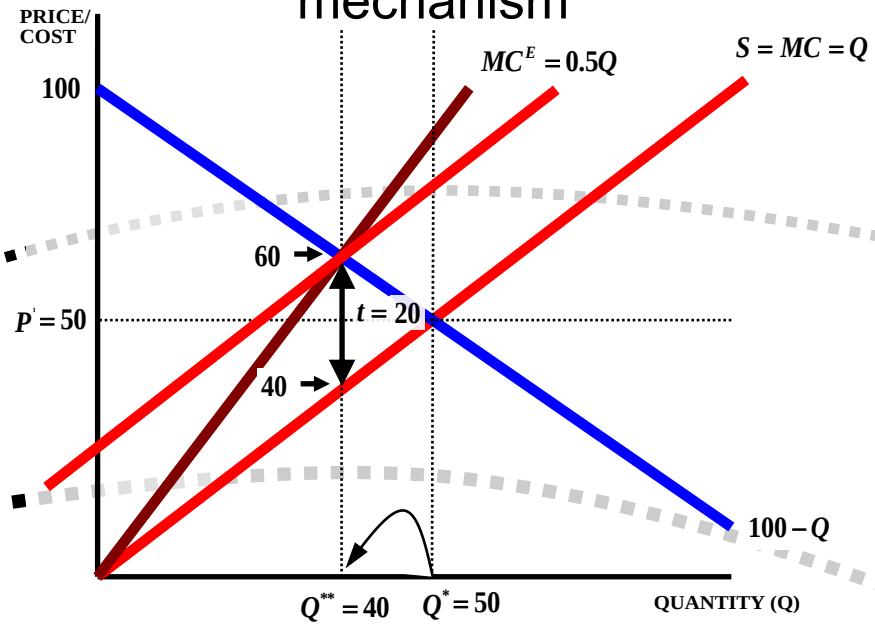


Arthur Cecil Pigou (1877 –1959)

"economic mechanism"

Carbon price

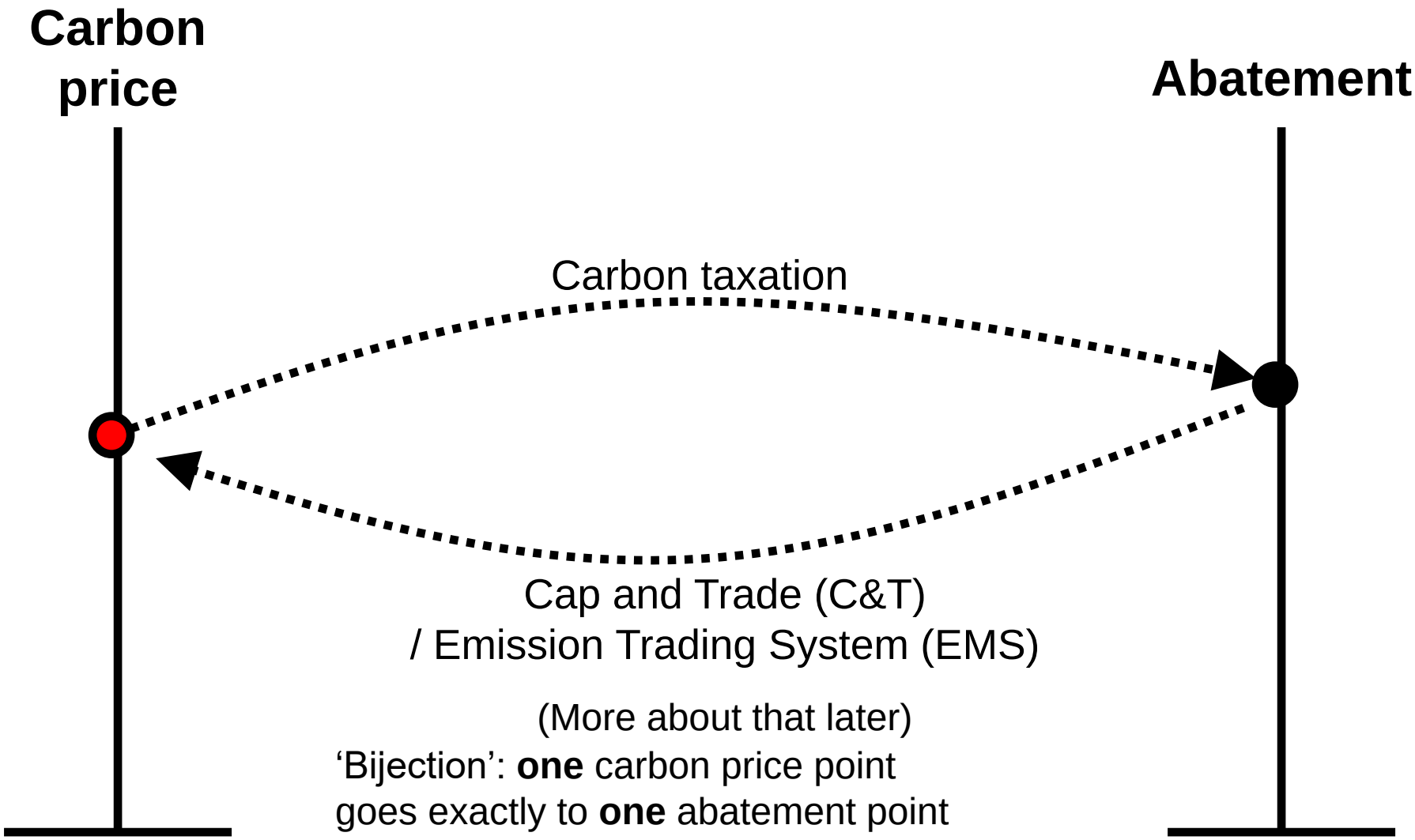
Abatement



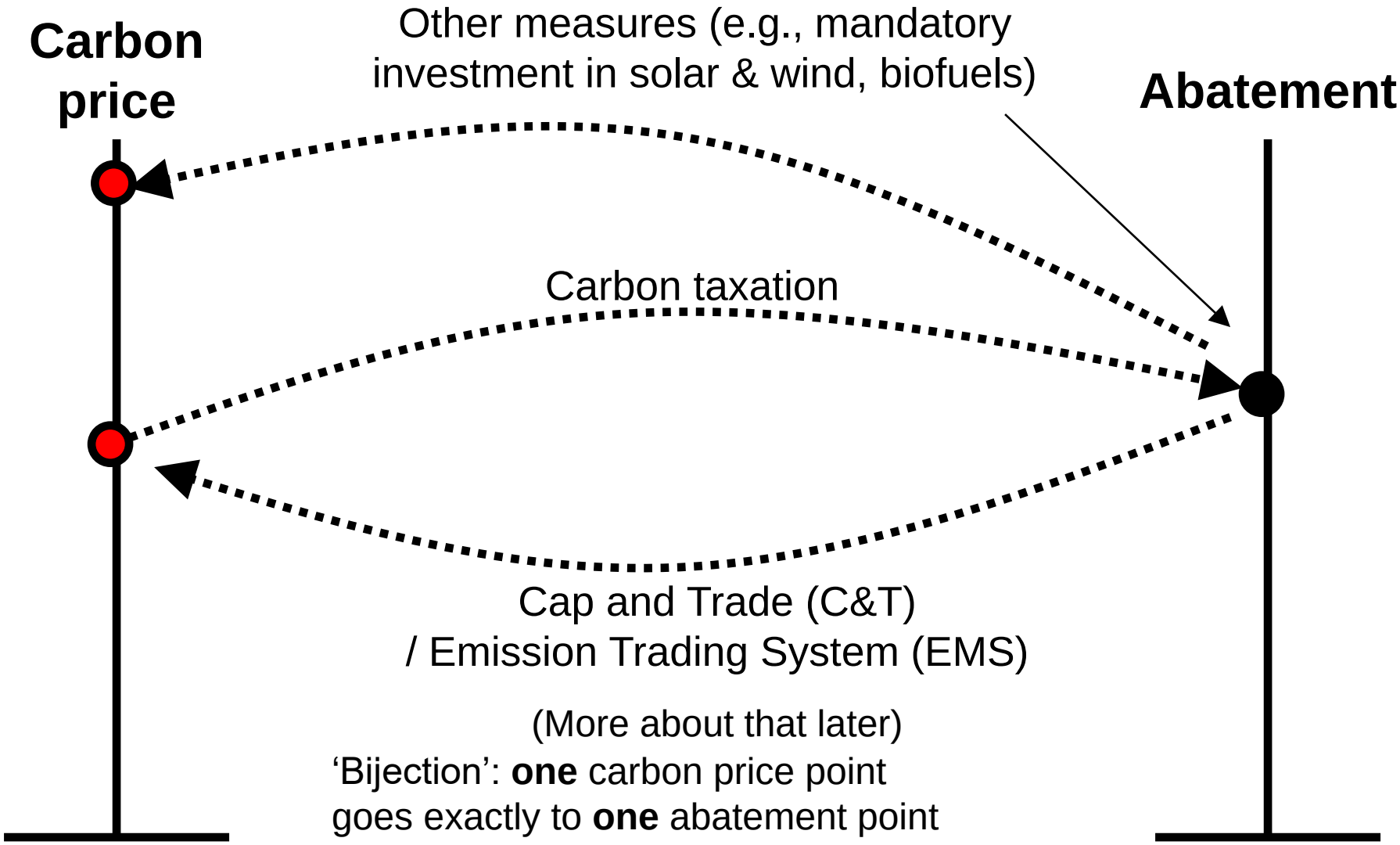
'Bijection': **one** carbon price point goes exactly to **one** abatement point

(https://en.wikipedia.org/wiki/Bijection)

Carbon price & abatement



Carbon price & abatement



(More about that later)

‘Bijection’: **one** carbon price point goes exactly to **one** abatement point

- Even if you don’t want or cant implement taxes or ETS, this talk is still of interest.
- Because any amount of abatement reached by a measure has an implicit abatement cost
  - Costs: x euro
  - Abatement: y ton CO2
  - Av.batement cost = x/y euro/tCO2

- Any abatement measure average cost corresponds to a tax level.
  - (Tax level that would lead to the same level of abatement.)

- Cargo bike instead of car or pub. transport:
  - Saves tCO2 -> abates tCO2
- Berlin decides to subsidize
- Calculate $/abatement cost of subsidies
  - Calculate abatement cost of the subsidies for cargo bikes
  - Calculate how much tCO2 abated
  - Divide cost by abatement
    - -> $/abatement
- Compare to social cost of tCO2
  - Social cost = $40~ $80/tCO2
- Abatement cost of Berlin bike subsidy scheme?
  - **$60 000/tCO2**
    - (=$430 000 / 7 tCo2)
- **Example of government picking a “winner”**

http://www.economist.com/finance-and-economics/2021/02/22/what-is-the-cheapest-way-to-cut-carbon

	Wind	Solar
• Marcantonini (2015, 2017)	• €55-160	€550-1000
• Abrell, Kosch and Rausch (JPE, 2019)	• €100-350,	€500-1700
• Greenstone, McDowell, & Nath (2019).	• $115	
• German Energy Blog, 2015	• €219	
• Muangjai et al (2020)(Thailand)	• $30	$150
• Compare with ETS	• €10/ton CO2	

- **2000-2020 EU** Renewable subsidy program was excessively ineffective and costly
  - 10x ~ 100x more expensive to alternative methods (ETS)
  - up to 17x~30x soc. marginal cost
- Waste of resources and precious time in EU
  - No public outcry or rolling heads…
  - Now:
    - Auctions for renewables (improvement as is market-based instrument)

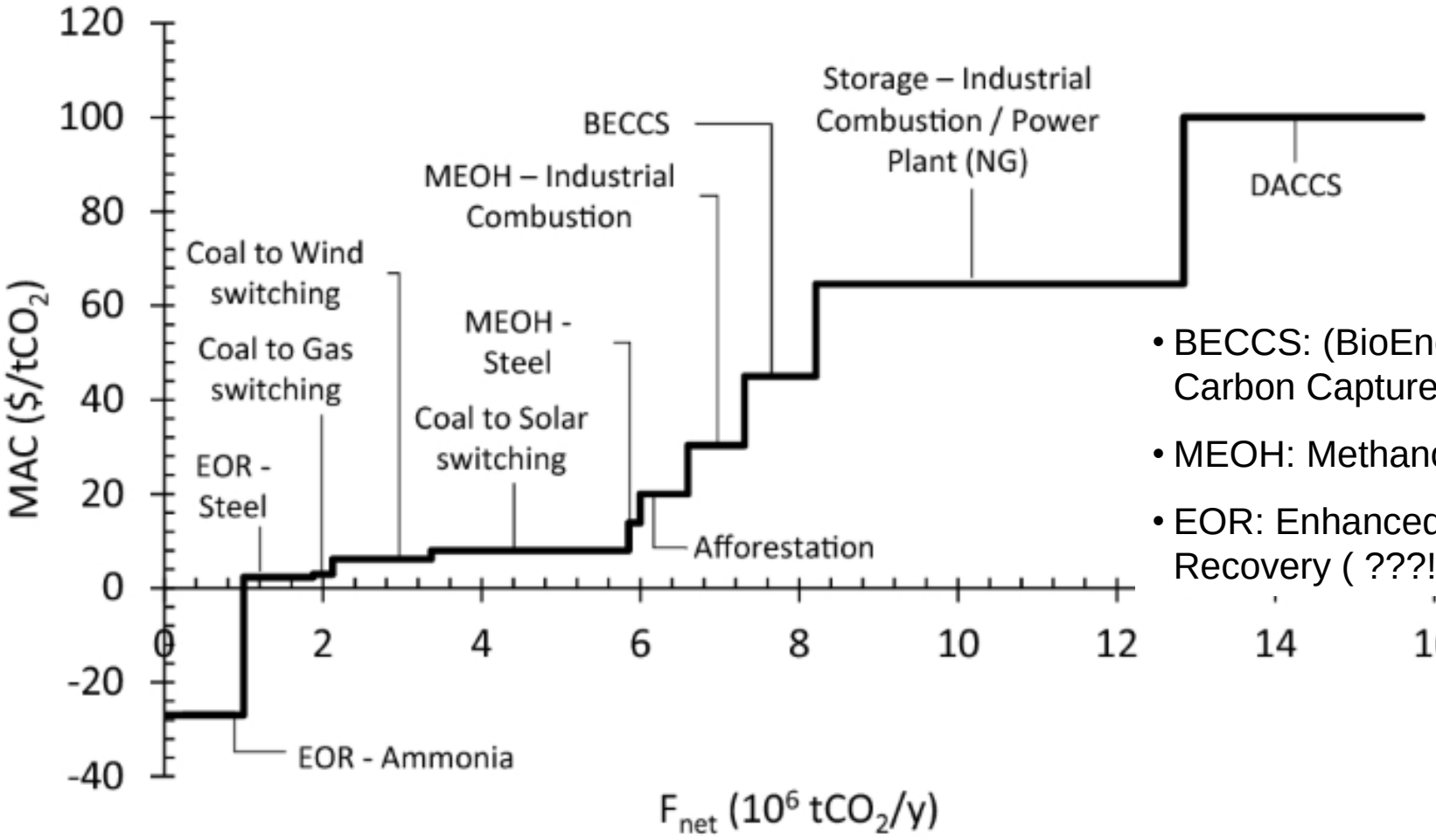
- Abatement is achieved by:
  1. reducing production
  2. changing technology (ICE to EV)
  3. different fuel (coal to gas)
  4. efficiency (house insulation, heat pumps)

We looked at that

We didn't look at that

- Marginal abatement costs
  - The cost of abating one more ton of CO2
  - Any possible way of abatement included!
  - Can be used to look at the interaction between different firms and different markets

- We often use Marginal Abatement Cost curves to show the cost for a firm to reduce emissions.
- Horizontal line: The total reduction of emissions.
- Vertical line: The marginal cost of abatement.

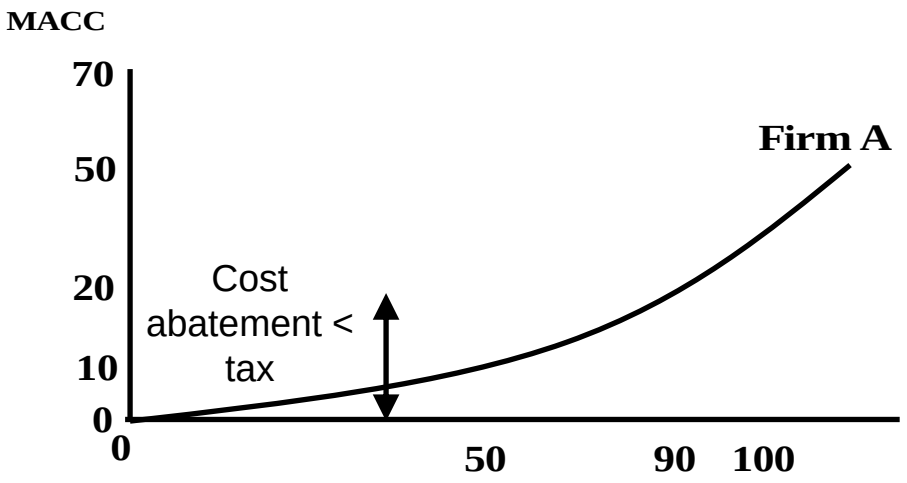


- BECCS: (BioEnergy with Carbon Capture & Storage)
- MEOH: Methanol fuel
- EOR: Enhanced Oil Recovery (???!!!) 😠

https://link.springer.com/article/10.1007/s10098-021-02095-y

Use MACC to analyze abatement choices

$$t = 20$$



Use MACC to analyze abatement choices

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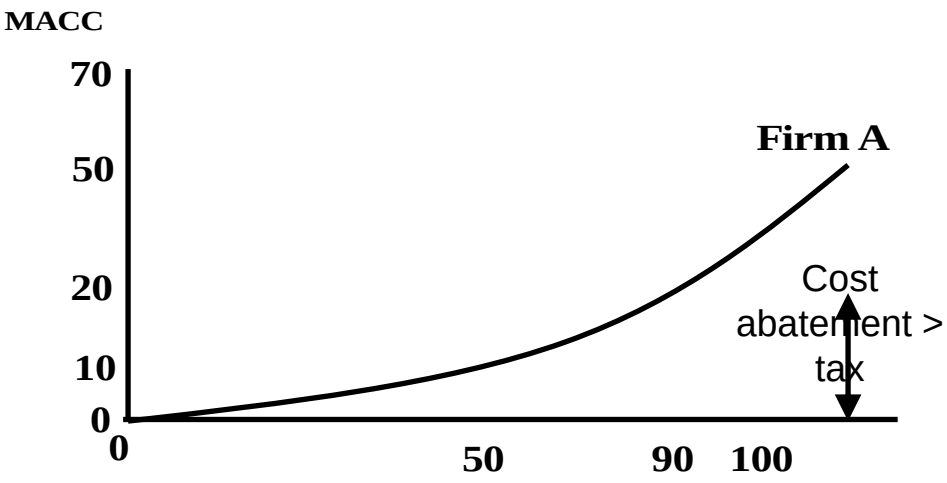
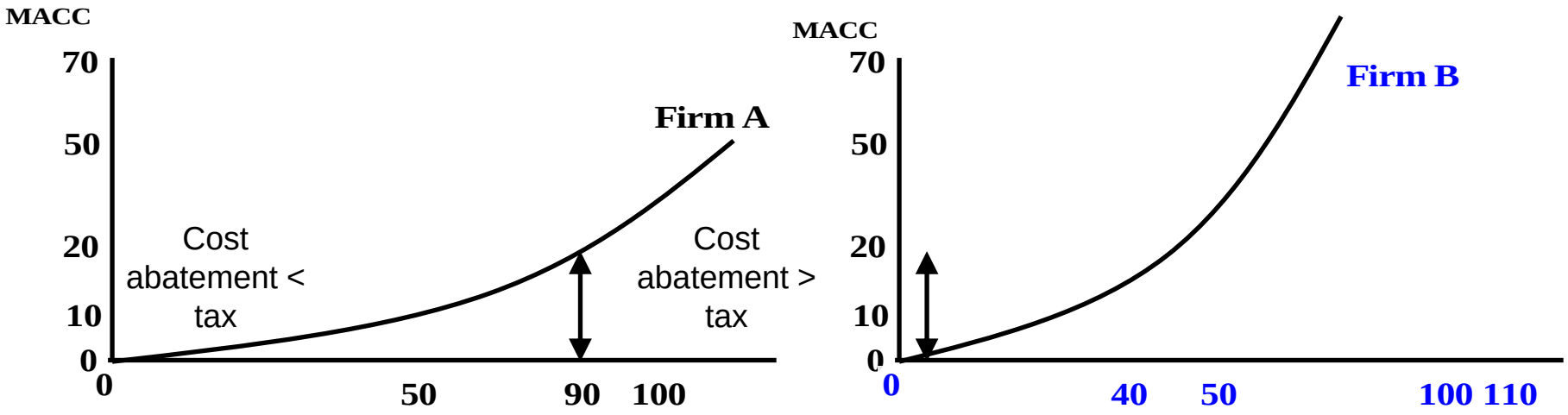


Use MACC to analyze abatement choices

$t = 20$

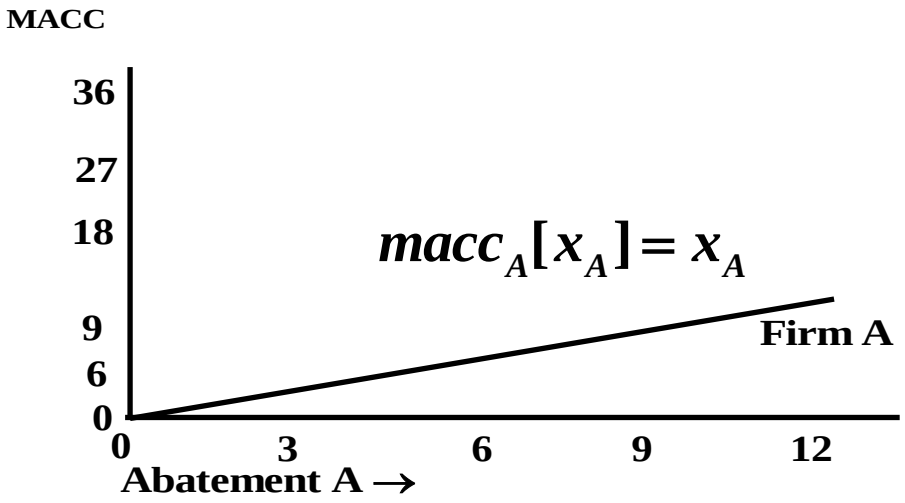


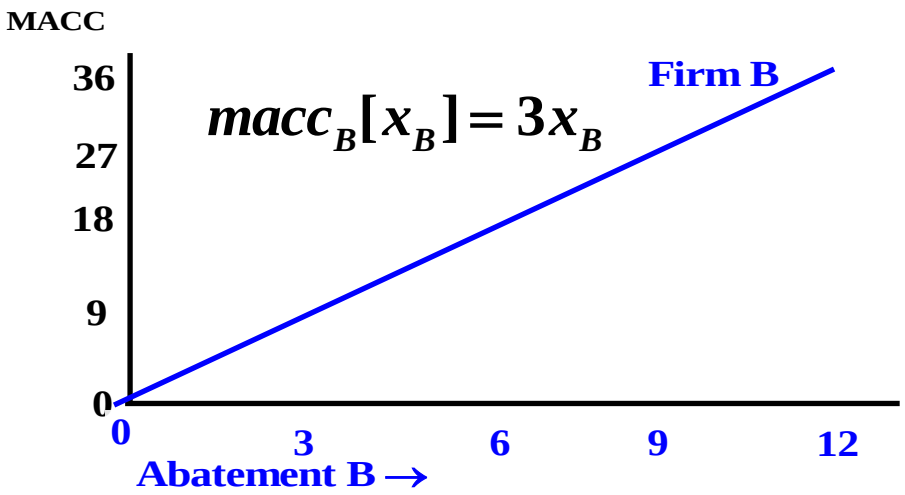
The tax works as a perfect coordination method! And makes different firms abate different amounts (which is optimal)!

Government doesn't need to know each firm's individual MACC for optimal coordination!!!

