Incentivizing Negative Emissions Through Carbon Shares

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December 2020

There is increasing momentum behind zero emission targets.

UK becomes first majo
pass net zero emission

New target will require the UK to bri
emissions to net zero by 2050.

ENVIRONMENT JUNE 27, 2019 / 1:12 PM / A YEAR AGO

France sets 2050 carbon-neutral target with new law

ESG OCTOBER 20, 2020 / 4:15 AM / UPDA

EU ministers to a
neutrality by 205

Executive Department
State of California

EXECUTIVE ORDER B-55-18 TO ACHIEVE CARBON NEUTRALITY

The Biden Plan will:

BIDEN PRESIDENT

Jul 21, 2020 - Energy & Environment

Apple vows to be carbon neutral by 2030

rgy economy and reaches net-zero

Feb 12, 2020 - Energy & Environment

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17 December 2019

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177 Companies Have Pledged to Reach Net-Zero Emissions by 2050

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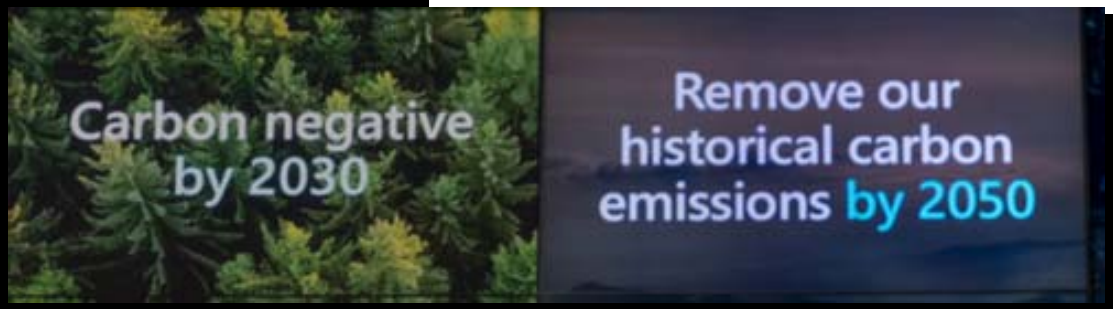
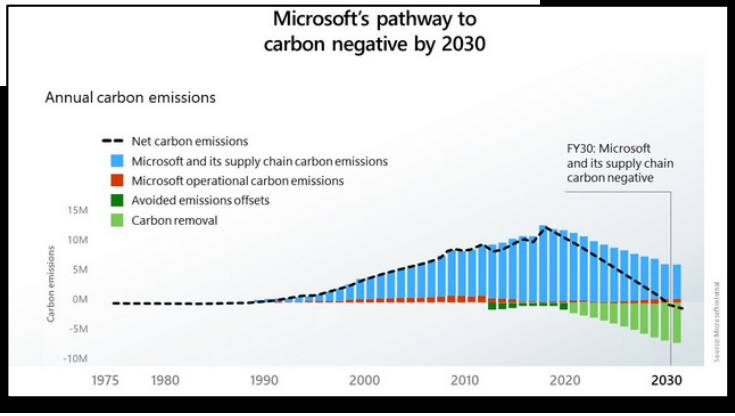
t

It is unlikely that stopping precisely at zero would be optimal.

Microsoft will be carbon negative by 2030

Jan 16, 2020 | Brad Smith - President

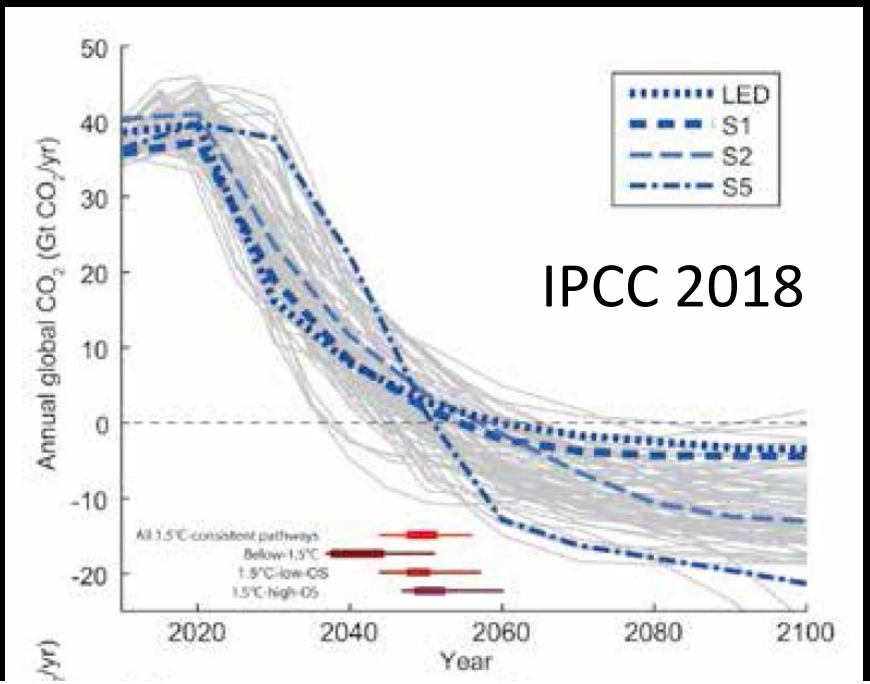