Analyze more closely with simpler MACCs

Use MACC to analyze abatement choices



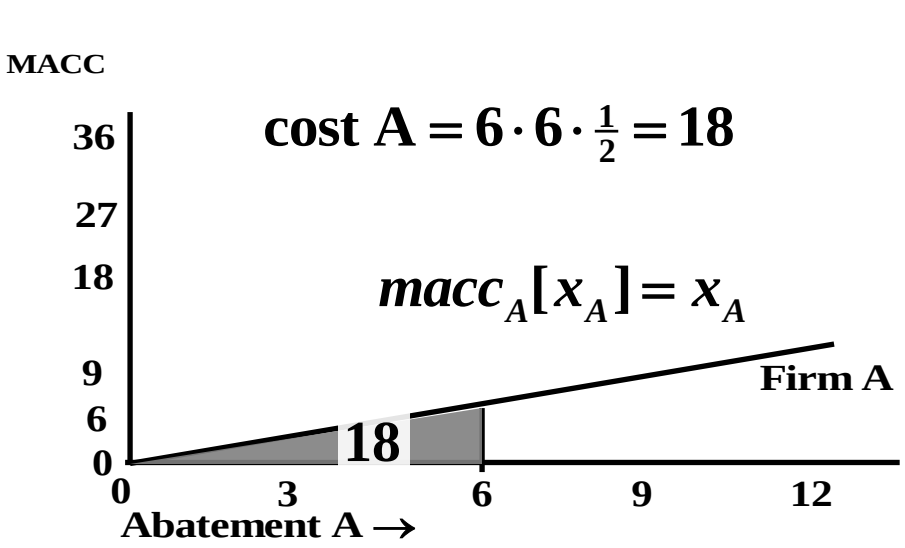


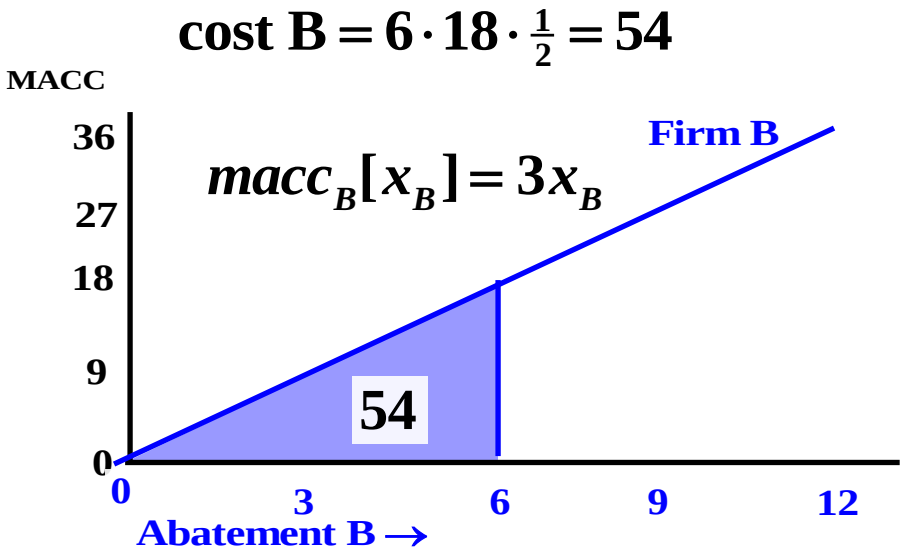
We need abatement of 12 units

- Let us compare two measures

1. Regulatory standards
   - Just give all firms the order to reduce pollution.
   - For example, all the same amount: 6 units each
2. Use a carbon tax

Suppose we have two firms



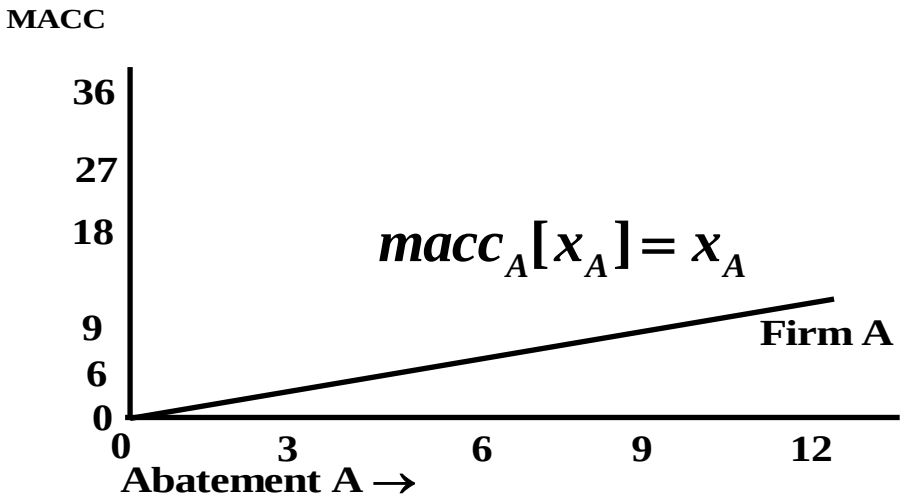


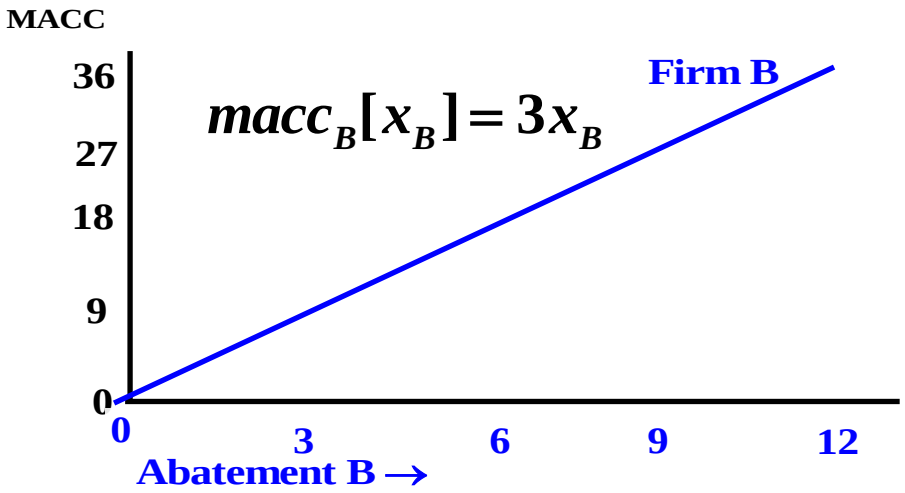
We need abatement of 12 units

1.Regulatory standards

- Each has to reduce pollution by 6 units
- What are the abatement costs?
- 18+54 = 72$

Carbon tax





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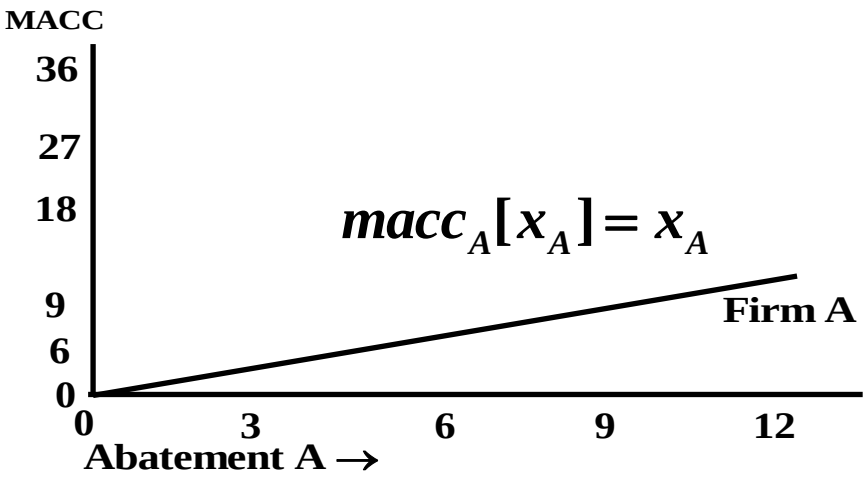
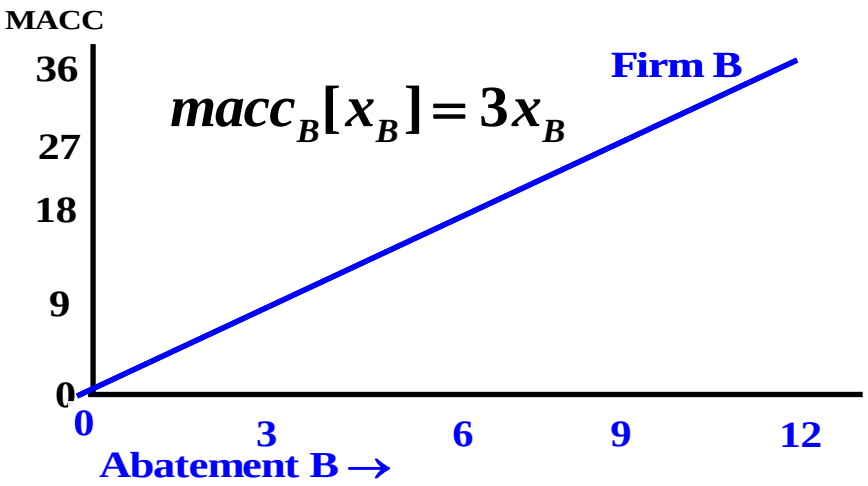
Carbon tax





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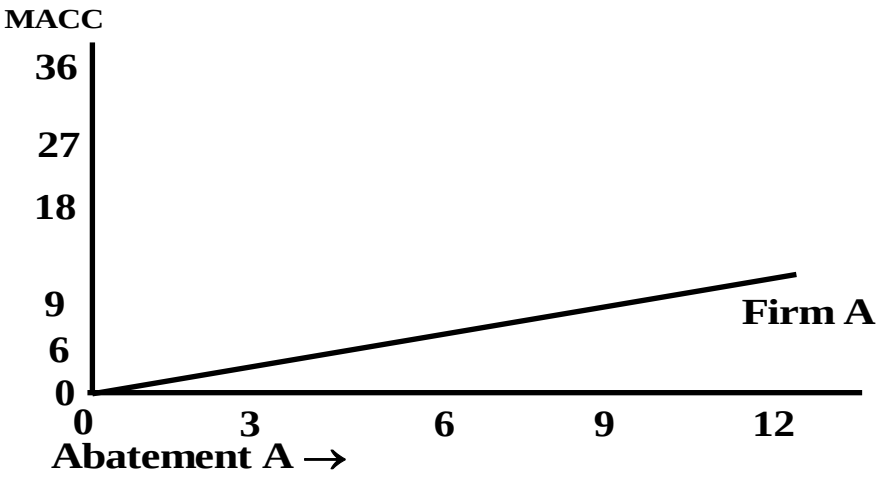
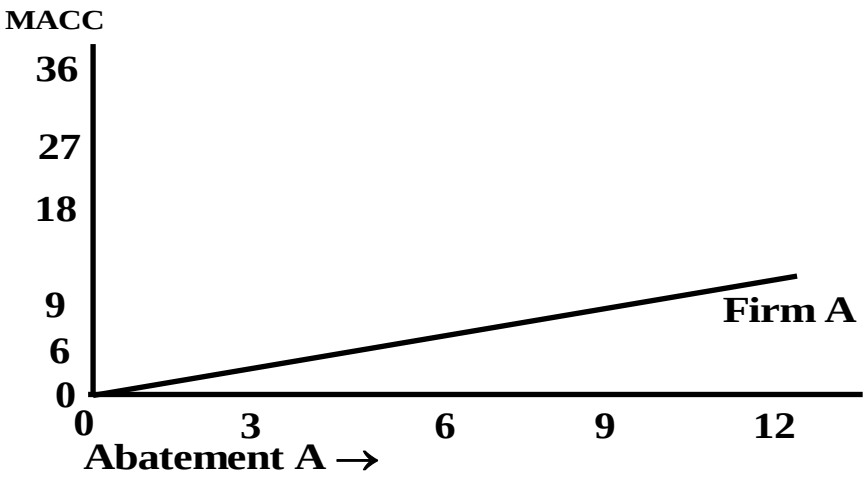
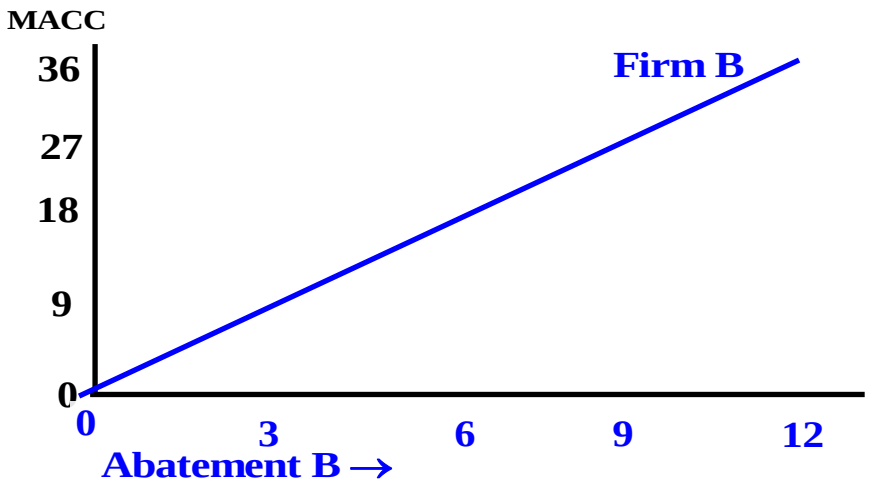


Carbon tax





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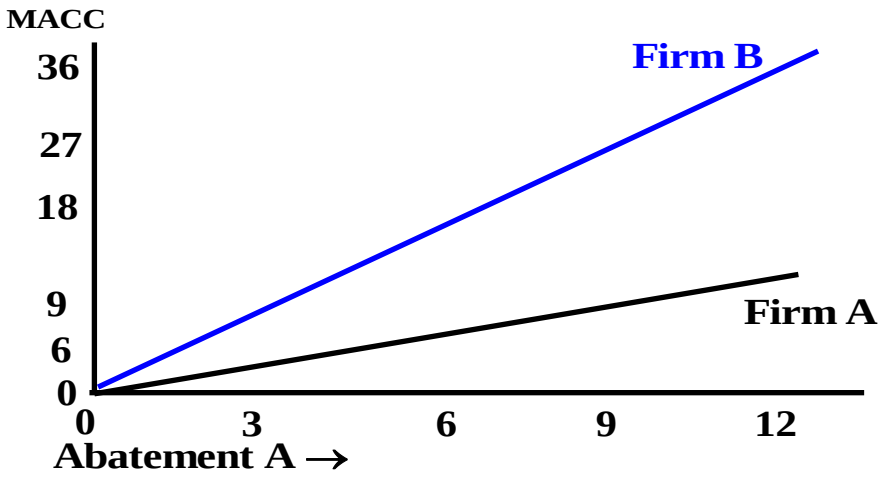
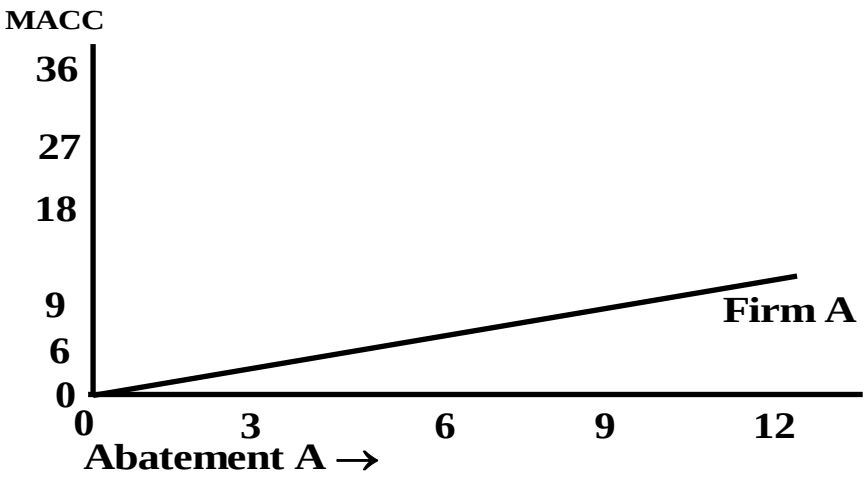
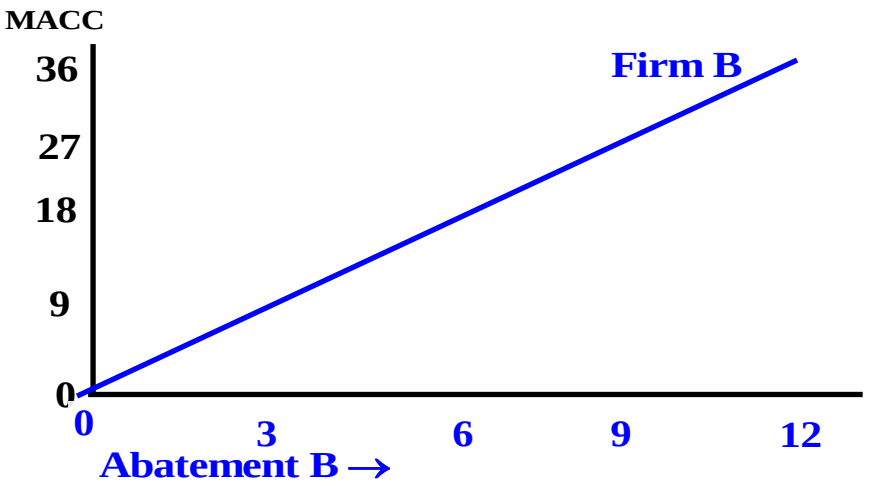


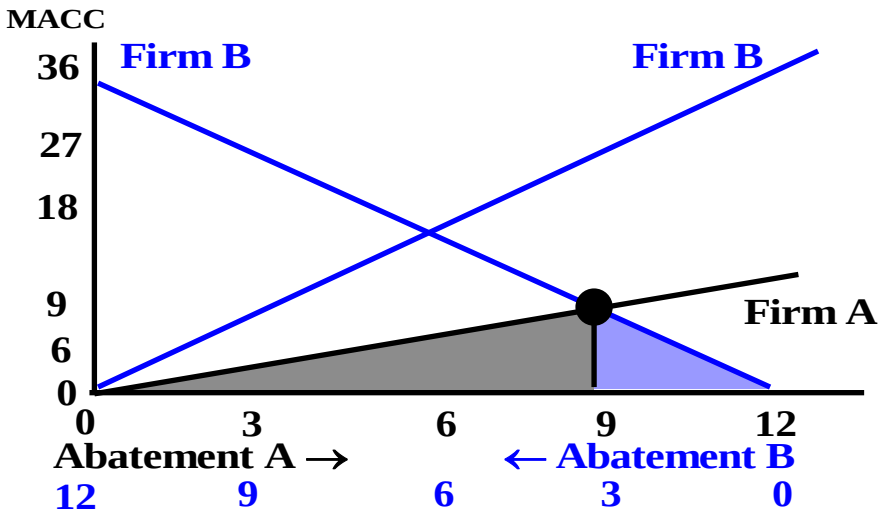
Carbon tax





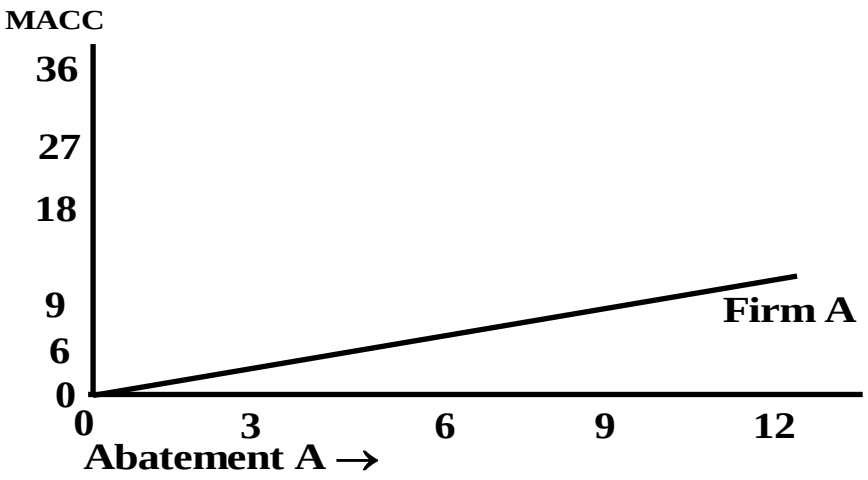
We need abatement of 12 units

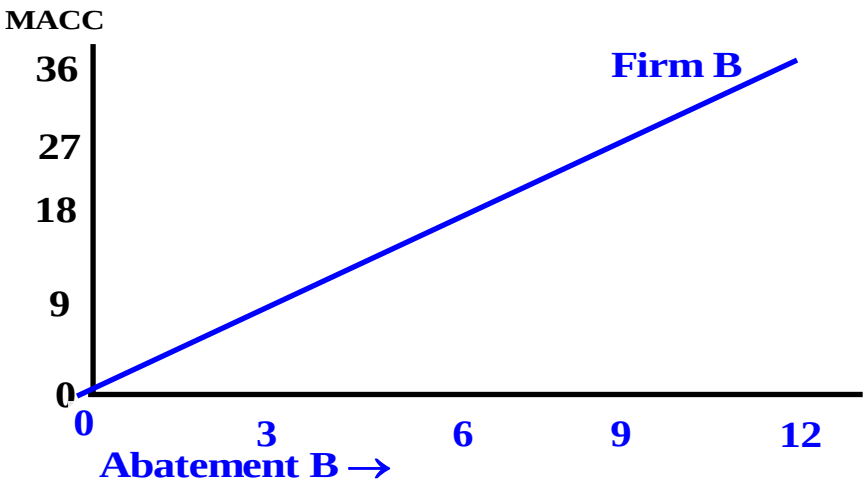
$$\text{cost A} = 9 \cdot 9 \cdot \tfrac{1}{2} = 40.5 \qquad \text{cost B} = 9 \cdot 3 \cdot \tfrac{1}{2} = 13.5$$



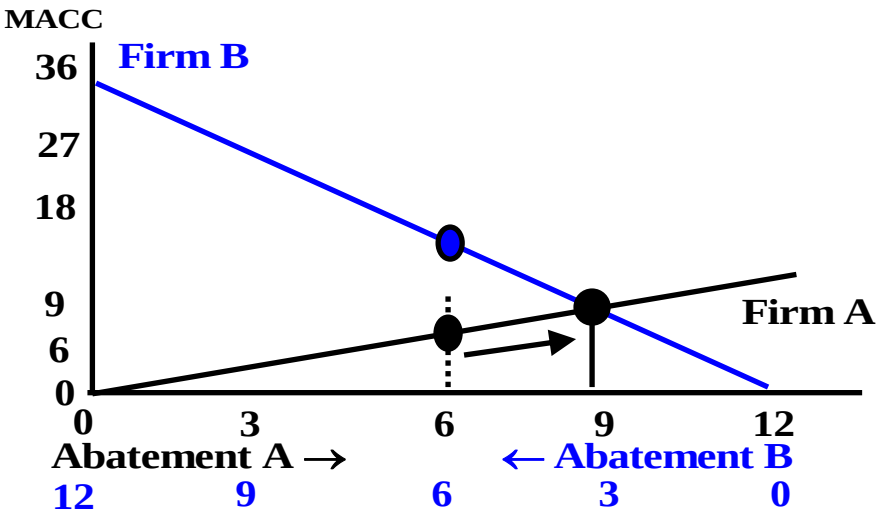
Intersection at A:9, B:3
Any other point is suboptimal. Why?
MACC of A and B must be equal
What is the tax rate?
Tax = 9
What are the abatement costs?
40.5+13.5=54$
Cheaper than regulatory standards!
(54$ < 74$)

Carbon tax





We need abatement of 12 units

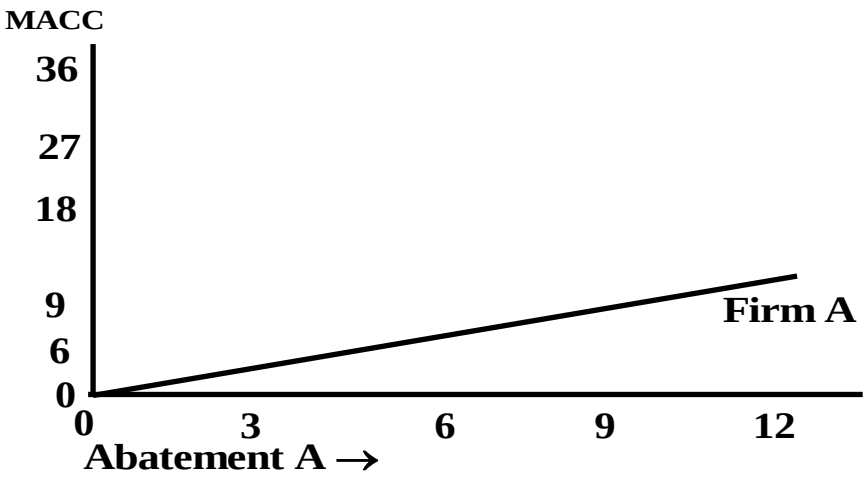


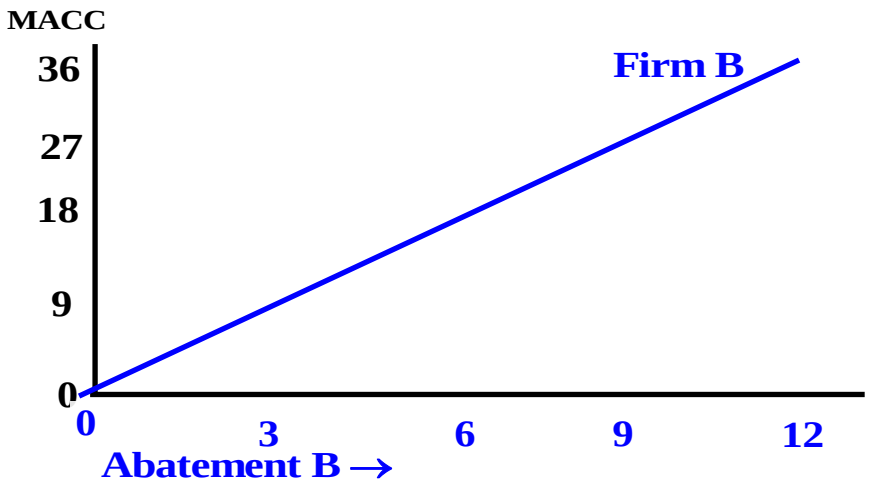
Suppose:
- Tax = 9
- The start position is A:6, B:6

What would happen?

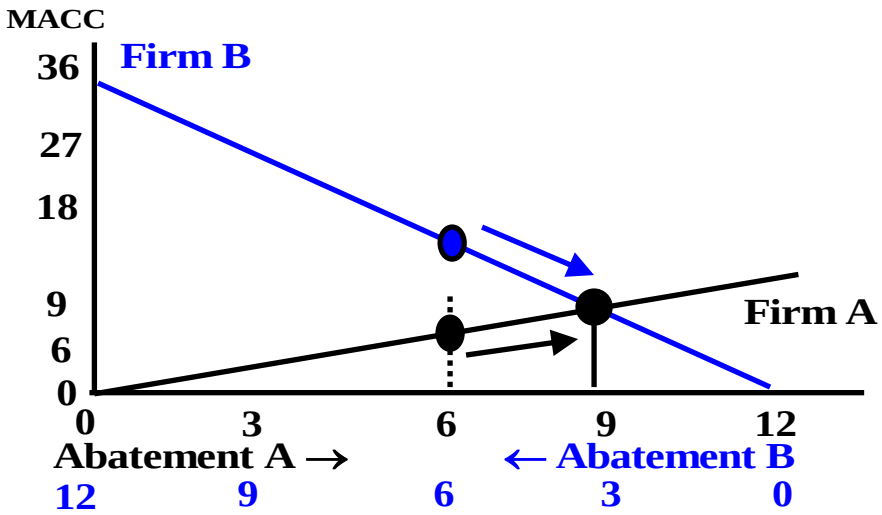
- For each unit A abates, he does not need to pay the tax of 9$
- Abating a unit costs now 6$
- So A wants to abate more

Carbon tax





We need abatement of 12 units



Suppose:
- Tax = 9
- The start position is A:6, B:6

What would happen?

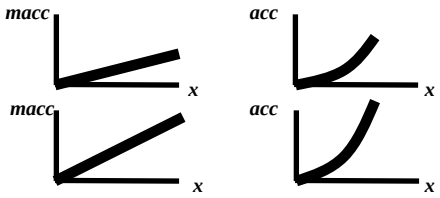
- For each unit B abates, he does not need to pay the tax of 9$
- Abating a unit costs B now 18$
- So B wants to abate less

- With some mathematics, this analysis can be done more directly

Compare the efficiency of carbon taxation with regulatory standards (command-and-control regulation)

- Suppose we found out we must reduce emission by 12 units. We have two firms

$$macc_A[x_A] = x_A \qquad macc_B[x_B] = 3x_B$$



$$acc_A[x_A] = \tfrac{1}{2}x_A^2 \qquad acc_B[x_B] = \tfrac{3}{2}x_B^2$$

regulatory standards

- Each firm reduces emissions by 6

$$ac_A = \tfrac{1}{2}\cdot 6^2 = 18$$
$$+\ ac_B = \tfrac{3}{2}\cdot 6^2 = \tfrac{3}{2}\cdot 36 = 54$$
$$Tac = 18 + 54 = 72$$

Carbon tax

$$macc_A = macc_B = t$$
$$x_A = 3x_B = t$$
$$x_A = 9$$
$$t = 9$$

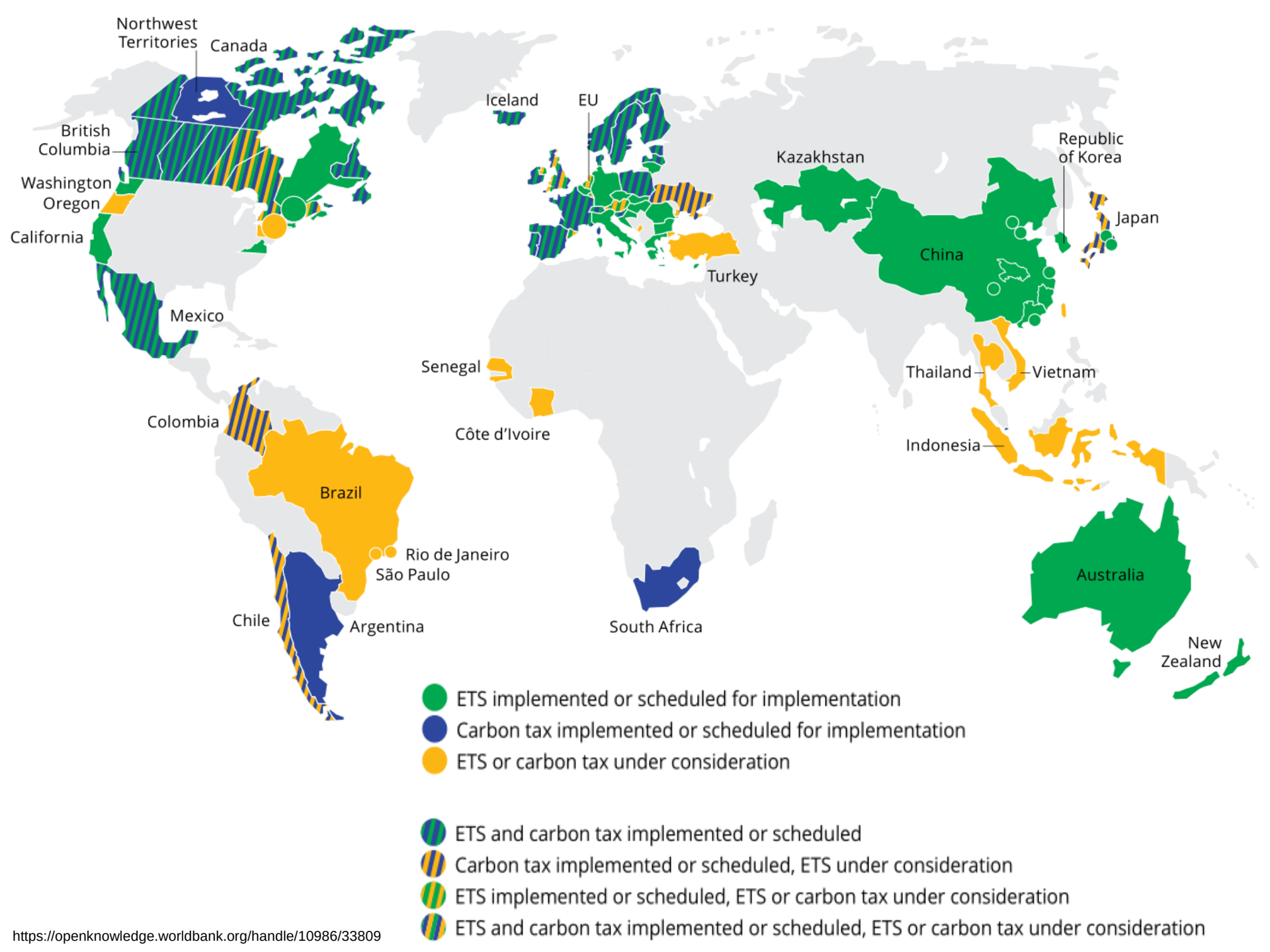
$$x_A + x_B = 12$$
$$3x_B + x_B = 12$$
$$\Leftrightarrow \quad x_B = 3$$

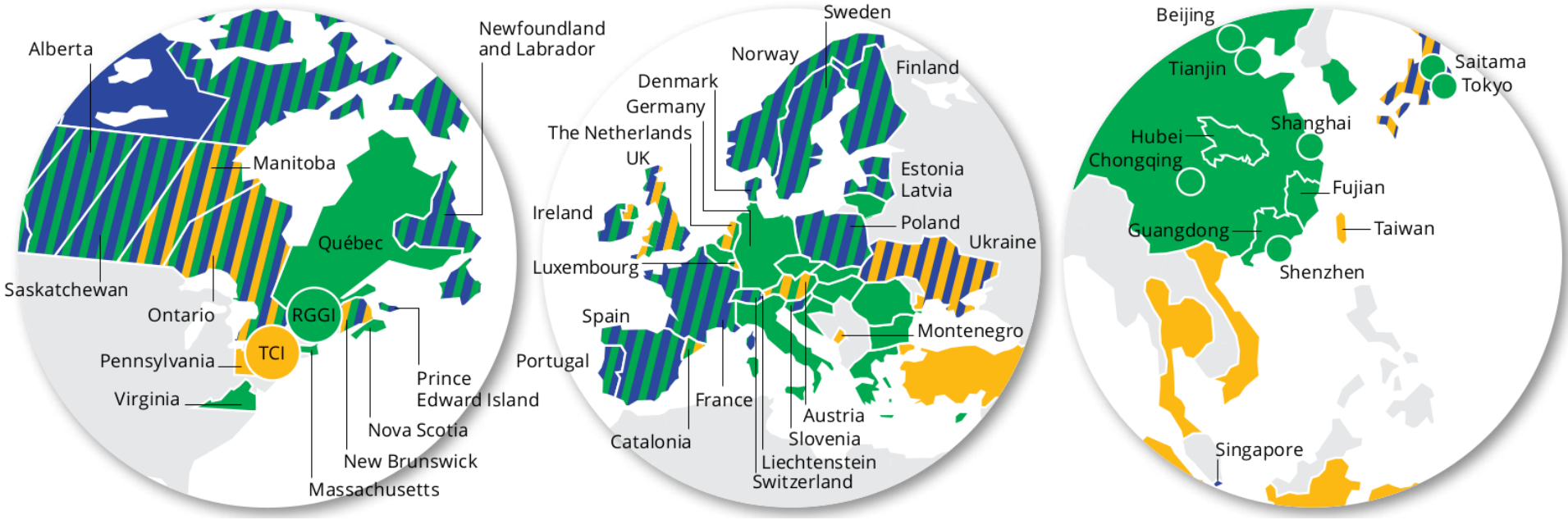
$$ac_A = \tfrac{1}{2}\cdot 9^2 = 40.5$$
$$+\ ac_B = \tfrac{3}{2}\cdot 3^2 = 13.5$$
$$Tac = 40.5 + 13.5 = 54$$

- What else to do now for economists (or even politicians)?
  - Nothing much
  - The externality has been addressed
  - The job has been done
  - This is the best we can get.
    - Improve decisions
      - Providing information
      - Probably still some minor adjustments
    - Efforts for better estimates of the optimal level of the carbon tax
    - (The marginal cost of CO2)

- Shouldn’t we still subsidize renewables, subsidize efficiency improvements?
  - In theory, no. Only if there are very specific additional market failures.
  - Most subsidies are partially ineffective, inefficient and expensive.
    - Measure of last resort (if you cannot make people pay tax)

- What to use the revenues for?
- Optimal (based on econ. analysis):
  1. Use it to address other externalities
     - Research
     - Lower income or business tax
  2. Divide equally among the population
- Suboptimal (not supported by econ. analysis):
  1. Give subsidies for mass-deployment to technologies favored by politicians/engineers
     - (at least 50% of revenue is spent this way in most places)





- All EU member countries have Emission Trading System (ETS)
- So many countries are considering to add a tax on top!
  - (Why have ETS ***and*** carbon tax?)

ETS implemented or scheduled for implementation
Carbon tax implemented or scheduled for implementation
ETS or carbon tax under consideration

ETS and carbon tax implemented or scheduled
Carbon tax implemented or scheduled, ETS under consideration
ETS implemented or scheduled, ETS or carbon tax under consideration
ETS and carbon tax implemented or scheduled, ETS or carbon tax under consideration

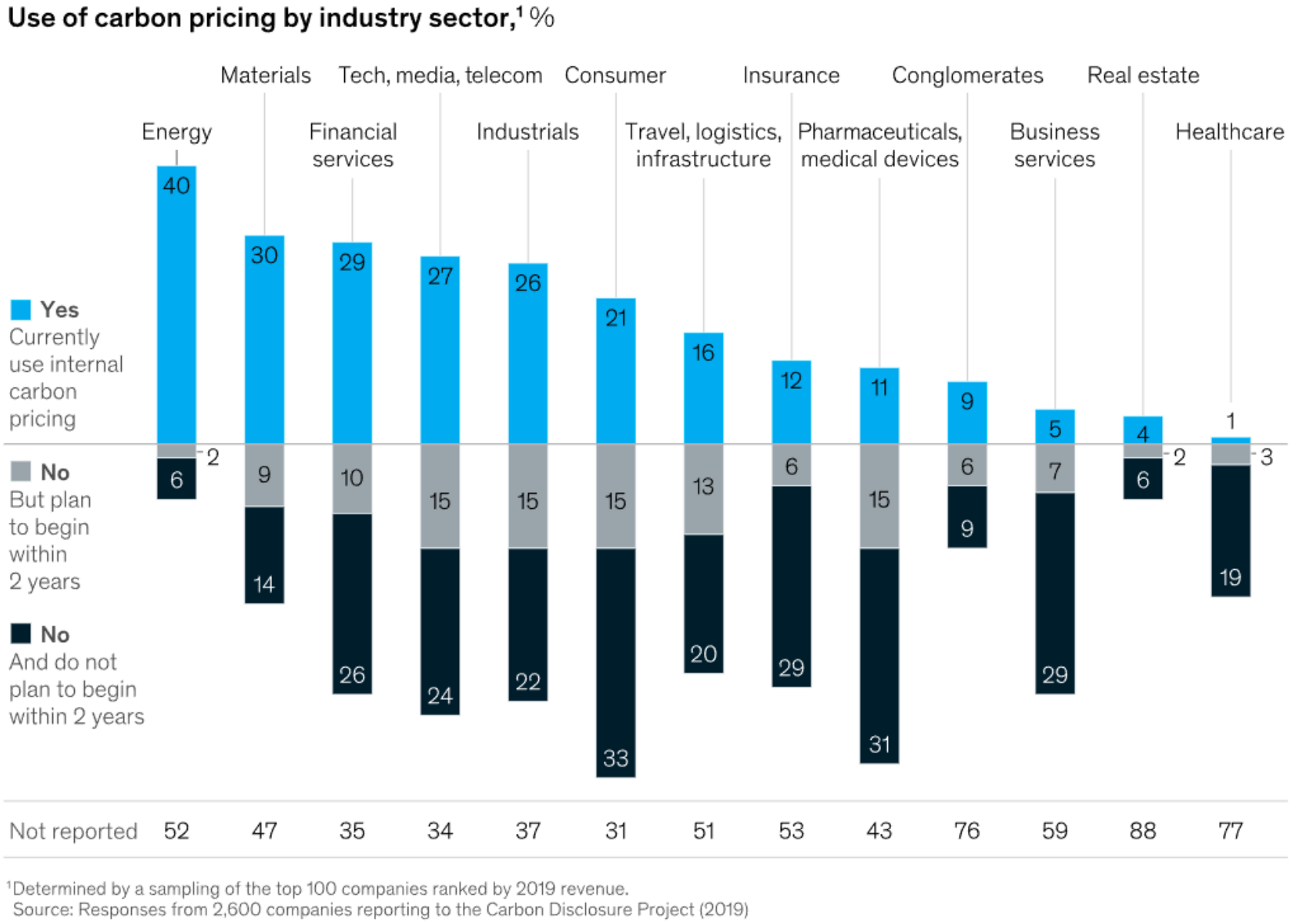
https://openknowledge.worldbank.org/handle/10986/35620

Corporate internal carbon pricing

- some companies set an internal tax on their carbon emissions
- so they can see how, where, and when their emissions could affect their profit-and-loss (P&L) statements and investment choices.
- Examples:
  - A European energy company's decided to close several power plants due to its internal tax
  - some US financial-services companies are using internal tax to identify low-carbon, high-return investment opportunities.

https://www.mckinsey.com/capabilities/strategy-and-corporate-finance/our-insights/the-state-of-internal-carbon-pricing

Corporate internal carbon pricing



[1]Determined by a sampling of the top 100 companies ranked by 2019 revenue.
Source: Responses from 2,600 companies reporting to the Carbon Disclosure Project (2019)

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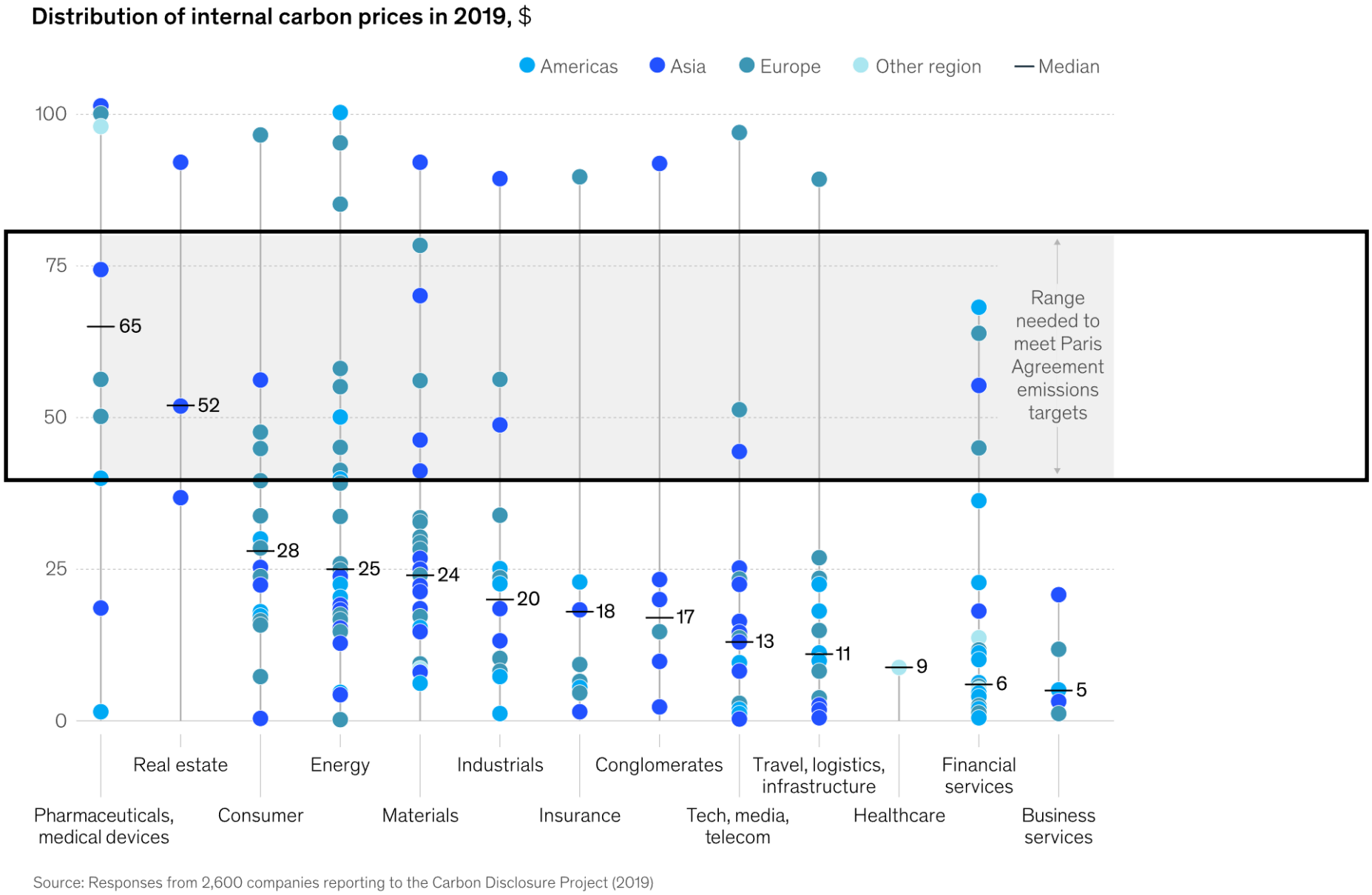
Corporate internal carbon pricing



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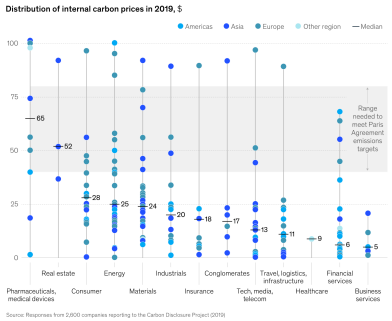
Corporate internal carbon pricing



Advantage and disadvantages?

- Advantages:
  - Tax = optimal instrument. If not government, then at least (some) businesses are doing it.
- Disadvantages:
  - Businesses set different tax rates
    - is inefficient!
  - Many businesses set tax rate not equal to marginal social cost
    - (too low and too high)
  - Government must commit to a policy of carbon reduction
    - Most businesses wont set taxes if they believe carbon emissions will not be costly for them.

https://www.mckinsey.com/capabilities/strategy-and-corporate-finance/our-insights/the-state-of-internal-carbon-pricing

Economics of pollution

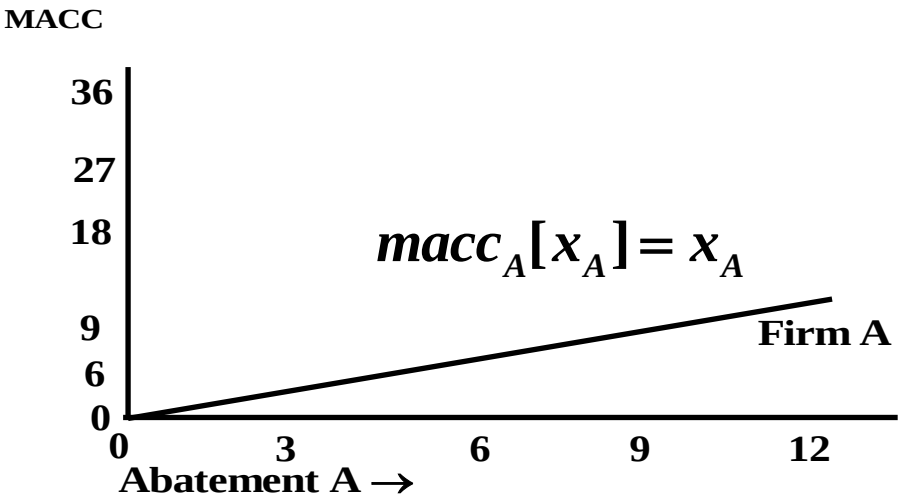
1. Refresh free market economics basics ✓
2. Introduce carbon emissions as an externality ✓
3. Introduce 2 possible solutions
    1. Carbon Tax ✓
    2. Emission Trading Scheme (ETS)
4. Overview carbon taxation & ETS in the world
5. ETS & substituting high-emission tech for low-emission tech.
6. What is better, carbon tax or ETS?

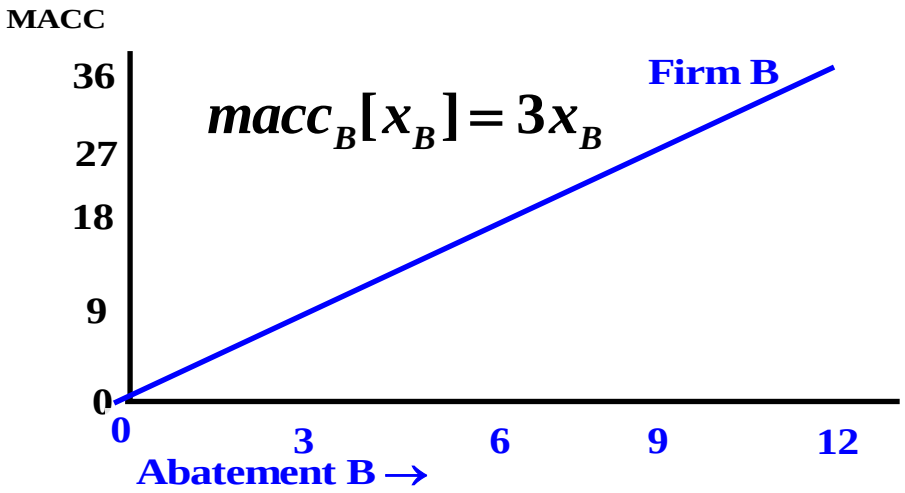
- Let us compare two measures

1. Regulatory standards
   - Just give all firms the order to reduce pollution.
   - For example, all the same amount: 6 units each
2. Use a carbon tax

   $x_A = 9,\ x_B = 3,\ t = 9$
3. Use a Emission Trading System (ETS)

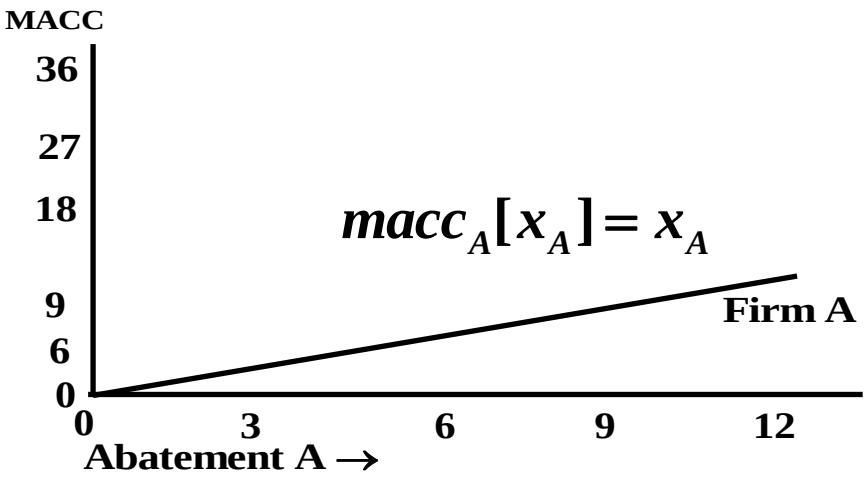
ETS

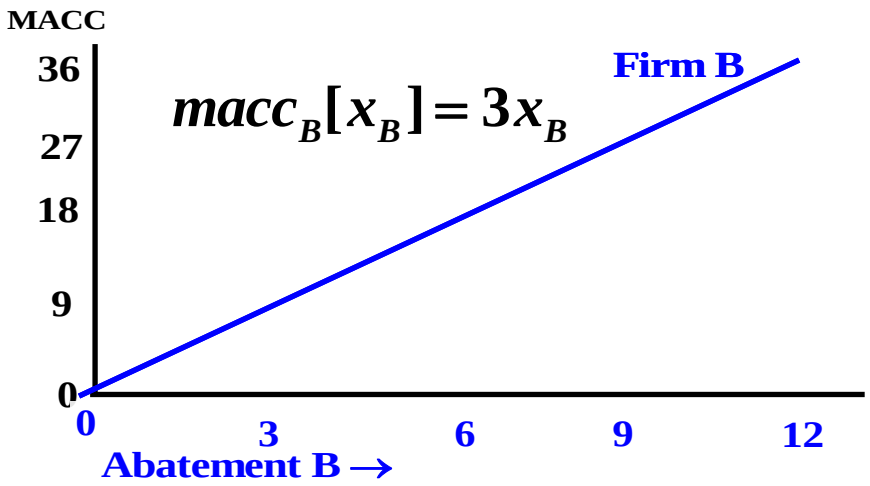




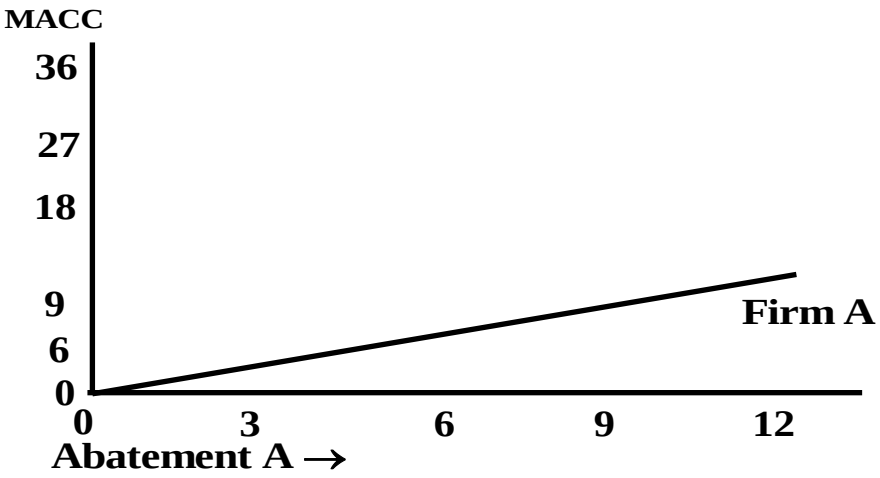
We need abatement of 12 units

ETS

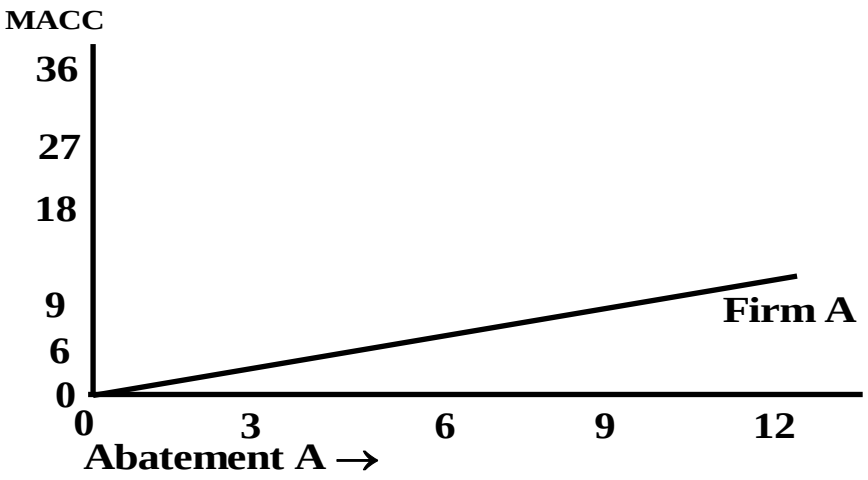


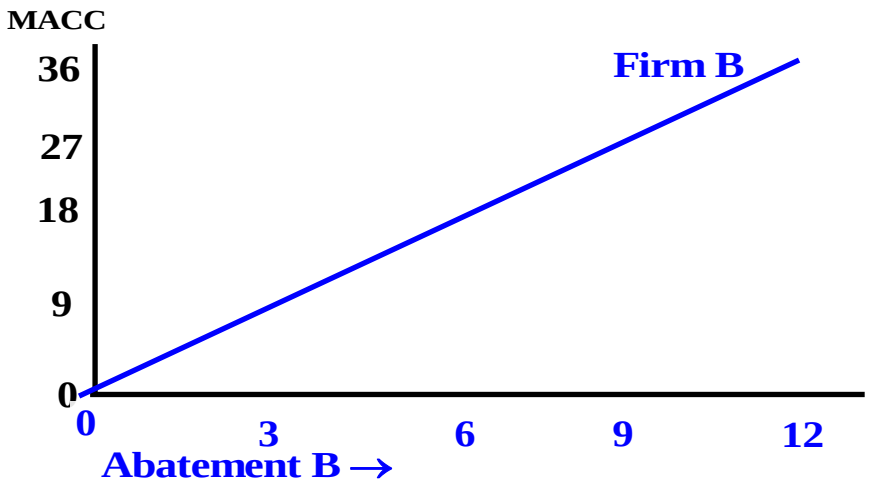


We need abatement of 12 units

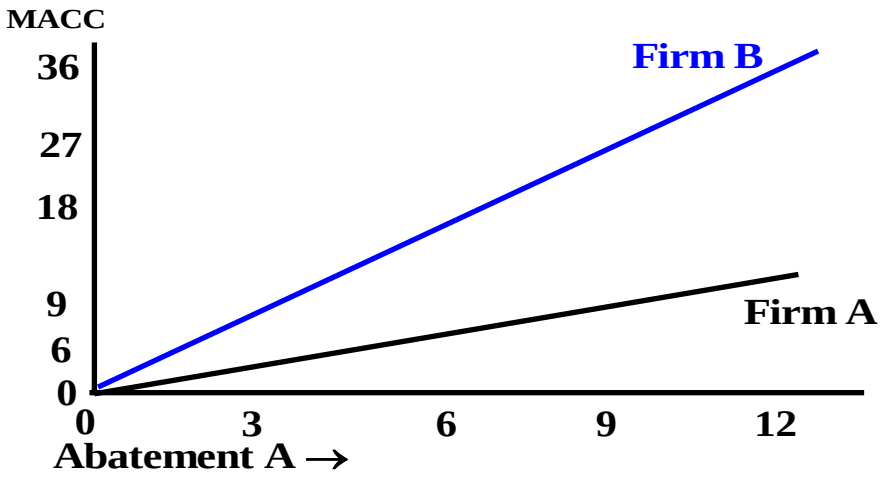


ETS

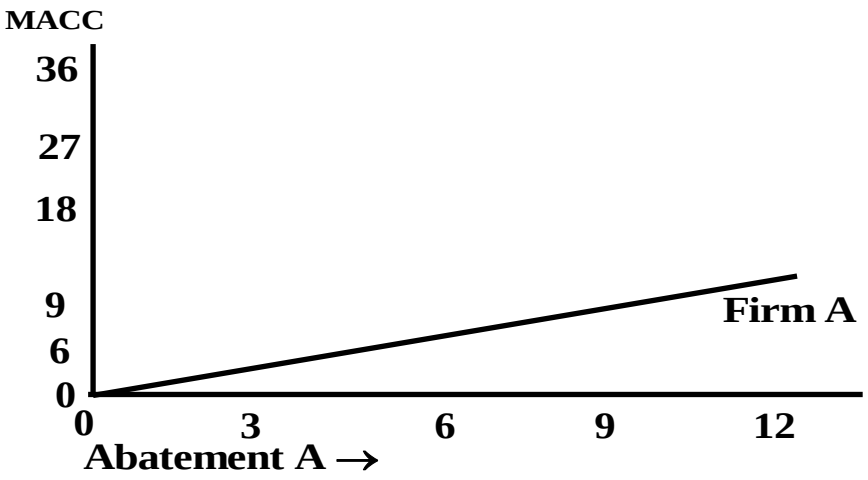


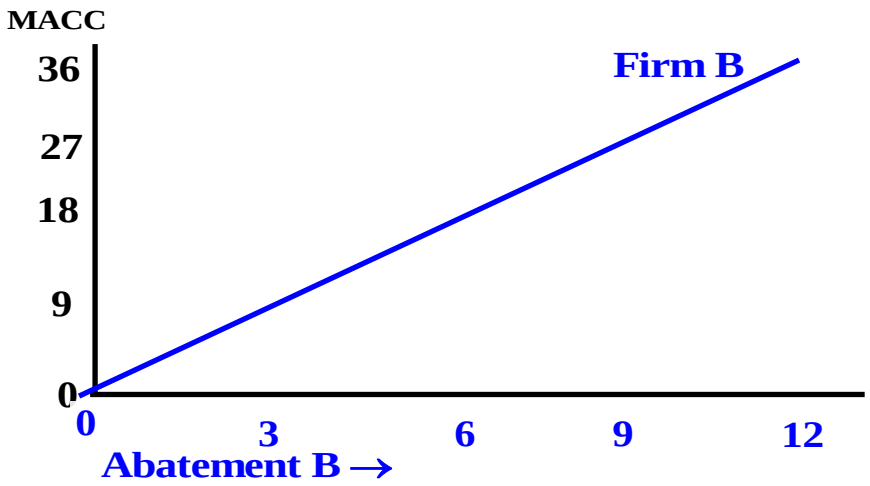


We need abatement of 12 units



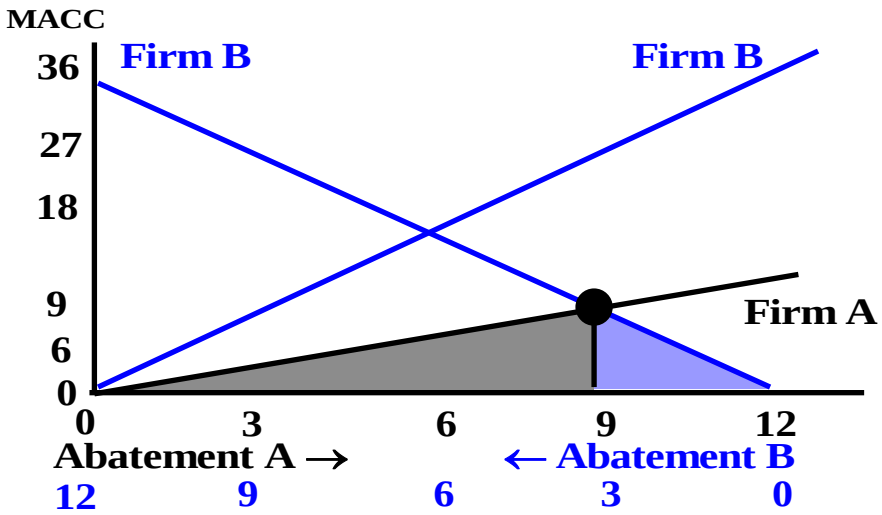
ETS





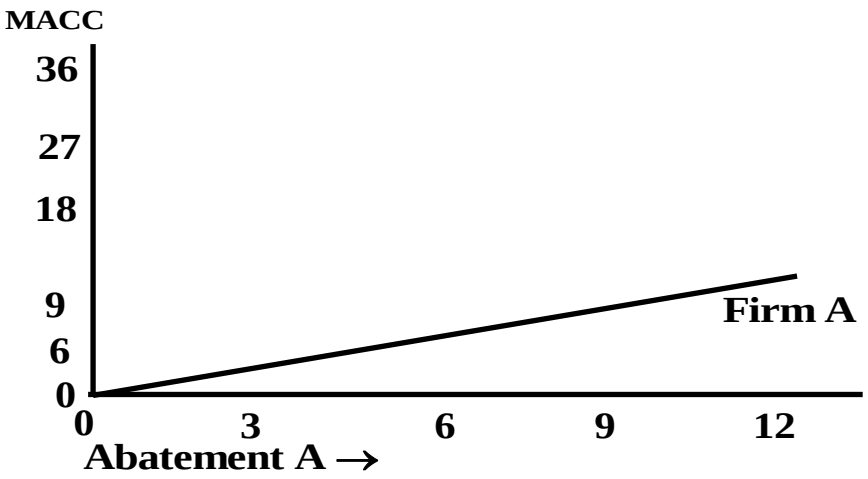
We need abatement of 12 units

$$\text{cost A} = 9 \cdot 9 \cdot \tfrac{1}{2} = 40.5 \qquad \text{cost B} = 9 \cdot 3 \cdot \tfrac{1}{2} = 13.5$$



Intersection at A:9, B:3
Any other point is suboptimal. Why?
MACC of A and B must be equal
What is the price of a permit in equilibrium?
$P = 9$
(Same as with tax!)
What are the abatement costs?
40.5+13.5=54$
(Same as with tax!)

ETS



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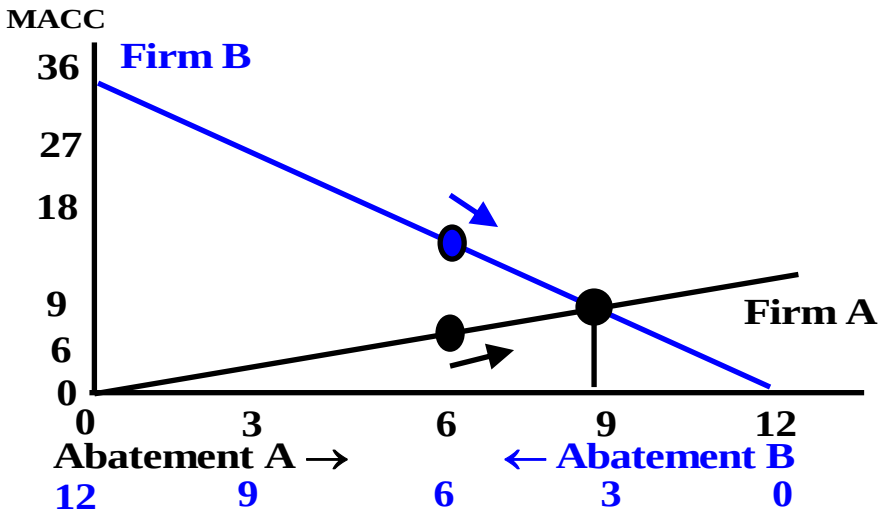


Suppose:
- The start position is A:6, B:6

What would happen?

- For A, abating a unit costs now 6$
- For B, abating a unit costs now 18$
- They could agree that A sells B a permit for a price in between, eg $10
- Then A increases profit
  - receive $10 (from B)
  - abates one more at cost of $6
  - **net increase profit: $4**
- Then B increases profit
  - pay $10 (to A)
  - abates 1 less reducing costs by $18
  - **net increase profit: $8**
- Both moved one unit to the right because of the permit trading
- Permit trading only stops once their marginal abatement costs are equal.
- This is where their MACCs cross

- With some mathematics, this analysis can be done more generally
  - But is bit more complicated
  - We need to find the demand function of a firm for permits
  - We find this by assuming that firms minimize their total cost in their production choices
  - Their choice options are:
    1. Abating (pay the abatement cost, but no permit necessary)
    2. Buy permit (pay the permit price, but no abatement necessary)

ETS

- Suppose we found out we must reduce emission by 12 units. We have two firms. Suppose each firm now (BAU) emits ***60*** units.

$macc_A[x_A] = x_A$ 

$acc_A[x_A] = \frac{1}{2}x_A^2$ $y_A = permits\ demand\ A$

$macc_B[x_B] = 3x_B$ 

$acc_B[x_B] = \frac{3}{2}x_B^2$ $y_B = permits\ demand\ B$

$$C_A[y_A] = \underbrace{\tfrac{1}{2}(60 - y_A)^2}_{\text{abatement cost}} + \underbrace{pp \cdot y_A}_{\text{permit cost}} \qquad C_B[y_B] = \tfrac{3}{2}(60 - y_B)^2 + pp \cdot y_B$$

$$\text{FOC: } 0 = \frac{dC_A[y_A]}{dy_A} \qquad \text{FOC: } 0 = \frac{dC_B[y_B]}{dy_B}$$

$$= -(60 - y_A) + pp \qquad = -3(60 - y_B) + pp$$

$$= y_A - 60 + pp \qquad = 3y_B - 3 \cdot 60 + pp$$

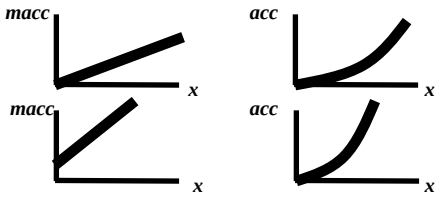
$$y_A = 60 - pp \qquad y_B = 60 - \tfrac{1}{3}pp$$

- How many permits GOV supplied in BAU?
  - 120
- How much permits GOV now supplies to get 12 units reduction?
  - 120-12=**108** $y_A + y_B = 108$

ETS

- Suppose we found out we must reduce emission by 12 units. We have two firms. Suppose each firm now (BAU) emits 60 units.

$$macc_1[x_1] = 2x_1 \qquad macc_2[x_2] = 3x_2 + 5$$



$$acc_1[x_1] = x_1^2 \qquad acc_2[x_2] = 1.5x_2^2 + 5x_2$$

$$y_A = \underbrace{60 - pp}_{y_A} \quad (+ y_B) = 51 \qquad y_B = \underbrace{60 - \tfrac{1}{3}pp}_{y_B} = 57$$

$$\Rightarrow 60 - pp + 60 - \tfrac{1}{3}pp = 108$$

$$\Leftrightarrow -pp - \tfrac{1}{3}pp = -12$$

$$\Leftrightarrow \tfrac{4}{3}pp = 12$$

$$\Leftrightarrow pp = \boxed{9}$$

$$x_A = 60 - y_A = 60 - 51 = \boxed{9}$$

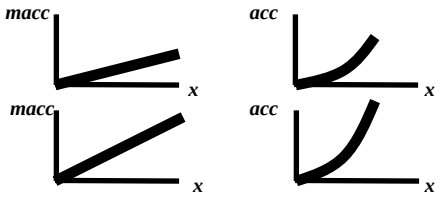
$$x_B = 60 - y_B = 60 - 57 = \boxed{3}$$

- How are we sure this is the right answer?
- Compare the outcomes to the optimal carbon tax!
- Abatement must be same & *pp=t*!

Tax

- Suppose we found out we must reduce emission by 12 units. We have two firms

$$macc_A[x_A] = x_A \qquad acc_A[x_A] = \tfrac{1}{2}x_A^2$$
$$macc_B[x_B] = 3x_B \qquad acc_B[x_B] = \tfrac{3}{2}x_B^2$$



regulatory standards

- Each firm reduces emissions by 6

$$ac_A = \tfrac{1}{2}\cdot 6^2 = 18$$
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$$Tac = 18 + 54 = 72$$

Carbon tax

$$macc_A = macc_B = t$$
$$x_A = 3x_B = t$$
$$t = 9$$

$$x_A + x_B = 12$$
$$3x_B + x_B = 12$$
$$\Leftrightarrow \quad x_B = 3$$
$$x_A = 9$$

$$ac_A = \tfrac{1}{2}\cdot 9^2 = 40.5$$
$$+\ ac_B = \tfrac{3}{2}\cdot 3^2 = 13.5$$
$$Tac = 40.5 + 13.5 = 54$$

- If:
  - you need to calculate things regarding an ETS,
  - you are only interested in the permit price *pp*, and the abatement by each firm
- Then:
  - you can simply calculate the optimal tax.

Economics of pollution

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3. Introduce 2 possible solutions
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    2. Emission Trading Scheme (ETS) ✓
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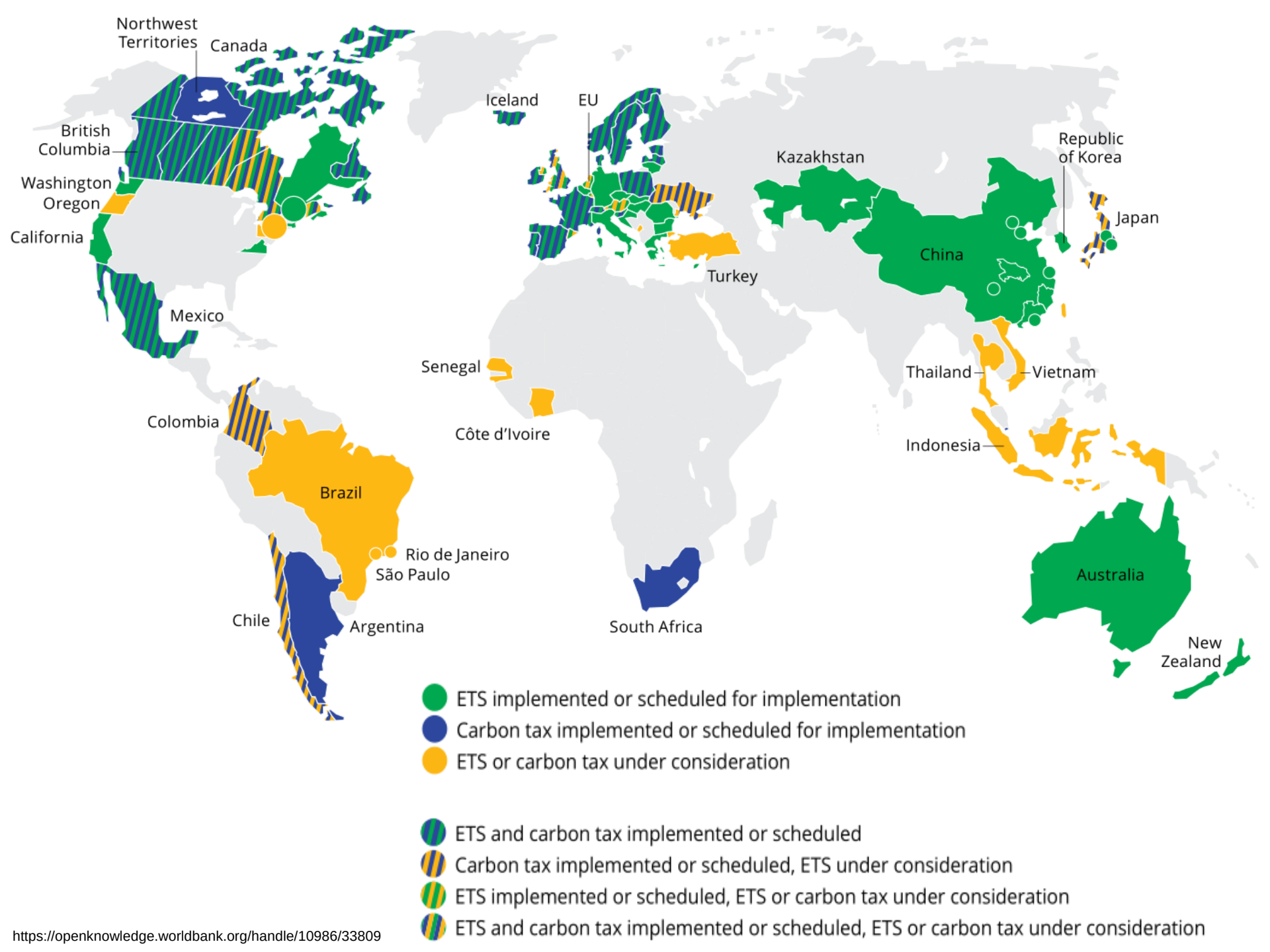
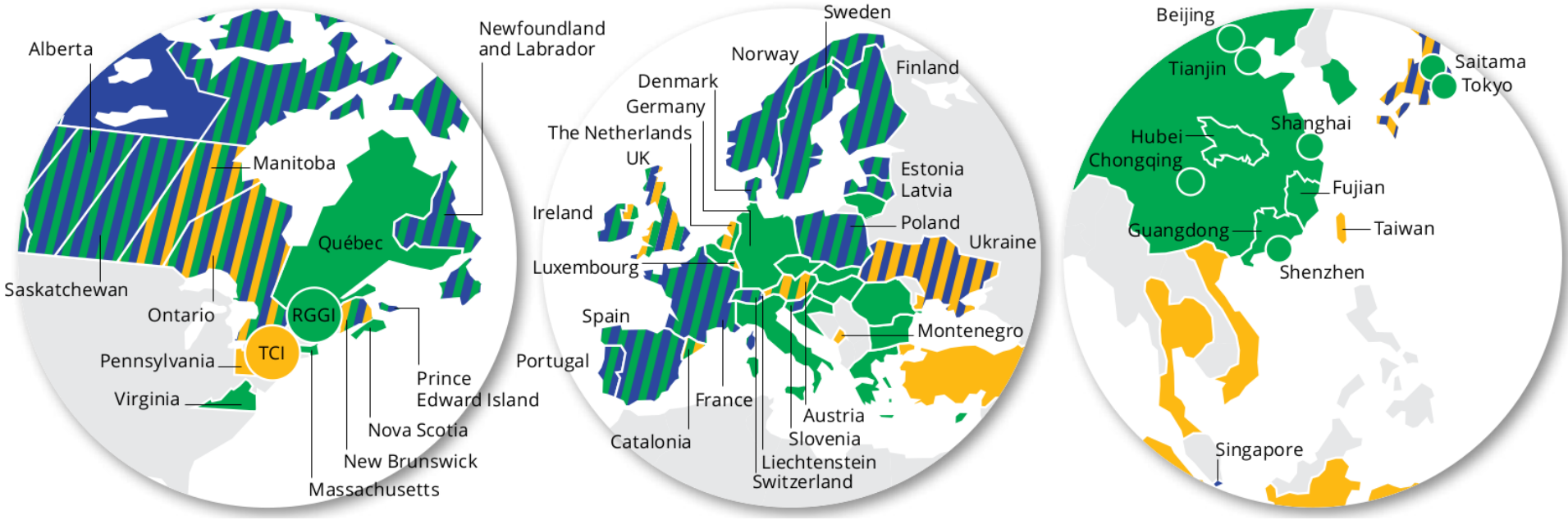
4. Overview carbon taxation & ETS in the world





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- So many countries are considering to add a tax on top!
  - (Why have ETS ***and*** carbon tax?)

ETS implemented or scheduled for implementation
Carbon tax implemented or scheduled for implementation
ETS or carbon tax under consideration

ETS and carbon tax implemented or scheduled
Carbon tax implemented or scheduled, ETS under consideration
ETS implemented or scheduled, ETS or carbon tax under consideration
ETS and carbon tax implemented or scheduled, ETS or carbon tax under consideration

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Share of global emissions covered by carbon pricing initiatives (ETS and carbon tax)

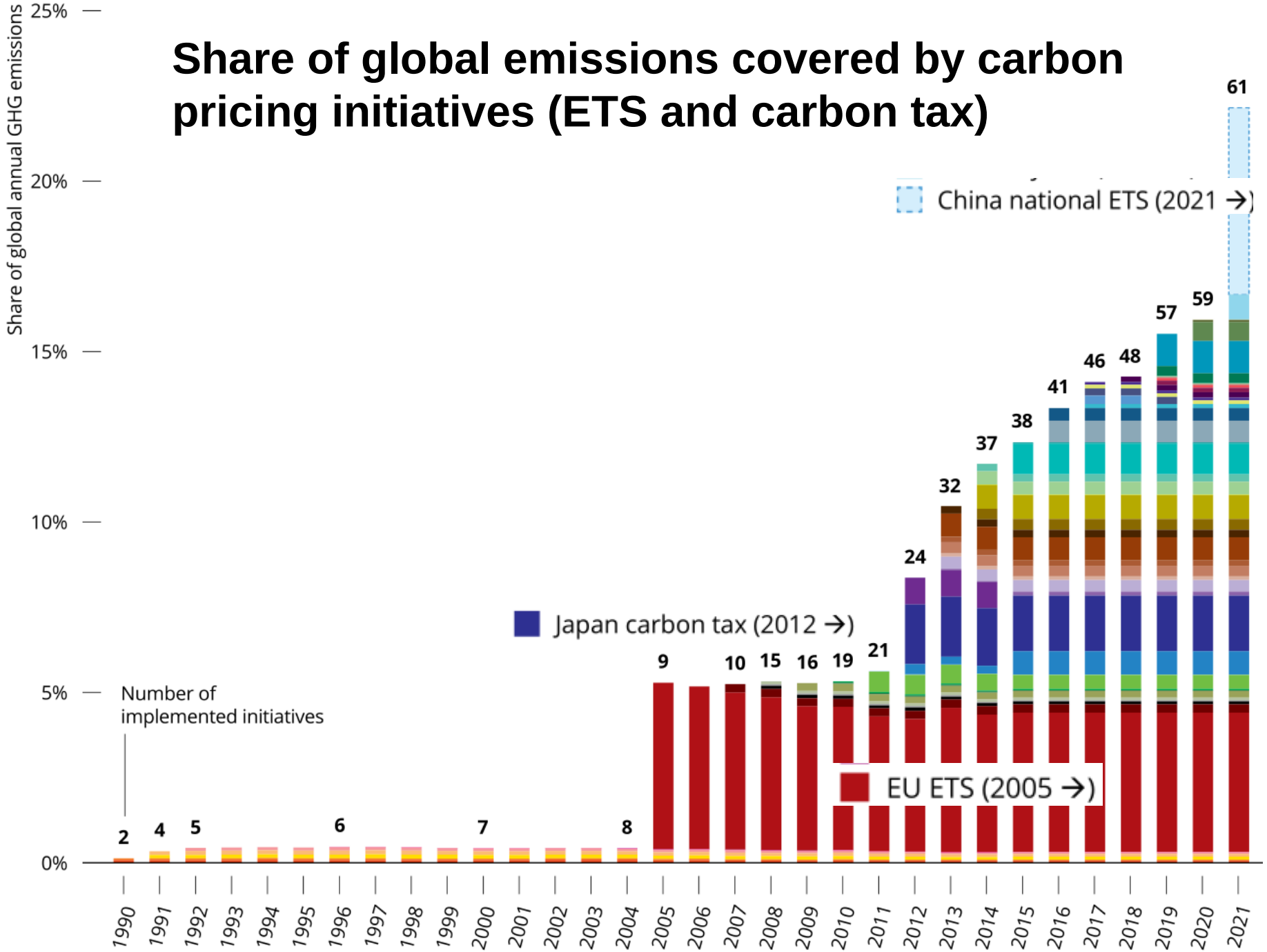

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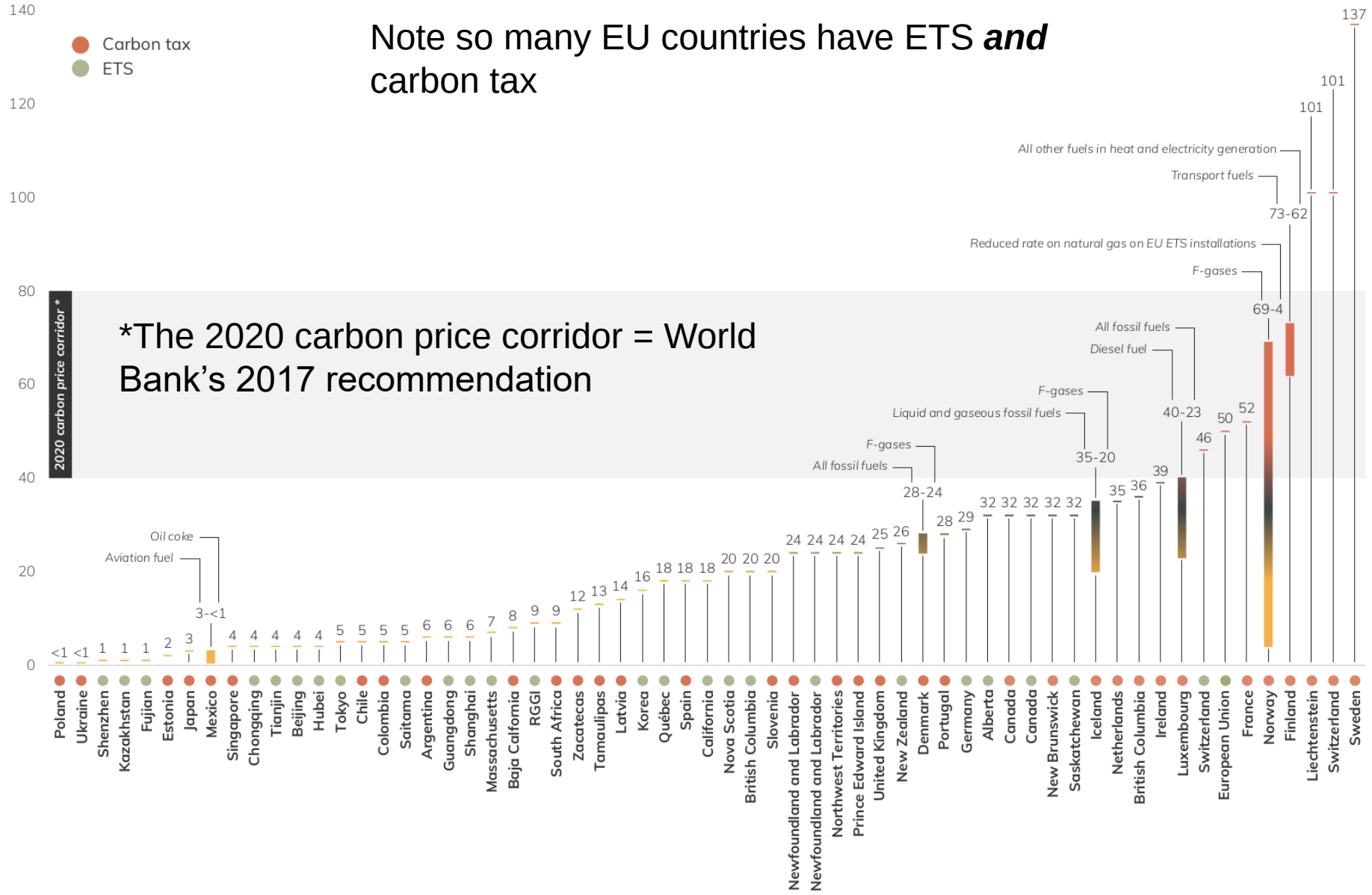
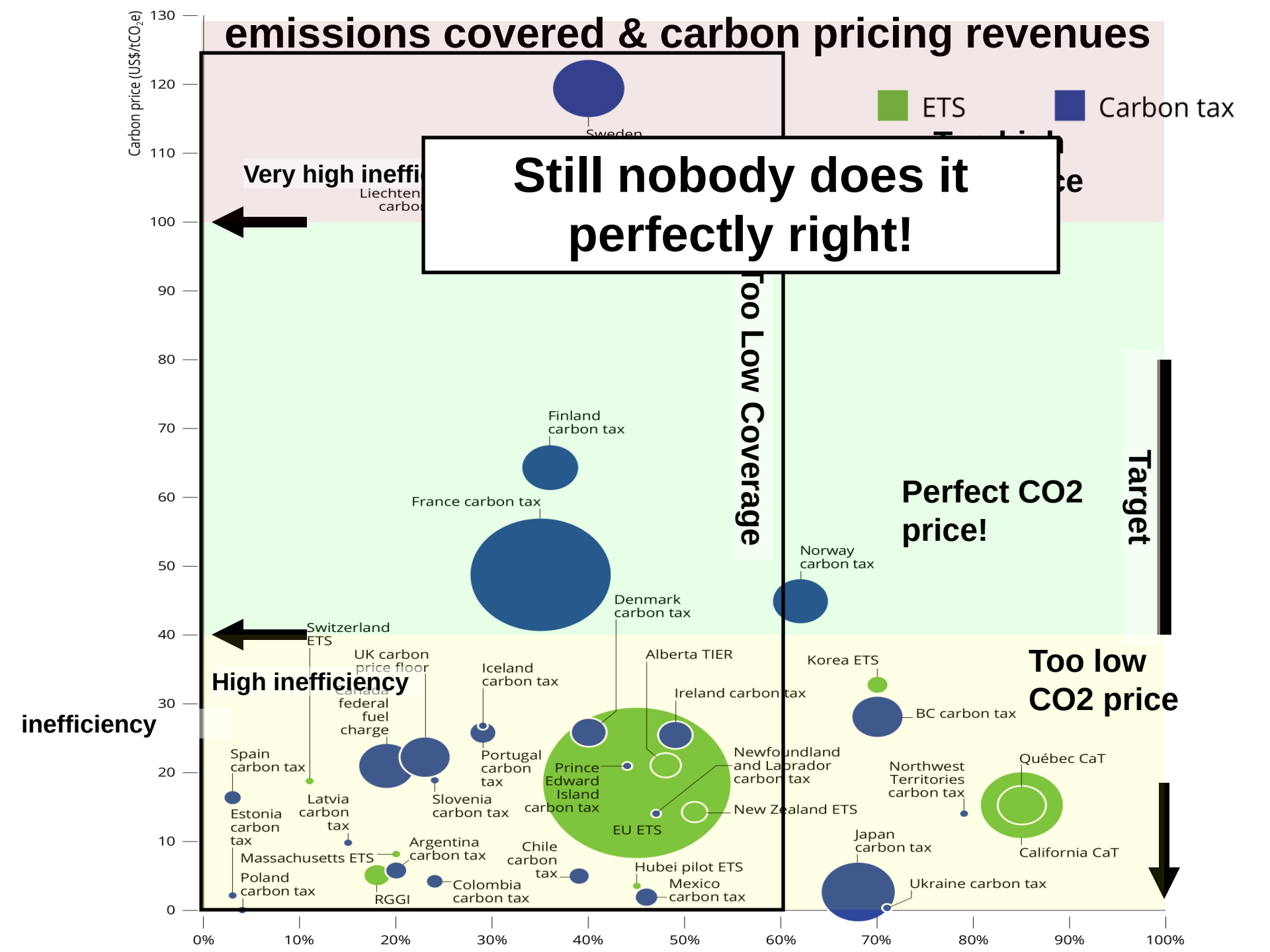
FIGURE 2.3
Carbon prices as of April 1, 2021




emissions covered & carbon pricing revenues
ETS
Carbon tax
Carbon price (US$/tCO2e)
Still nobody does it perfectly right!
Very high ineffi
Too Low Coverage
Target
Perfect CO2 price!
High inefficiency
Too low CO2 price
inefficiency
Sweden
Finland carbon tax
France carbon tax
Norway carbon tax
Denmark carbon tax
Switzerland ETS
UK carbon price floor
Iceland carbon tax
Alberta TIER
Ireland carbon tax
Korea ETS
BC carbon tax
Canada federal fuel charge
Spain carbon tax
Portugal carbon tax
Prince Edward Island carbon tax
Newfoundland and Labrador carbon tax
Québec CaT
Northwest Territories carbon tax
Estonia carbon tax
Latvia carbon tax
Slovenia carbon tax
EU ETS
New Zealand ETS
Japan carbon tax
California CaT
Massachusetts ETS
Argentina carbon tax
Chile carbon tax
Hubei pilot ETS
Poland carbon tax
RGGI
Colombia carbon tax
Mexico carbon tax
Ukraine carbon tax
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

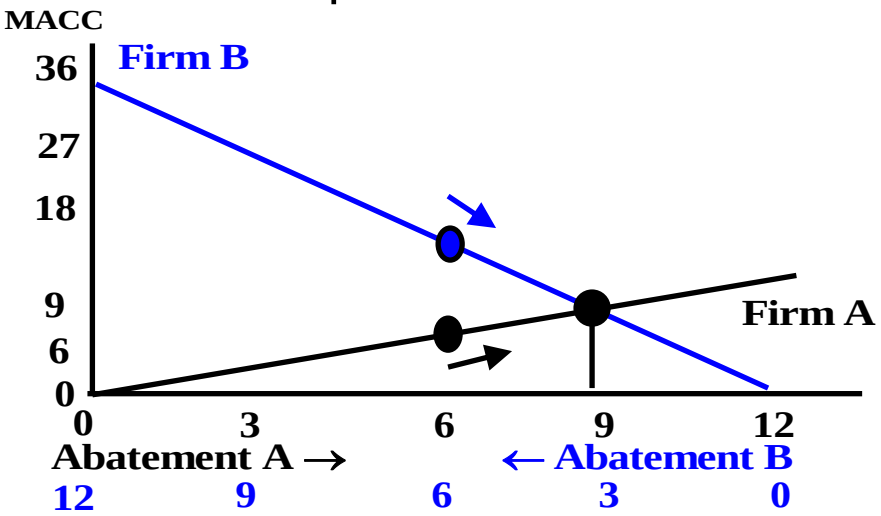
Carbon taxes concretely

- What should be the global carbon tax in $?
  - $40~$100/ton CO2
  - increase with 2% a year (inflation correction)
- So maximum for traveling 1000km:
  - For car:
    - ~$14 for car (for the whole car)
      - ~0.2 kg/km = 0.2 ton/1000km -> $8~$20
  - For plane:
    - ~$14 taking plane (per person)
      - ~0.2 kg/km = 0.2ton/1000km -> $8~$20
  - **But, you would pay only about 40%~75% of this in LT!**
    - Because industry will start to make transport less polluting
    - low-emission technologies will replace high-emission ones
- Numbers are somewhat sensitive about assumptions of type of car/plane, how many people in the car/plane, how high the plane flies, etc…

Conclusion

- The number of countries putting a price on CO2 is increasing
  - Either by tax, ETS or both
- However, the price is mostly wrong
  - Too low, sometimes far too low (<$2)
  - In a few individual cases too high ($137)

- **Most visible source of efficiency loss due to:**
  - only part of emitting activities taxed
  - Different carbon prices



- Efficiency requires that the marginal abatement cost is the same
  - In all countries
  - Over all activities in each country
    - Producing electricity
    - Driving a car
    - Agricultural activities (breeding cows for beef)
- A tax in the range $40-$100/Ton would affect costs, but not dramatically
  - Planes more than (full) car drives

Economics of pollution

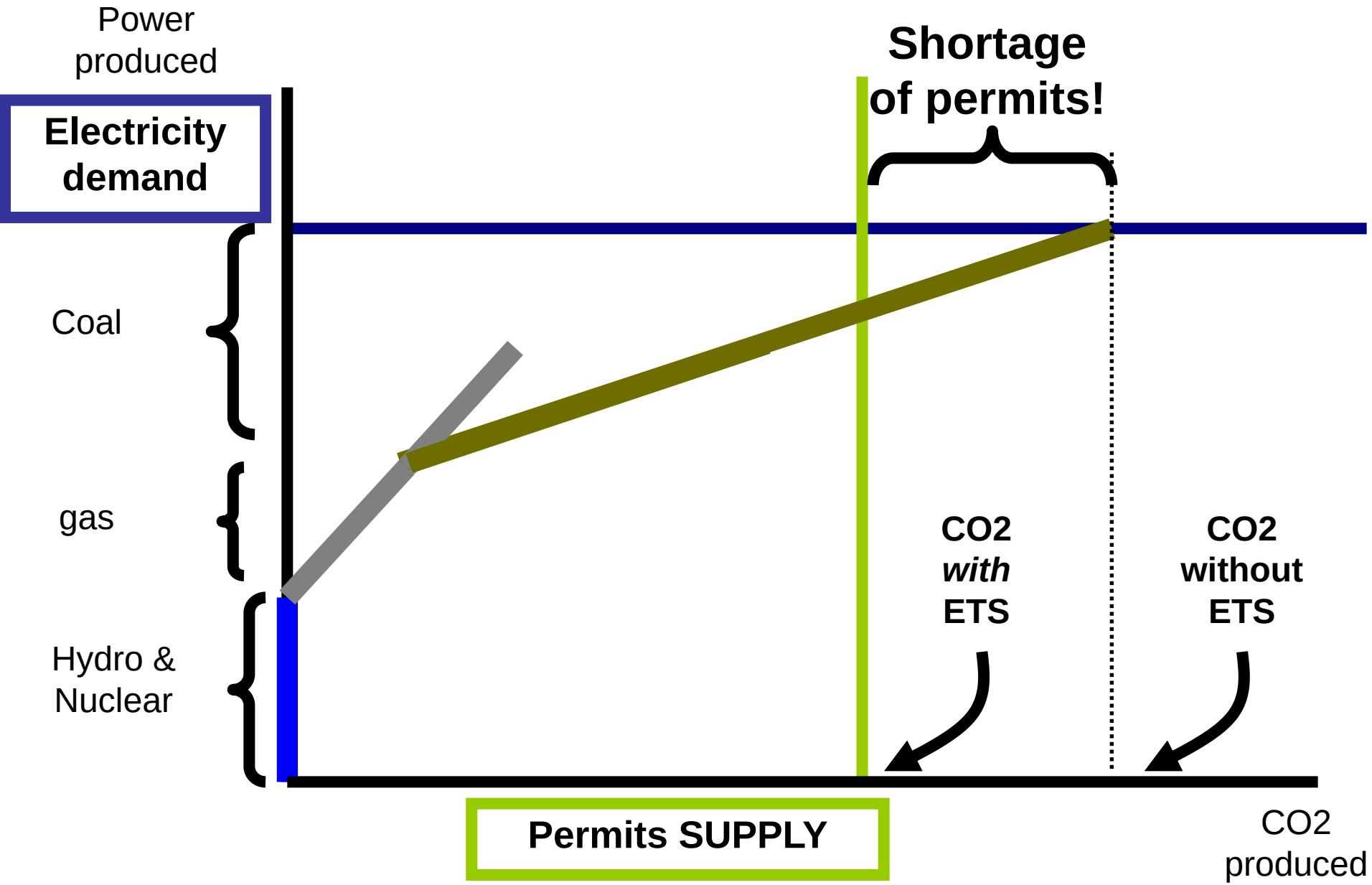
1. Refresh free market economics basics ✓
2. Introduce carbon emissions as an externality ✓
3. Introduce 2 possible solutions
    1. Carbon Tax ✓
    2. Emission Trading Scheme (ETS) ✓
4. Overview carbon taxation & ETS in the world ✓
5. ETS & substituting high-emission tech for low-emission tech.
6. What is better, carbon tax or ETS?

ETS

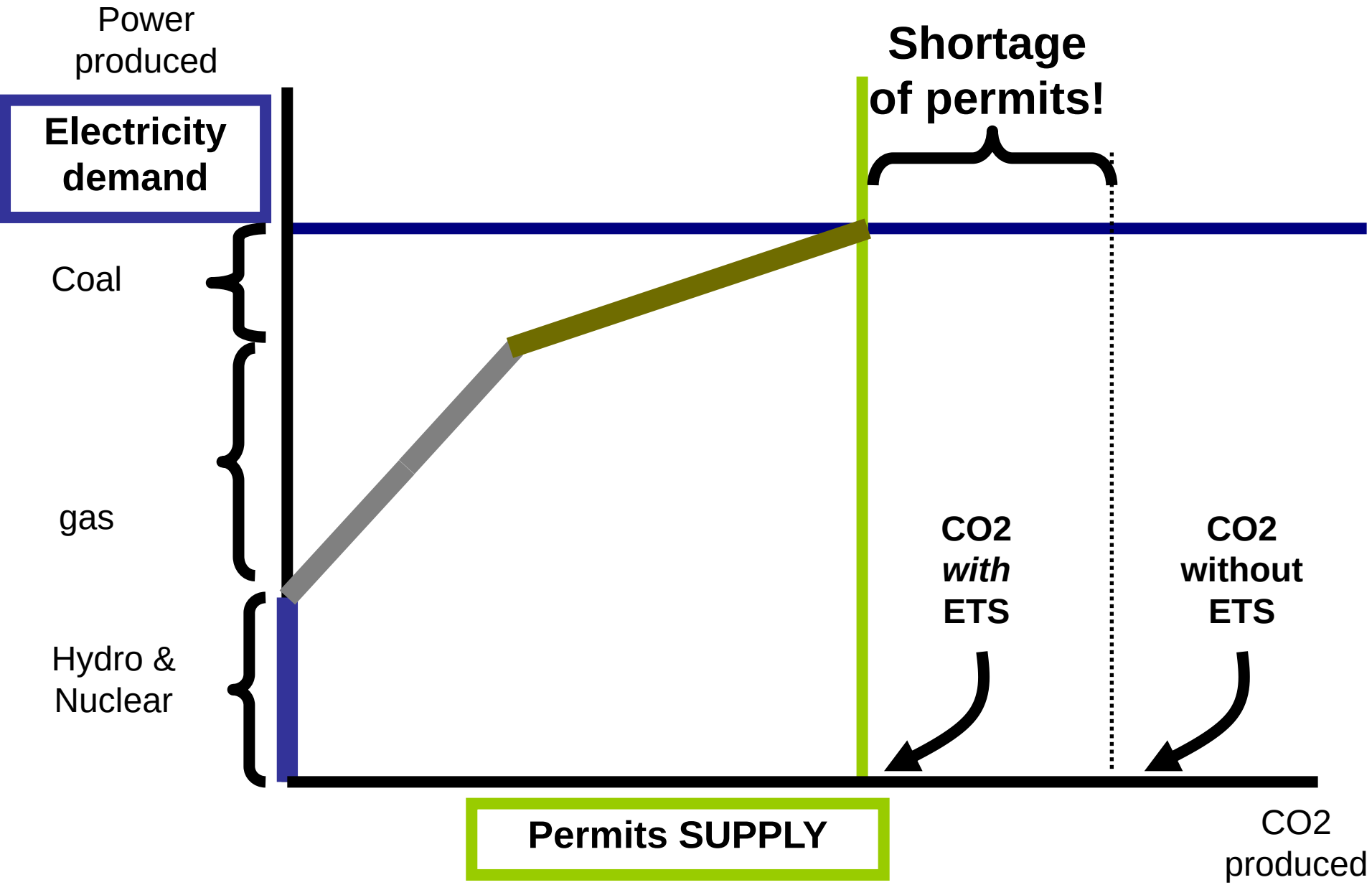
6. ETS & substituting high-emission tech for low-emission tech.

   The example of coal-gas switching

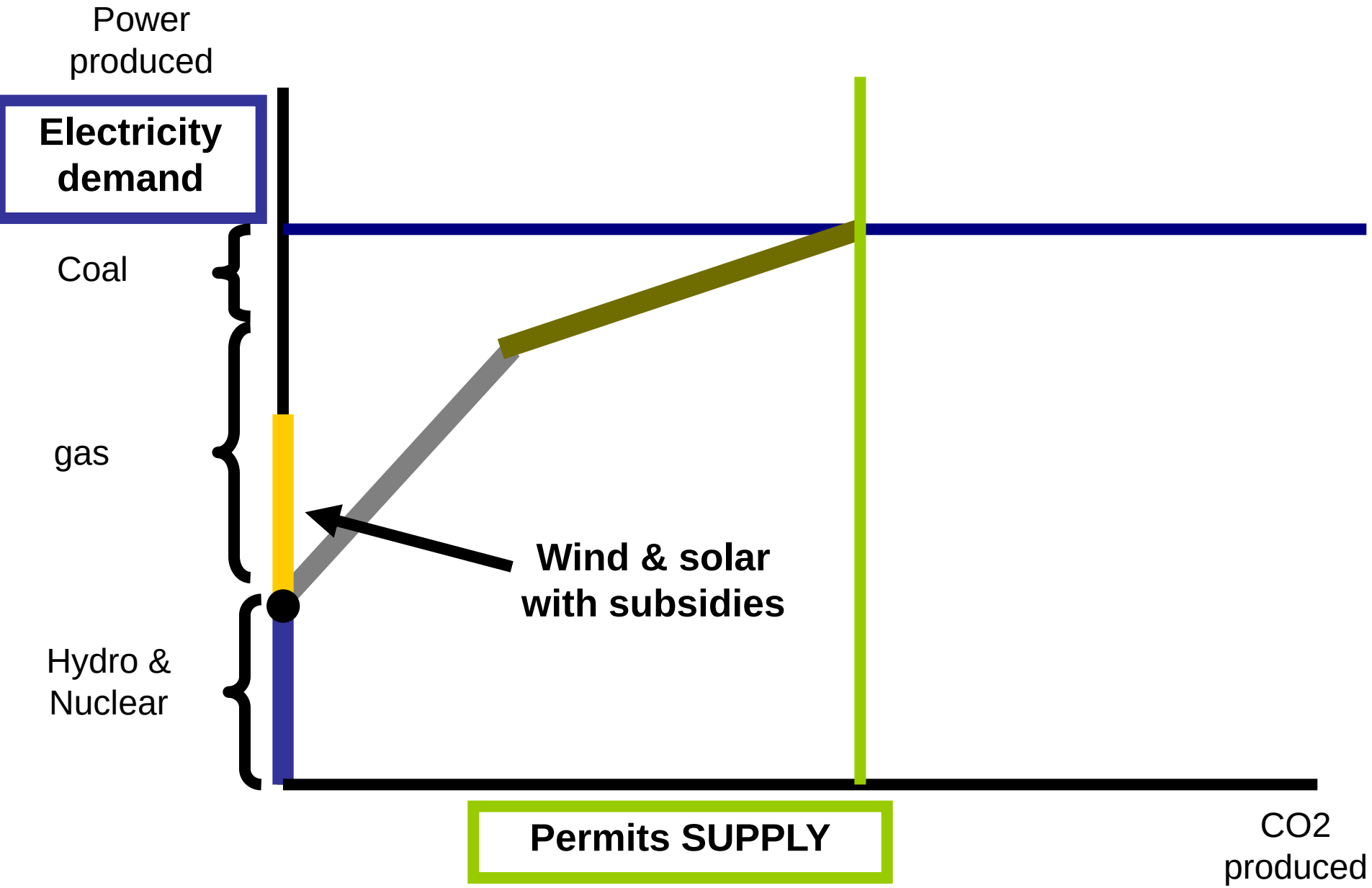
ETS reduces CO2 emissions



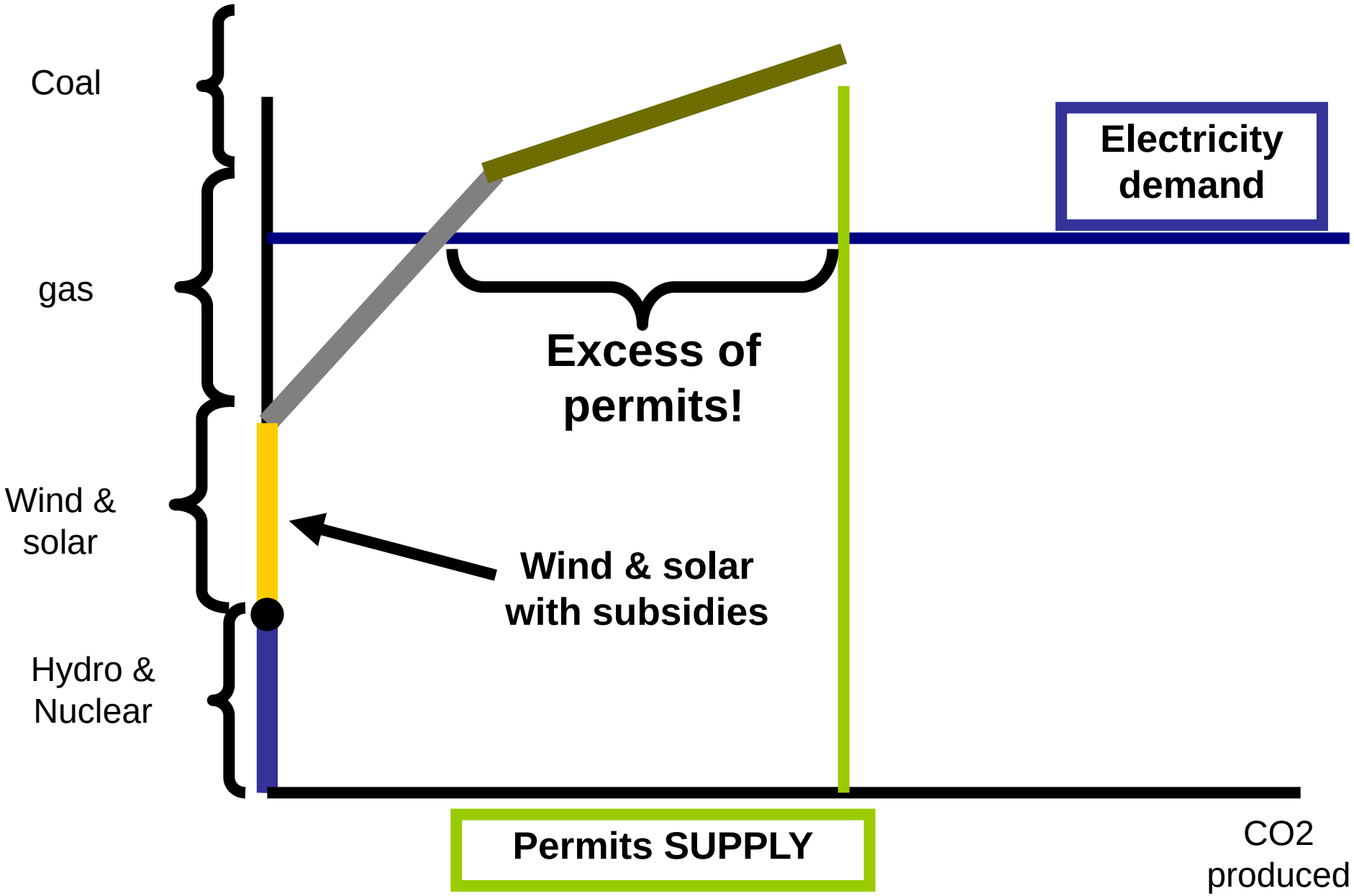
ETS reduces CO2 emissions



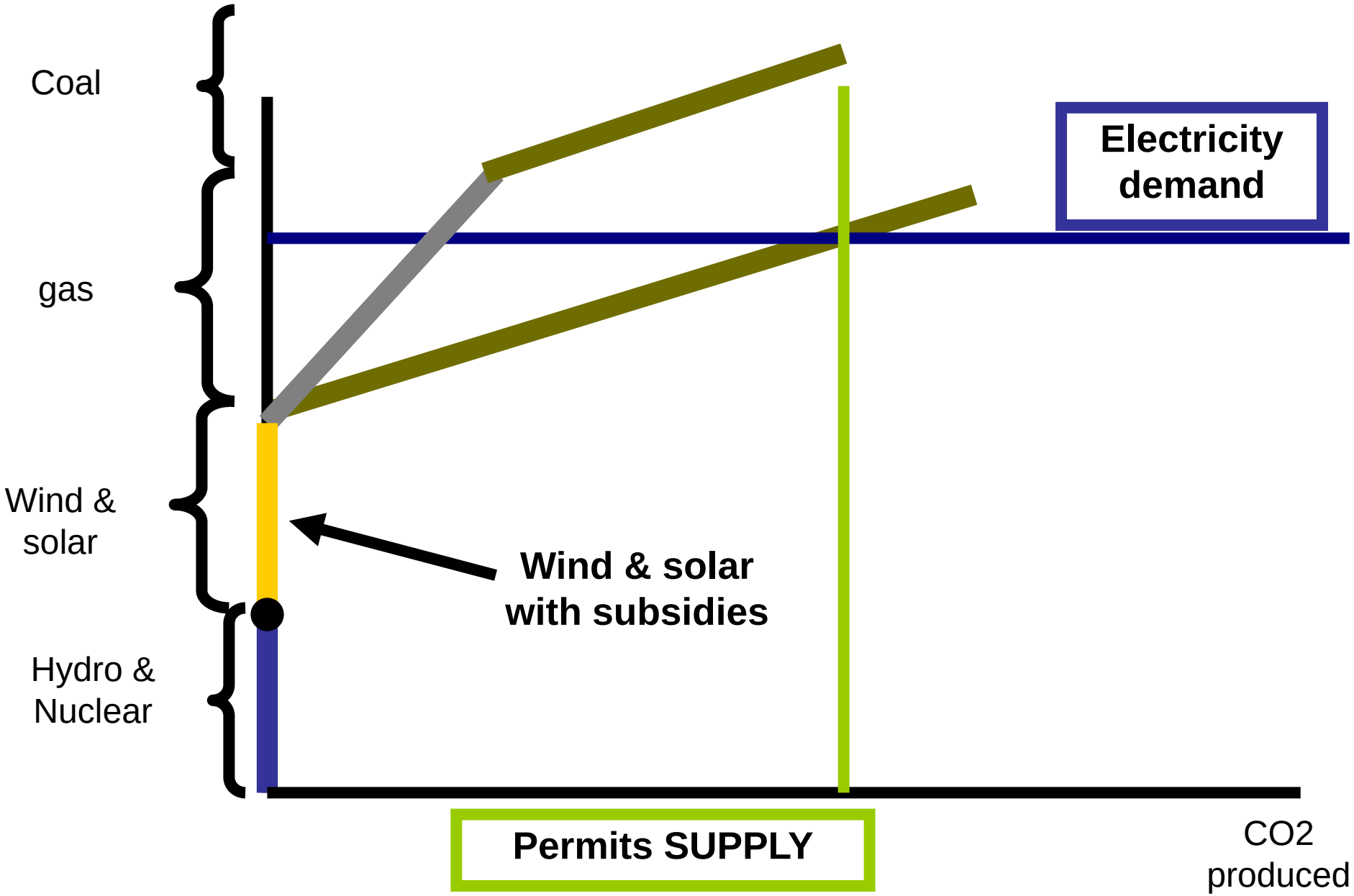
ETS affects generation choices



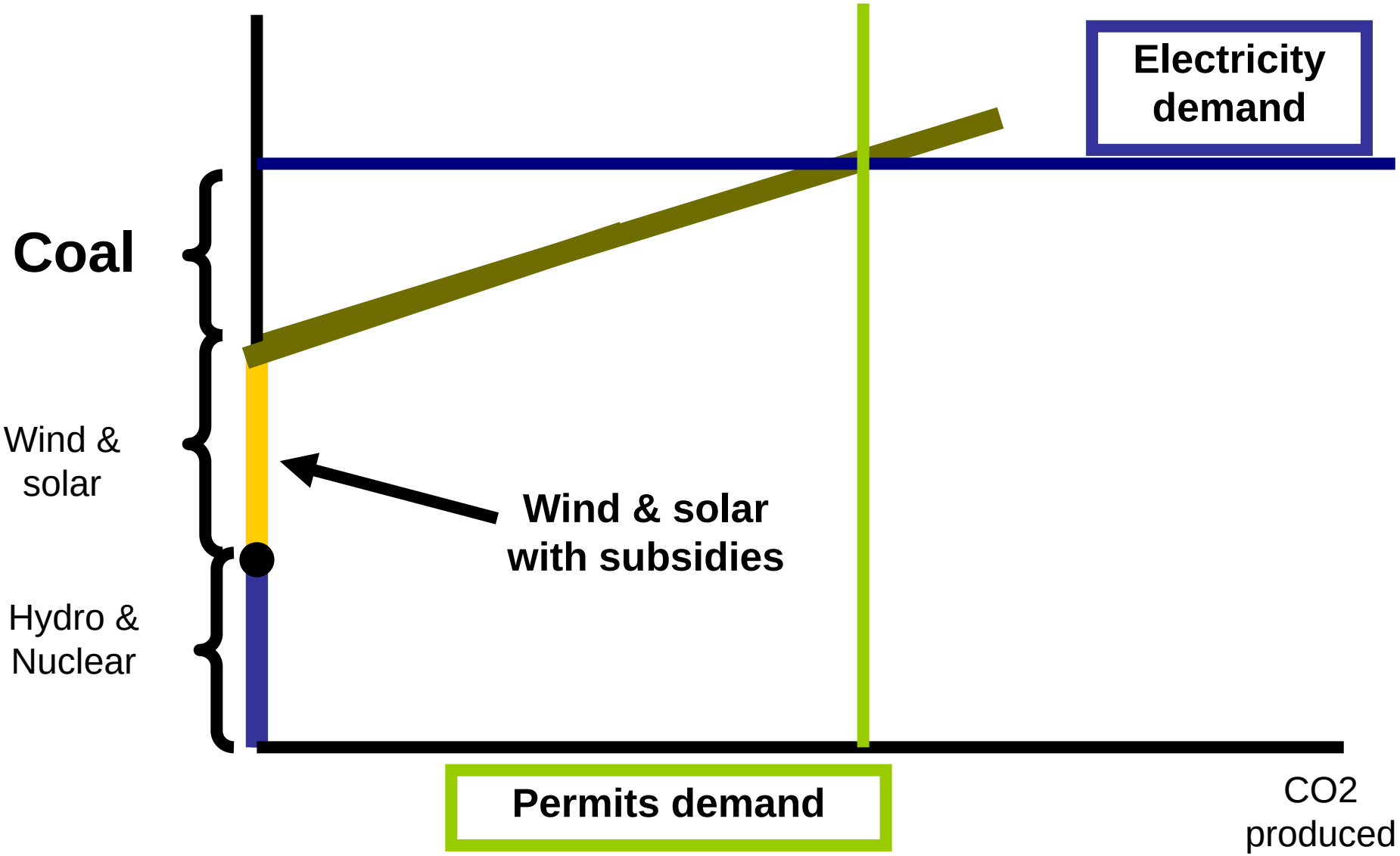
ETS affects generation choices



ETS affects generation choices



ETS affects generation choices



Carbon Taxing

1. Refresh free market economics basics
2. Introduce carbon emissions as an externality
3. Introduce carbon tax
4. Overview carbon taxation in the world
5. How to divide the abatement task in the world?
6. Carbon taxation case for power generation industry

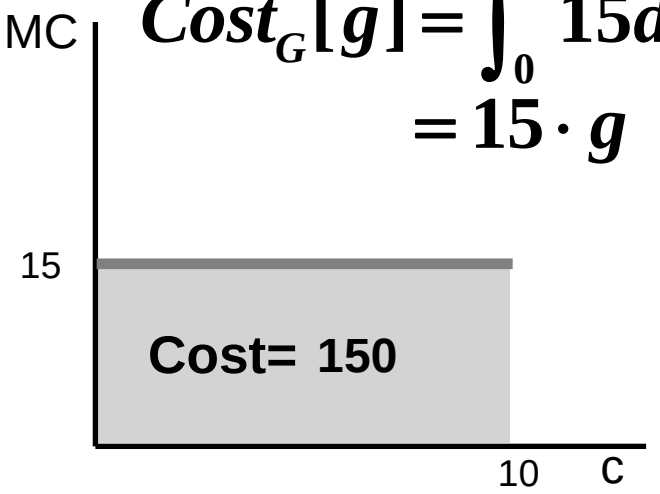
Elective

- (Not part of the course or exam)

- Let’s create a basic model

Gas:
- MC=15
- FC=0
- Em=1

$$Cost_G[g] = \int_0^g 15\,dj = 15 \cdot g$$



Y = Energy produced (GWh)

Electricity demand

10

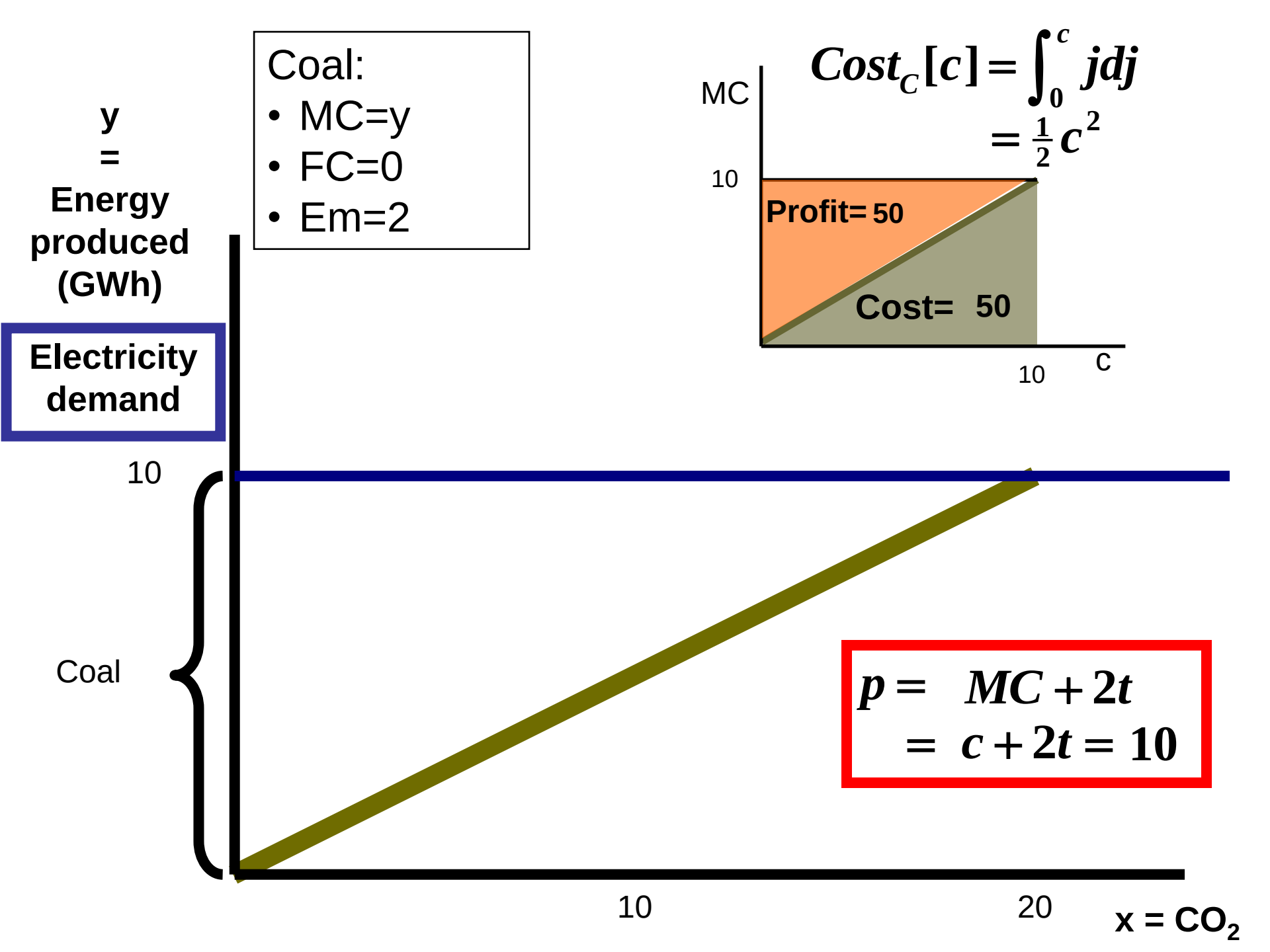
Gas

10

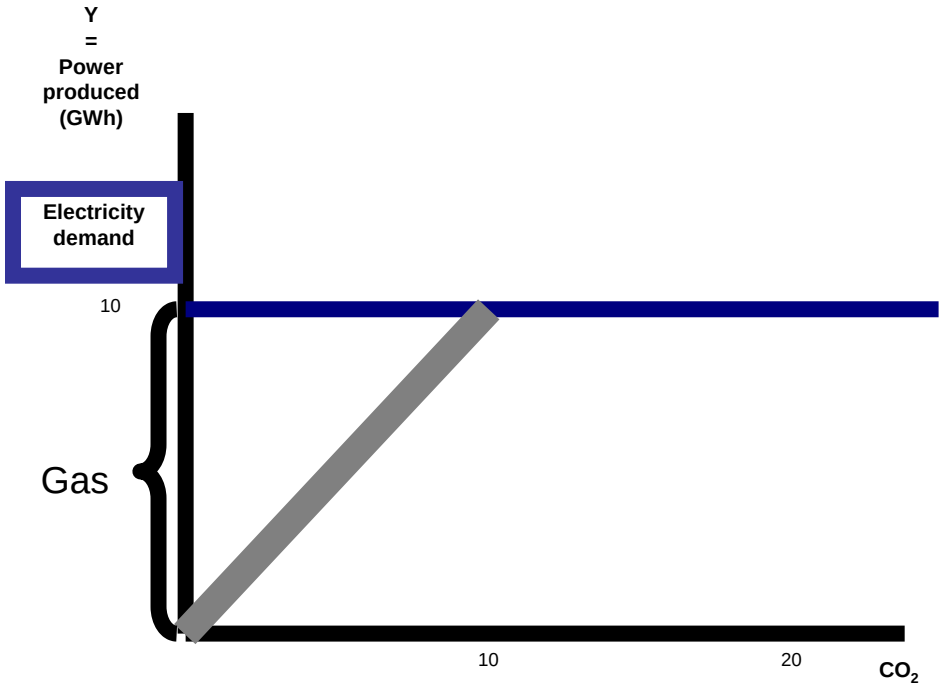
20

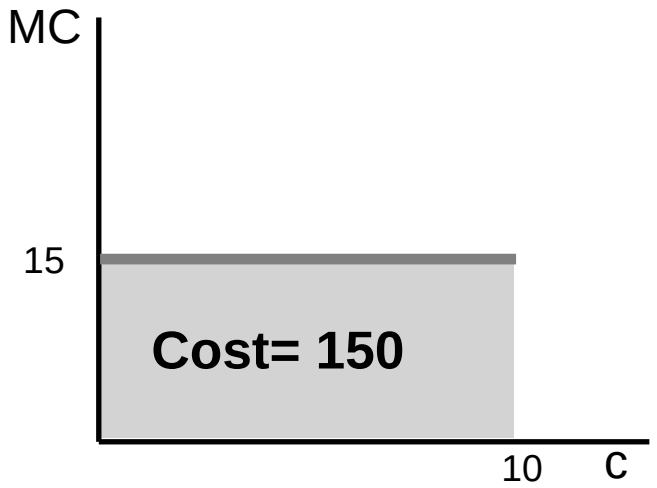
CO_2

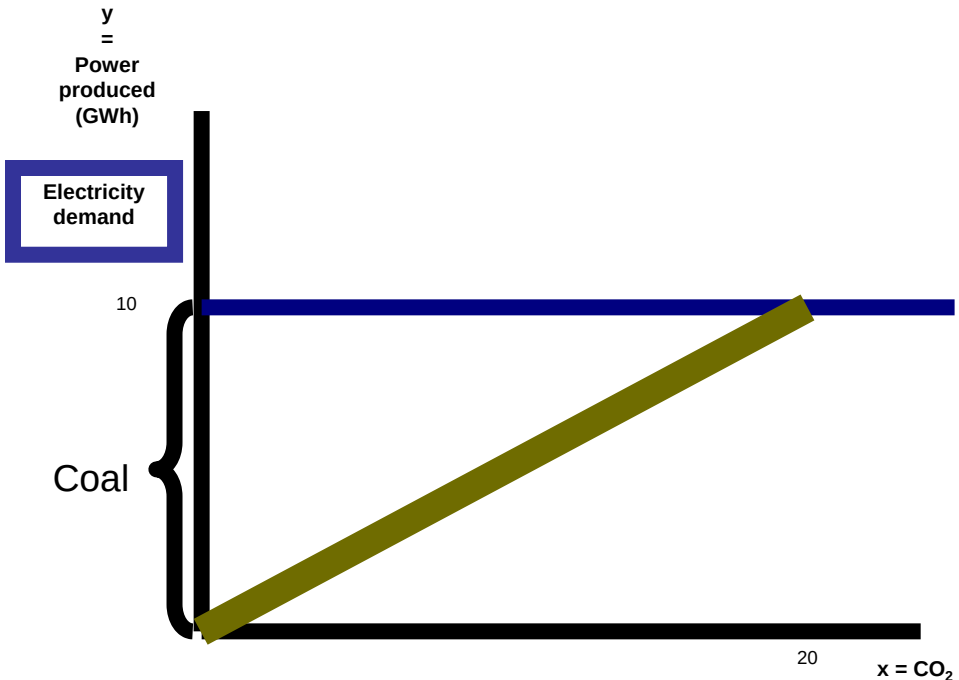
$$p = MC + t = 15 + t = 15$$

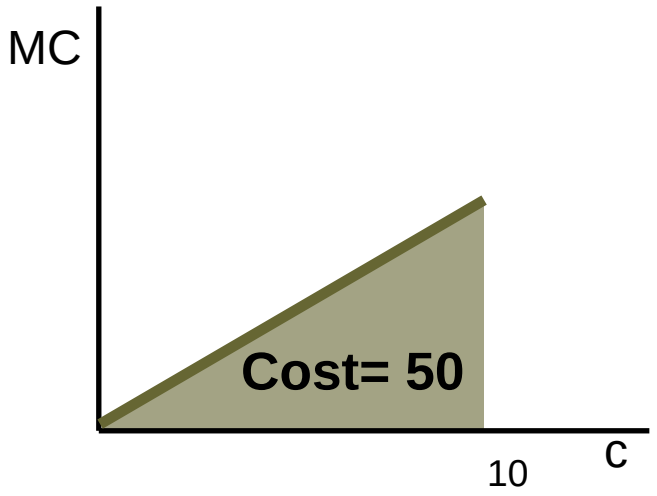

Coal:
• MC=y
• FC=0
• Em=2
$Cost_C[c] = \int_0^c jdj$
$= \frac{1}{2}c^2$
MC
10
Profit= 50
Cost= 50
10
c
y
=
Energy produced (GWh)
Electricity demand
10
Coal
$p = MC + 2t$
$= c + 2t = 10$
10
20
x = CO_2

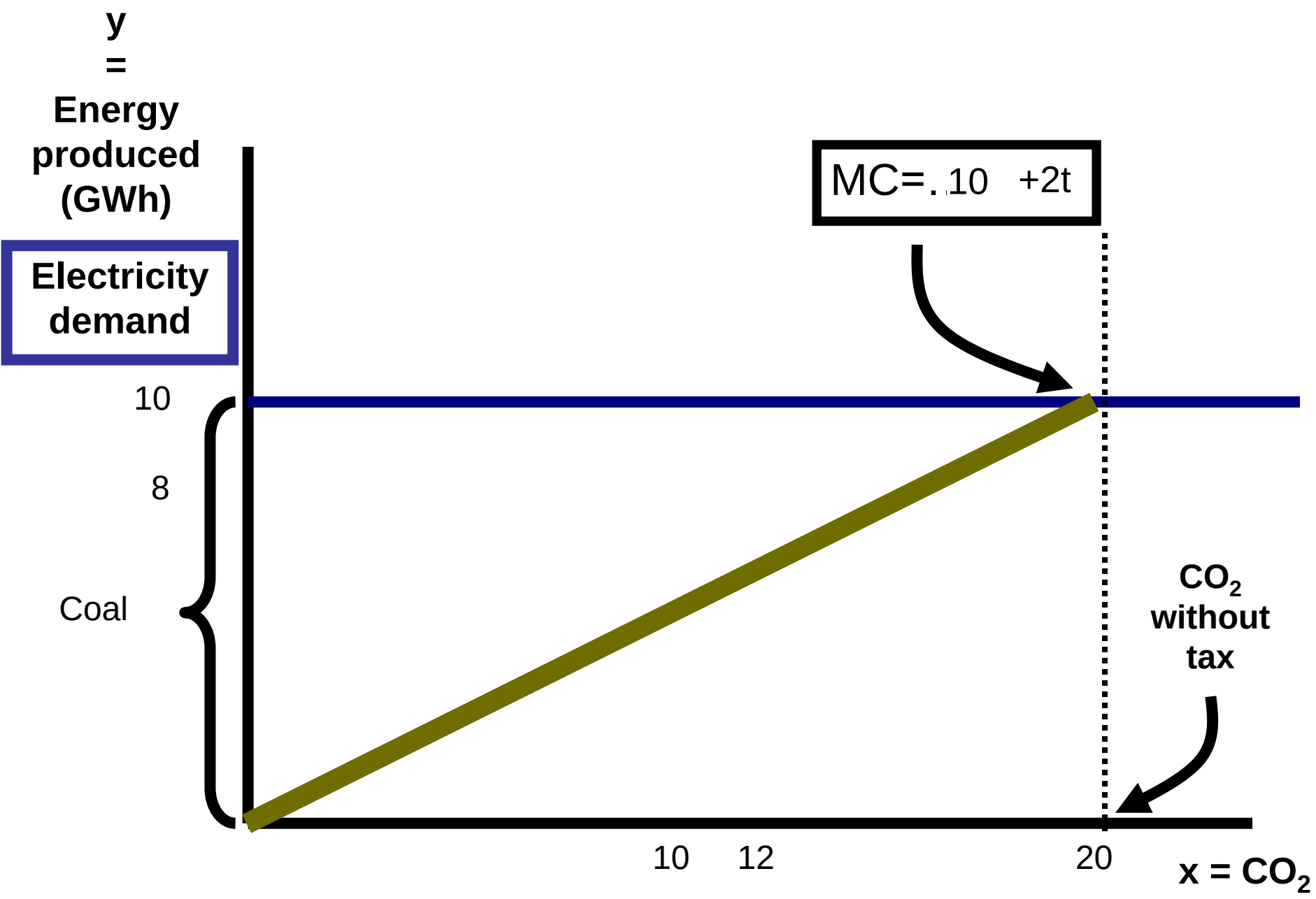
Which one to use?










y
=
Energy produced (GWh)
Electricity demand
MC=.10 +2t
10
8
Coal
CO_2 without tax
10
12
20
x = CO_2

	System Costs (Payment under perfect redistribution)	Coal Profit	Total paid for solar subsidy	Energy Price	Total paid for energy	Tax (t)	Tax revenue
1. No policy	50	50	-	10	100	0	0
2. Carbon tax							

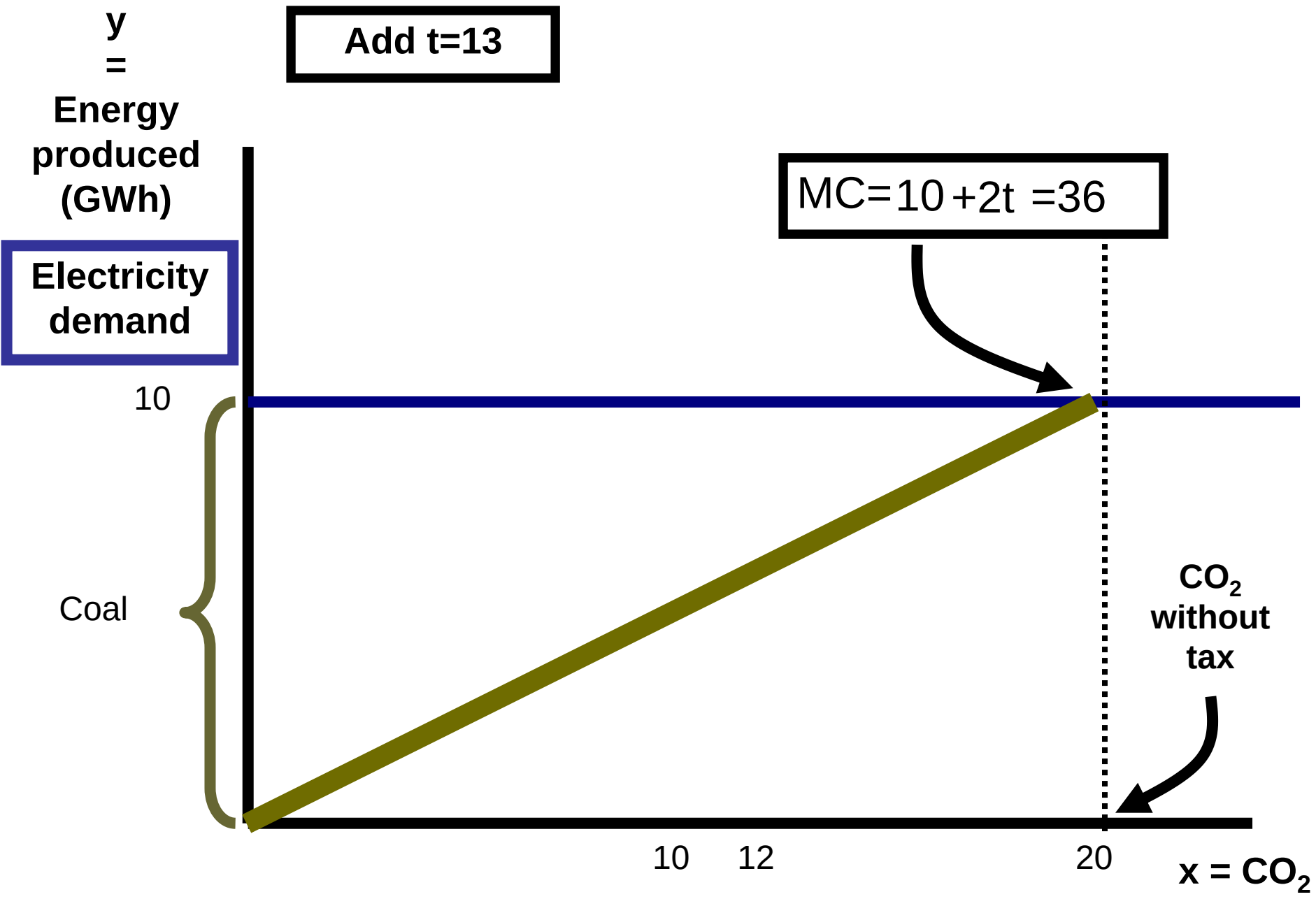
Note:

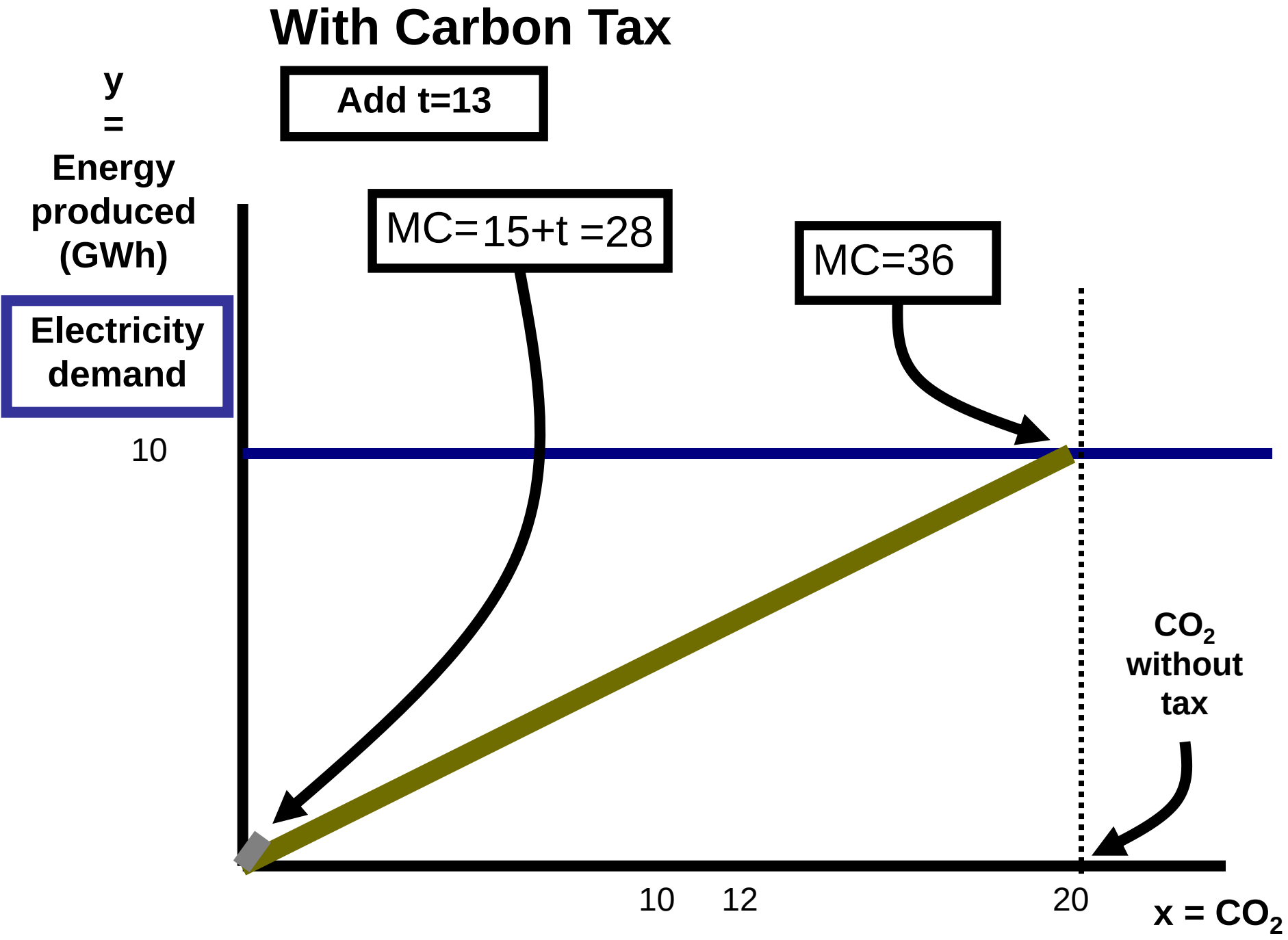
System cost + Coal Profit + Tax revenue

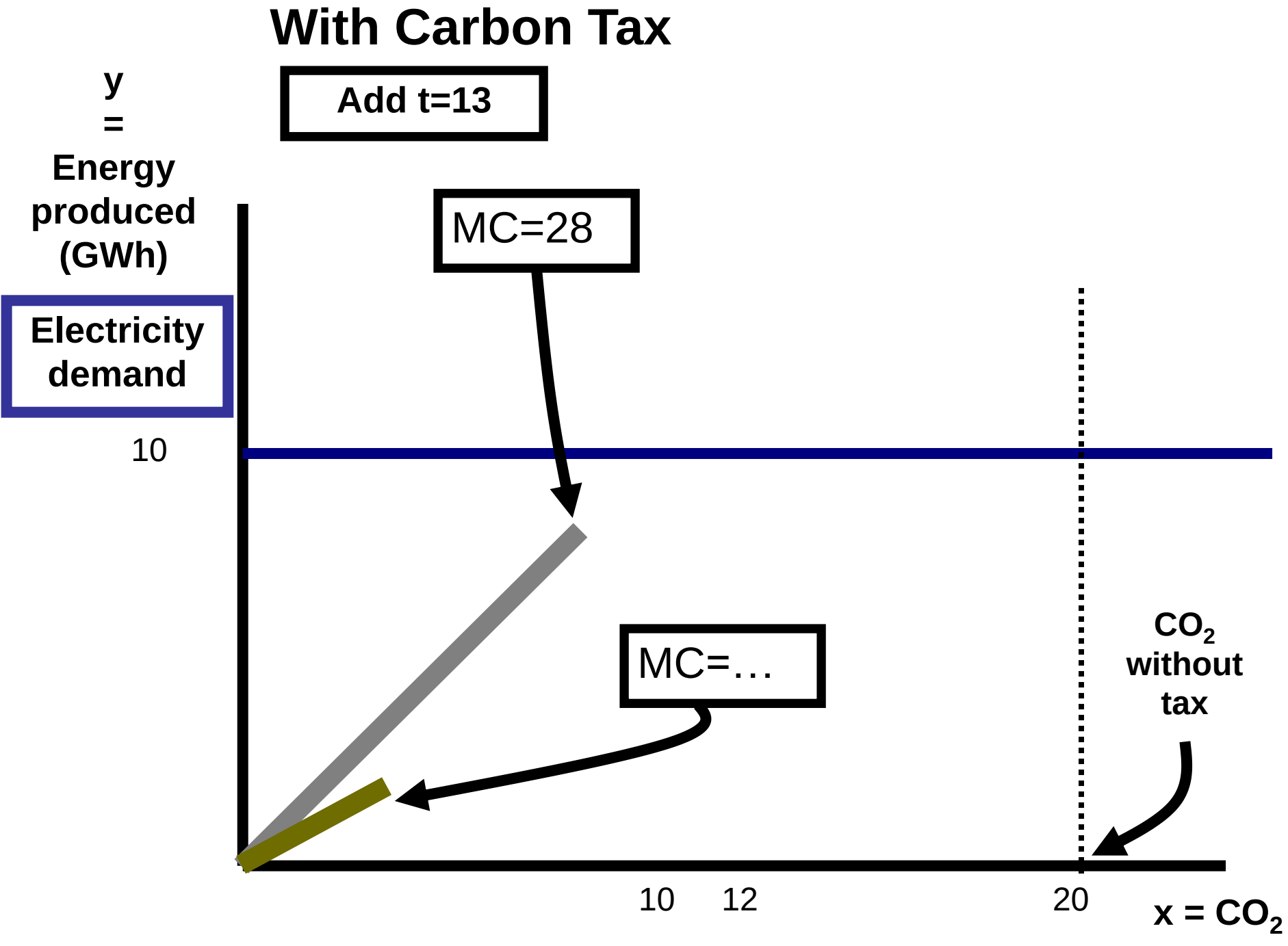
= Total paid for energy

Profit by Coal = 10 * 10 * .5 = 50

With Carbon Tax



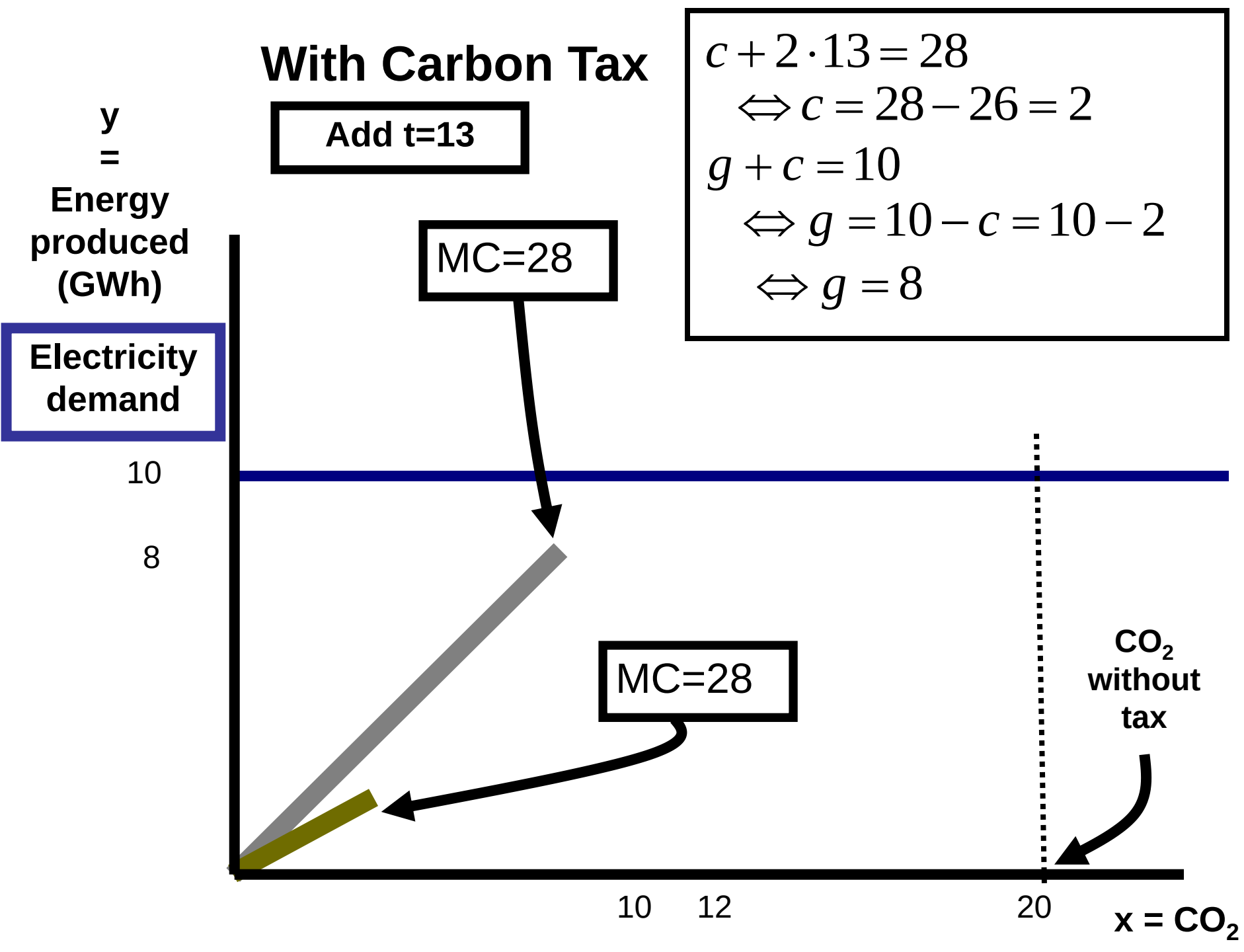

With Carbon Tax
Add t=13
y
=
Energy produced (GWh)
Electricity demand
MC=15+t =28
MC=36
10
CO_2 without tax
10
12
20
x = CO_2


With Carbon Tax
Add t=13
y
=
Energy produced (GWh)
Electricity demand
MC=28
10
MC=…
CO_2 without tax
10
12
20
x = CO_2

With Carbon Tax

Add t=13

$$c + 2 \cdot 13 = 28$$
$$\Leftrightarrow c = 28 - 26 = 2$$
$$g + c = 10$$
$$\Leftrightarrow g = 10 - c = 10 - 2$$
$$\Leftrightarrow g = 8$$



With Carbon Tax

Add t=13

$$c + 2 \cdot 13 = 28$$
$$\Leftrightarrow c = 28 - 26 = 2$$
$$g + c = 10$$
$$\Leftrightarrow g = 10 - c = 10 - 2$$
$$\Leftrightarrow g = 8$$

y = Energy produced (GWh)

MC=28

Electricity demand

10

Coal

8

Gas

Tax revenue?
8 x 13 +
2 x 13 x 2
= 156

CO_2 with tax

CO_2 without tax

8 10 12 20

x = CO_2

	System Costs (Payment under perfect redistribution)	Coal Profit	Total paid for solar subsidy	Energy Price	Total paid for energy	Tax (t)	Tax revenue
1. No policy	50	50	-	10	100	0	0
2. Carbon tax	122	2	-	28	280	13	156

- Total Abatement cost: $72
- Average abatement cost: $9 ($72/8)

Note:

System cost + Coal Profit + Tax revenue

= Total paid for energy

Profit by Coal = 2 * 2 * .5 = 2

Economics of pollution

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4. Overview carbon taxation & ETS in the world ✓
5. ETS & substituting high-emission tech for low-emission tech. ✓
6. What is better, carbon tax or ETS?

- How do tax and ETS compare

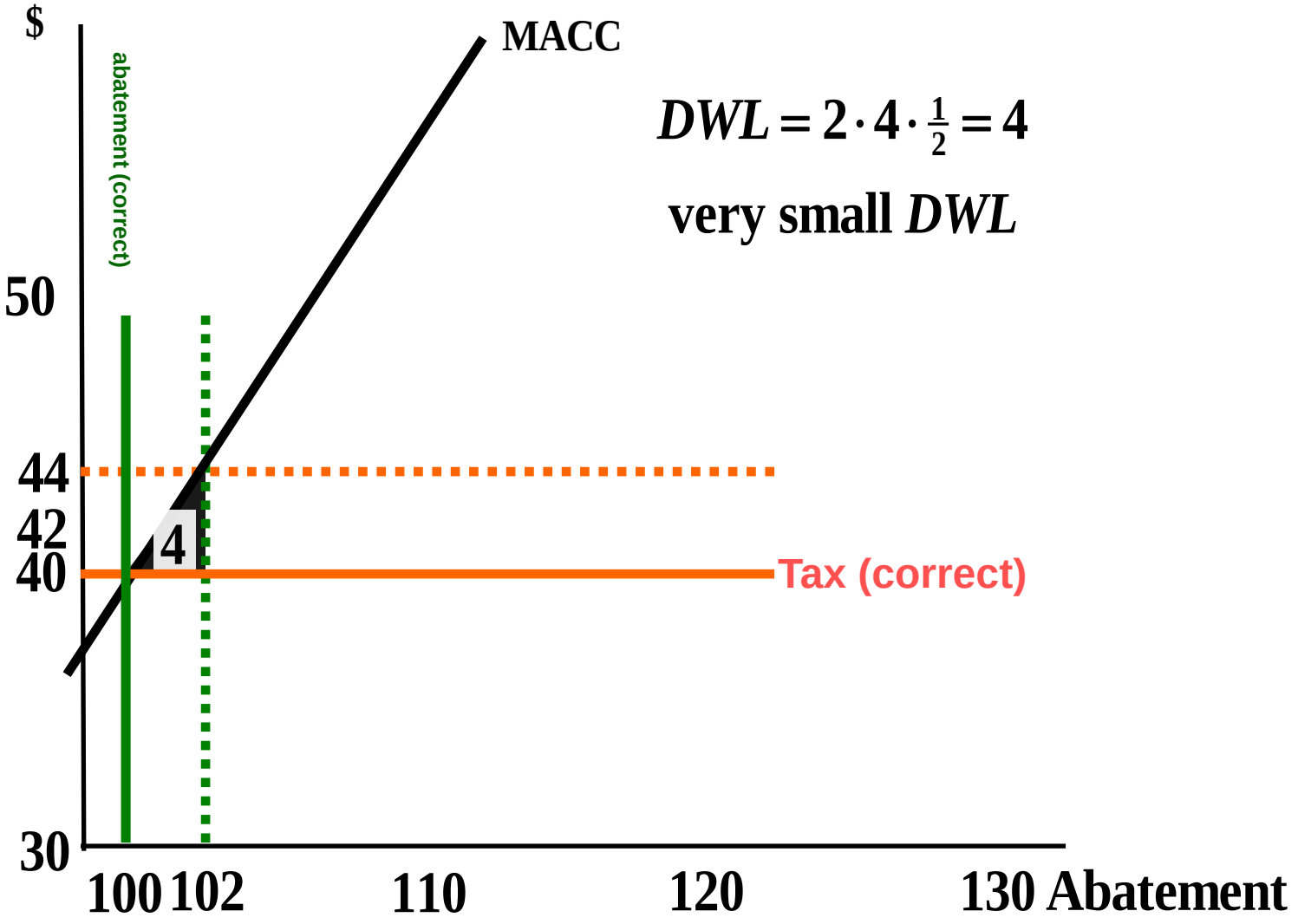
1. Efficiency argument **Tax wins**
2. Political economy argument
    1. Popular support **ETS wins**
    2. Carbon emitting industry support

1. Efficiency argument

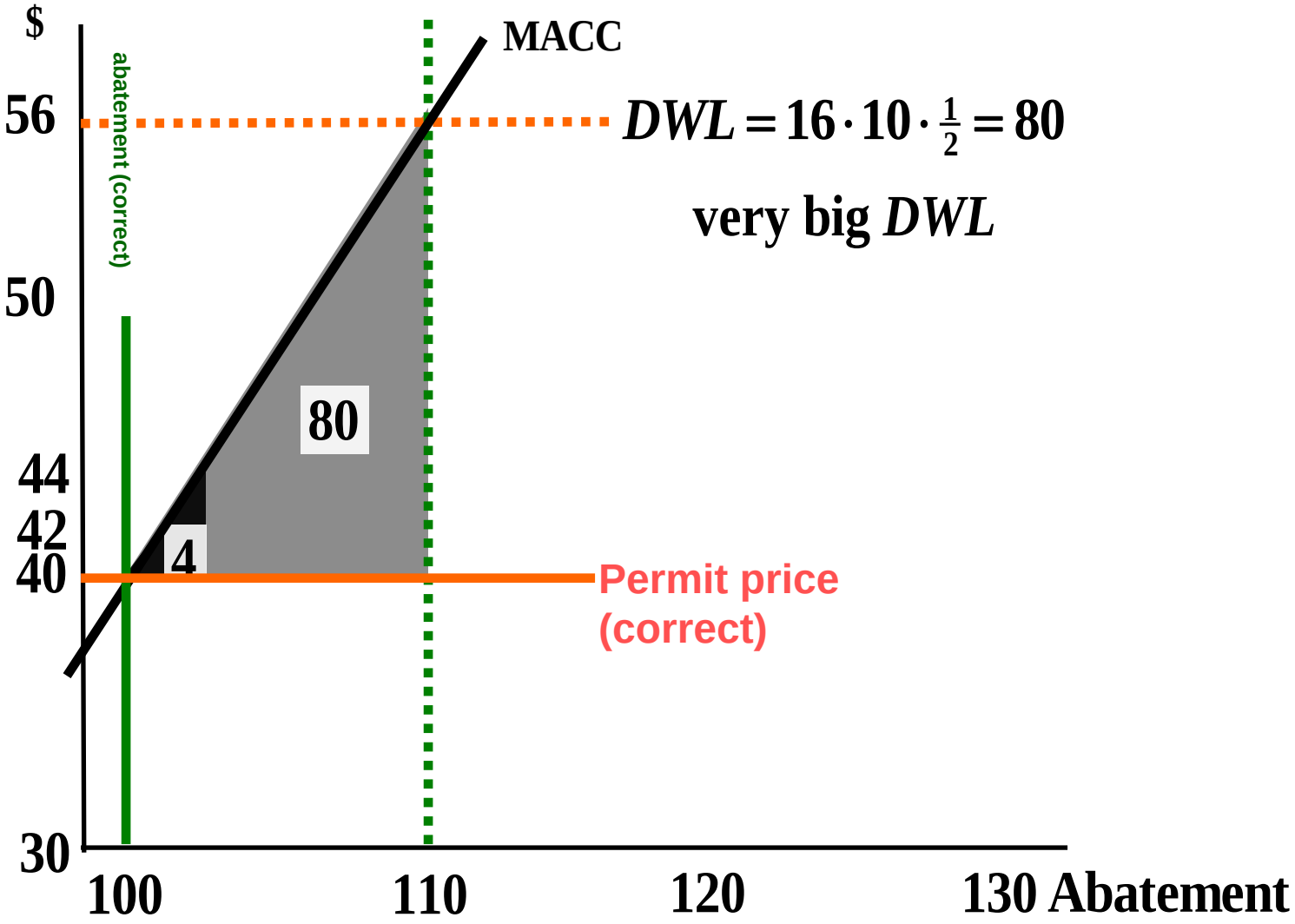
- If we make a mistake in our targets, what mechanism will bring the largest damage?
- Tax
  - Too high (or low) tax rate
  - Let’s look at a tax 10% too high
- ETS
  - Too high (or low) abatement level
  - Let’s look at an abatement level 10% too high

- We assume that the MACC is steep
  - Abating additional units rapidly increases costs
    - Realistic assumption

- Suppose the social cost of CO2 is 40$/TCO2
  - The optimum tax is thus 40$/TCO2
- But, we make an error and believe the social cost is 44$/TCO2
- What is the damage? (DWL)



- Suppose we figured out we should abate 100 TCO2
  - The permit prices will thus be 40$/TCO2
- But, we make an error and believe we should abate 110 TCO2
- What is the damage? (DWL)



- We assume that the MACC is steep
  - Abating additional units rapidly increases costs
  - Result:
    - Tax is more efficient, more robust to errors!
      - And we can be sure there are errors!

- What if we assume that the MACC is shallow?
  - Abating additional units does not affect costs a lot

- Suppose the social cost of CO2 is 40$/TCO2
  - The optimum tax is thus 40$/TCO2
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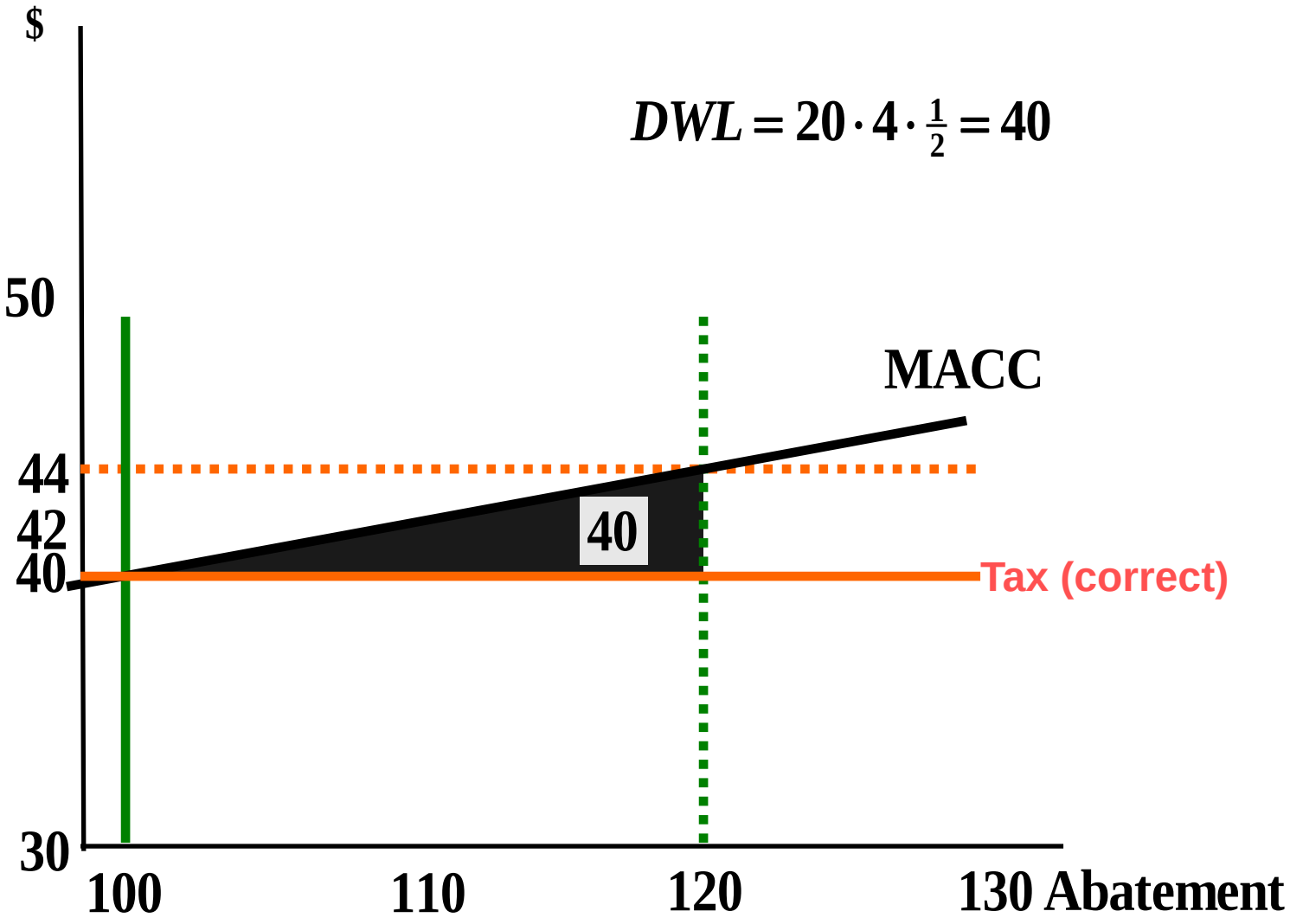

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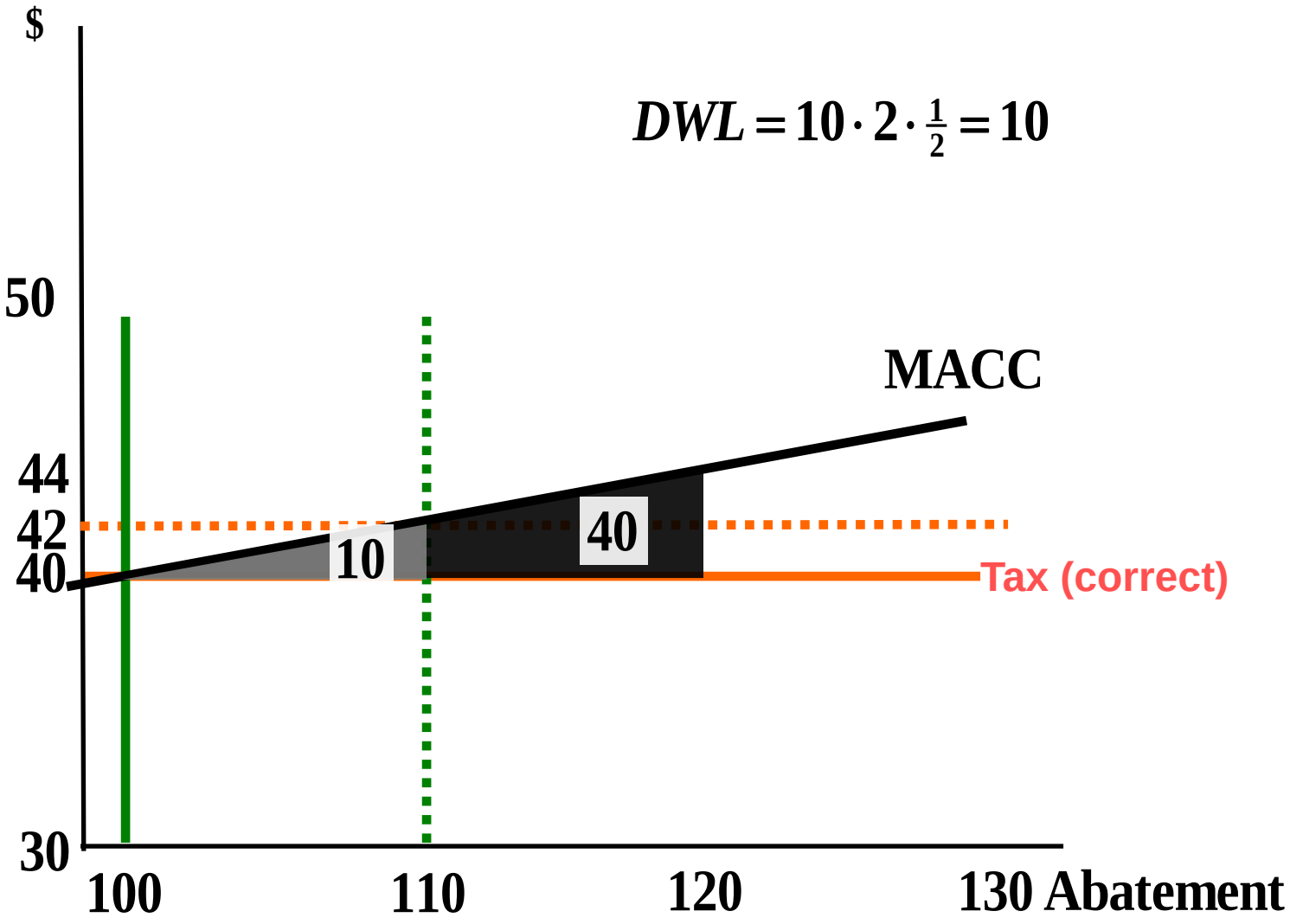


- We assume that the MACC is steep
  - Abating additional units rapidly increases costs
  - Result:
    - Tax is more efficient, more robust to errors!
      - And we can be sure there are errors!

- What if we assume that the MACC is shallow?
  - Abating additional units does not affect costs a lot
  - Result:
    - ETS is more efficient, more robust to errors!

  - It is generally believed the MACC is relatively steep.
  - Thus the **carbon tax** wins the efficiency argument

We have indeed seen this for the EU ETS

- EUA (permit) price strongly affected by disturbances
  - Economic crisis
  - covid
- Such wild price variations lead to accumulated DWLs

2. Political economy argument

1. People/ households/ journalists

- TAX:
  - People don’t like taxes
  - worry about the government getting more tax money
    - » Can be wasted on corruption or useless projects (“white elephants”) (or can be put to very good use)
- ETS
  - People don’t understand ETS well, and thus less opposition
    - » Most people don’t understand that it is basically a tax.
  - If permits are given to industry, no money to government
    - » But when permits are auctioned, the government gets the money of the auction
    - » the same as an equivalent tax

https://en.wikipedia.org/wiki/White_elephant

2. Political economy argument

2. Carbon emitting industry support

- TAX:
  - The tax increases prices and decreases demand
  - Industries don’t like the direct transfer to government

- ETS
  - The ETS increases prices and decreases demand
  - If permits given to Industries, they probably become more profitable than without ETS

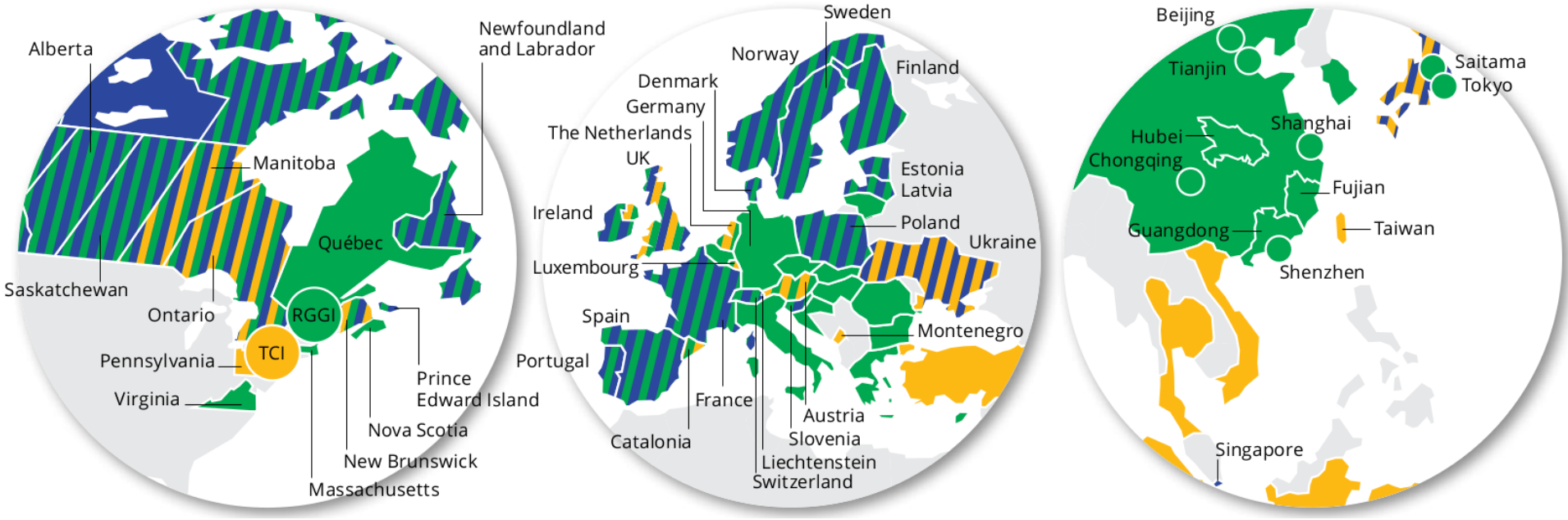
https://en.wikipedia.org/wiki/White_elephant

- Thus an ETS is generally more popular (less unpopular) with
  - Consumers
    - (is a mistake: a misperception)
  - Industry
    - (is correct, if part of permits not auctioned, but given)

- ETS wins the political support argument

Suggestion for a possible solution

- Start with an ETS
  - the political support makes it easier to implement than a carbon tax
- Add a minimum price and maximum price
  - People will want this, because the volatility of the ETS price visibly costly and painfull.
  - Min and max price lowers price volatility -> lowers the DWL of ETS
  - The price will probably most of the time be at the maximum or minimum!
- Narrow the distance between minimum and maximum price
- Now you are have basically the same as a carbon tax



- All EU member countries have Emission Trading System (ETS)
- So many countries are considering to add a tax on top!
  - (Why have ETS ***and*** carbon tax?)
- We now understand why EU countries are adding a tax!

ETS implemented or scheduled for implementation
Carbon tax implemented or scheduled for implementation
ETS or carbon tax under consideration

ETS and carbon tax implemented or scheduled
Carbon tax implemented or scheduled, ETS under consideration
ETS implemented or scheduled, ETS or carbon tax under consideration
ETS and carbon tax implemented or scheduled, ETS or carbon tax under consideration

https://openknowledge.worldbank.org/handle/10986/35620

- But ETS + tax
- ETS with min and max price
- Not the same!

- ETS+tax prevent the permit price
  - from becoming too low **Yes!**
  - from becoming too high **No!**

- Carbon tax versus ETS is a useful debate
- But, maybe a bit a “luxury problem”
- After all, both are 1st best measures to combat global warming
- Most of the EU measures to combat global warming are 2nd or 3rd best measures
  - Subsidies for selected technologies
  - Billions of $ have been wasted on “green energy white elephants”

Economics of pollution

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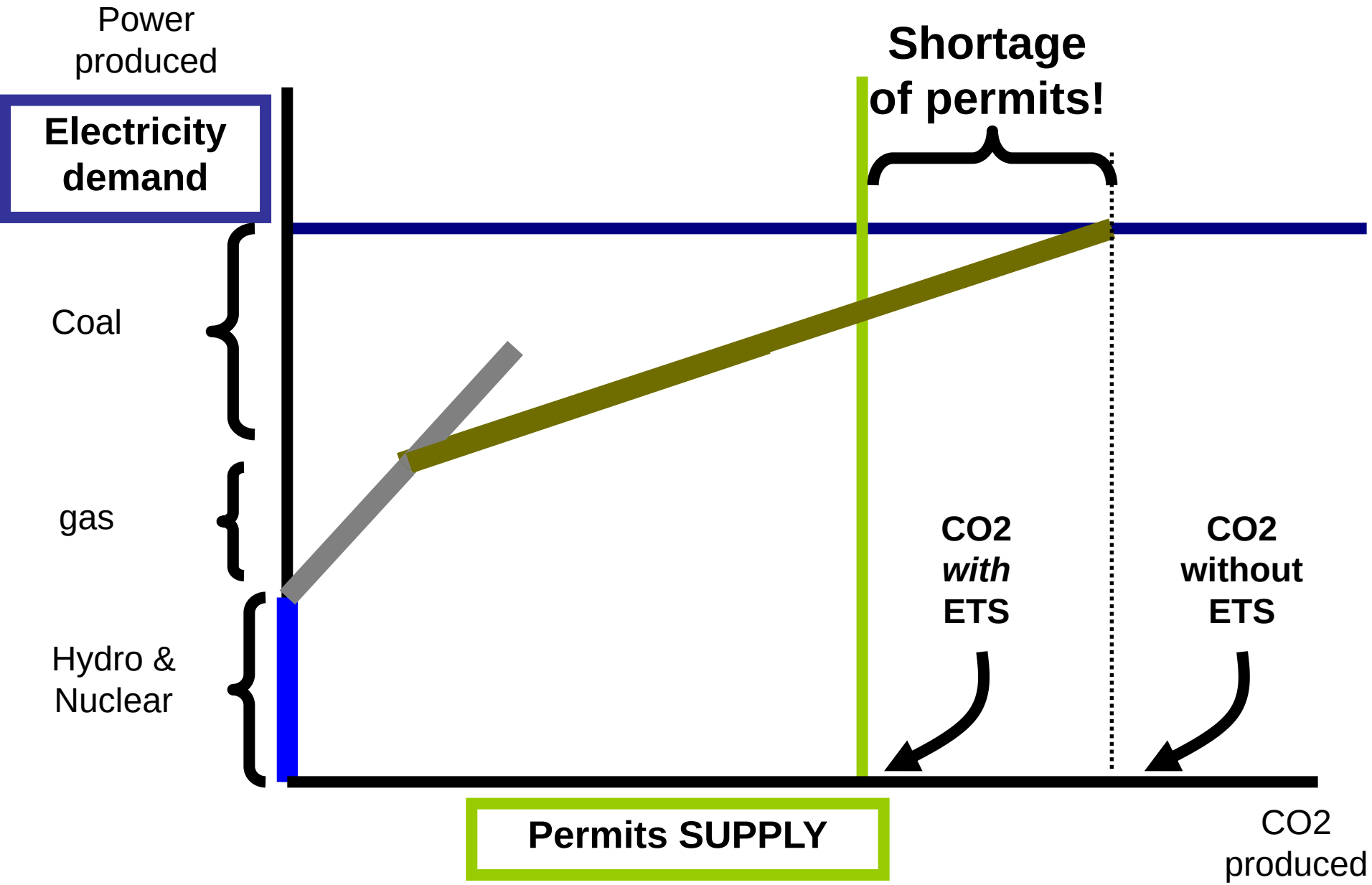
3. Introduce 2 possible solutions
    1. Carbon Tax ✓
    2. Emission Trading Scheme (ETS) ✓
4. Overview carbon taxation & ETS in the world ✓
5. ETS & substituting high-emission tech for low-emission tech. ✓
6. What is better, carbon tax or ETS? ✓

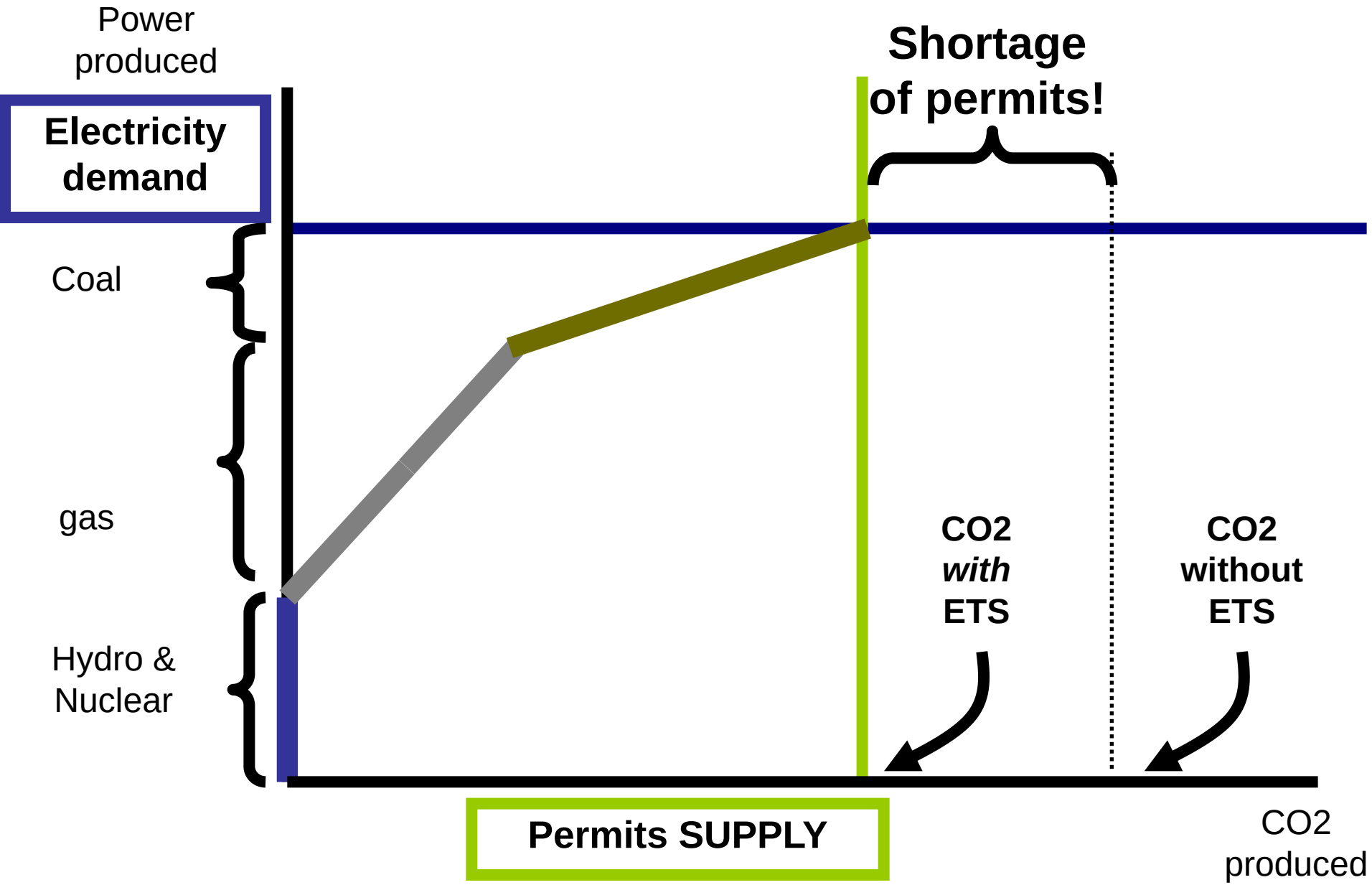
- Interesting issue
  - Remember EU is using ETS
  - ETS covers the electricity industry

- What is the effect of these subsidies on total CO2 emissions in the EU?
  - Zero!
  - Because, EU emission are under ETS

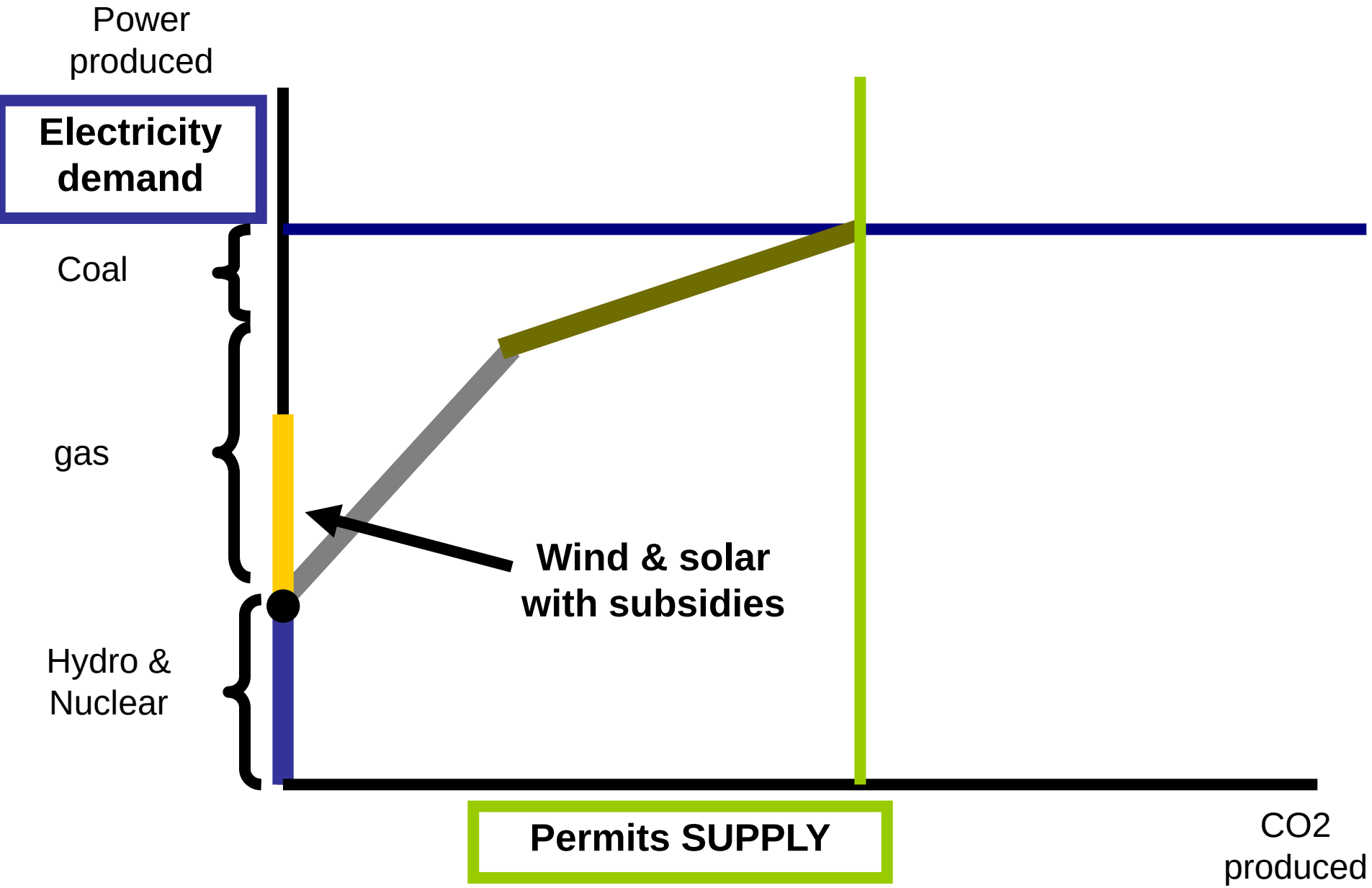
ETS reduces CO2 emissions



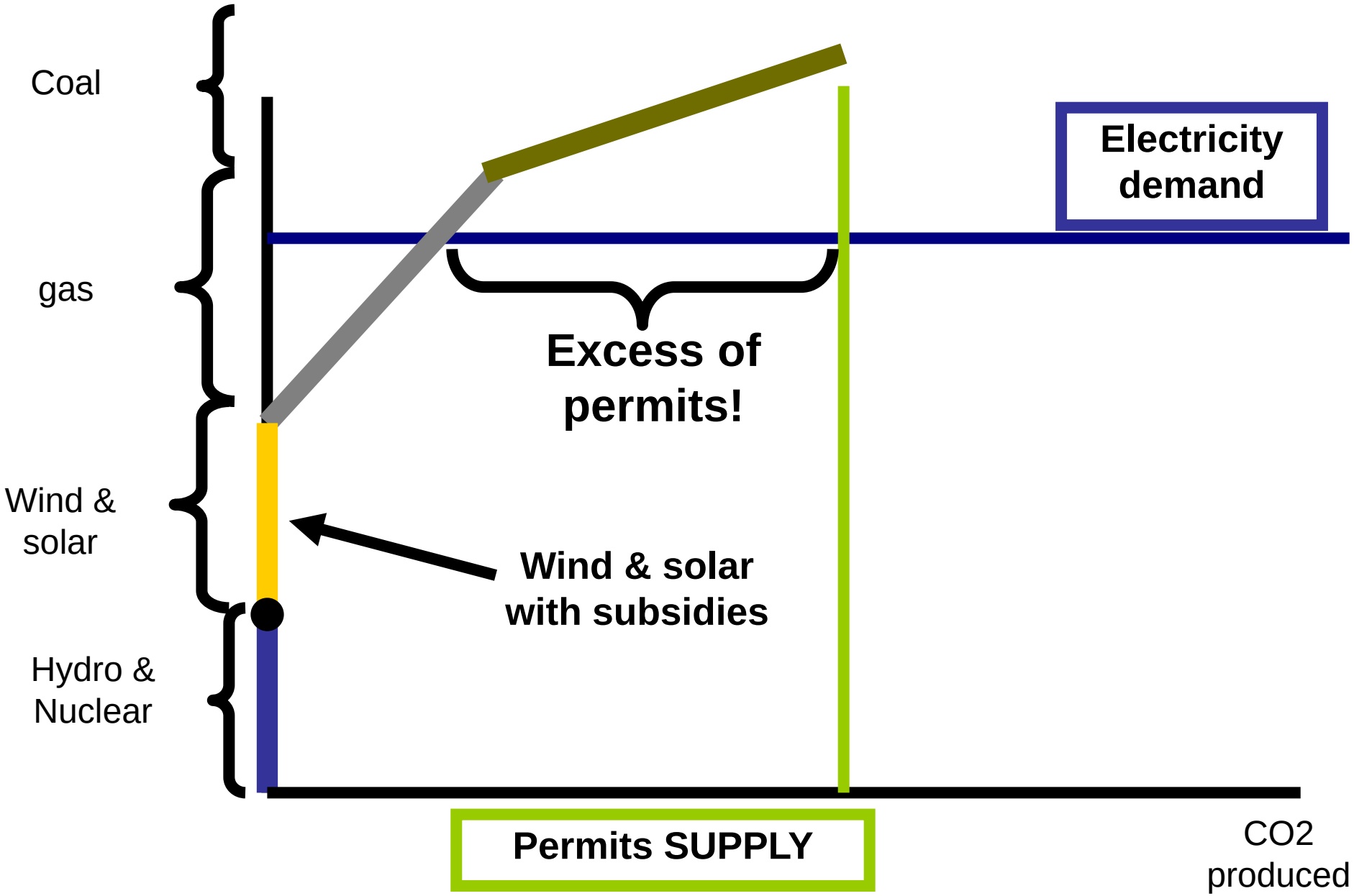
ETS reduces CO2 emissions



ETS affects generation choices



ETS affects generation choices



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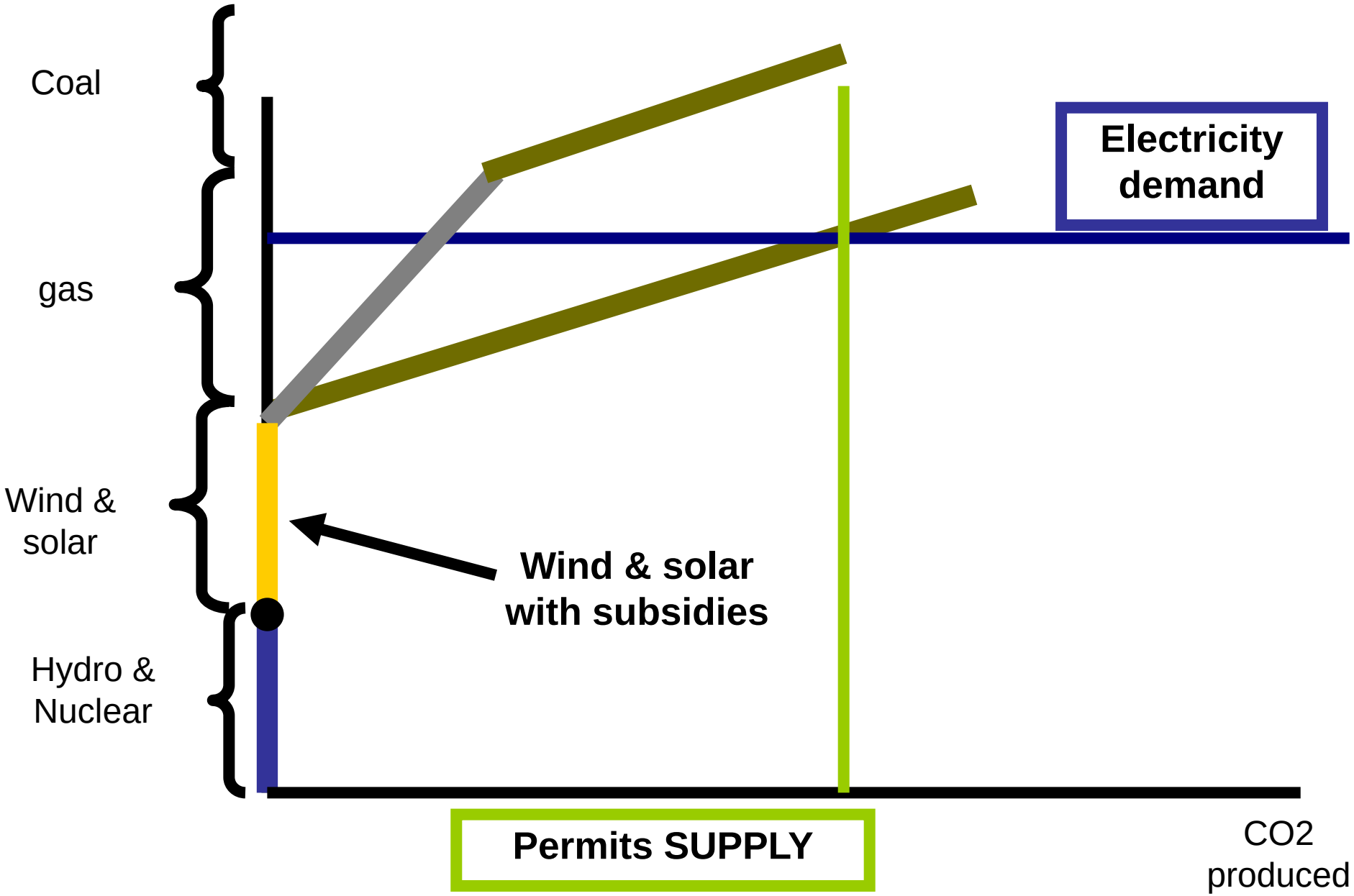

ETS affects generation choices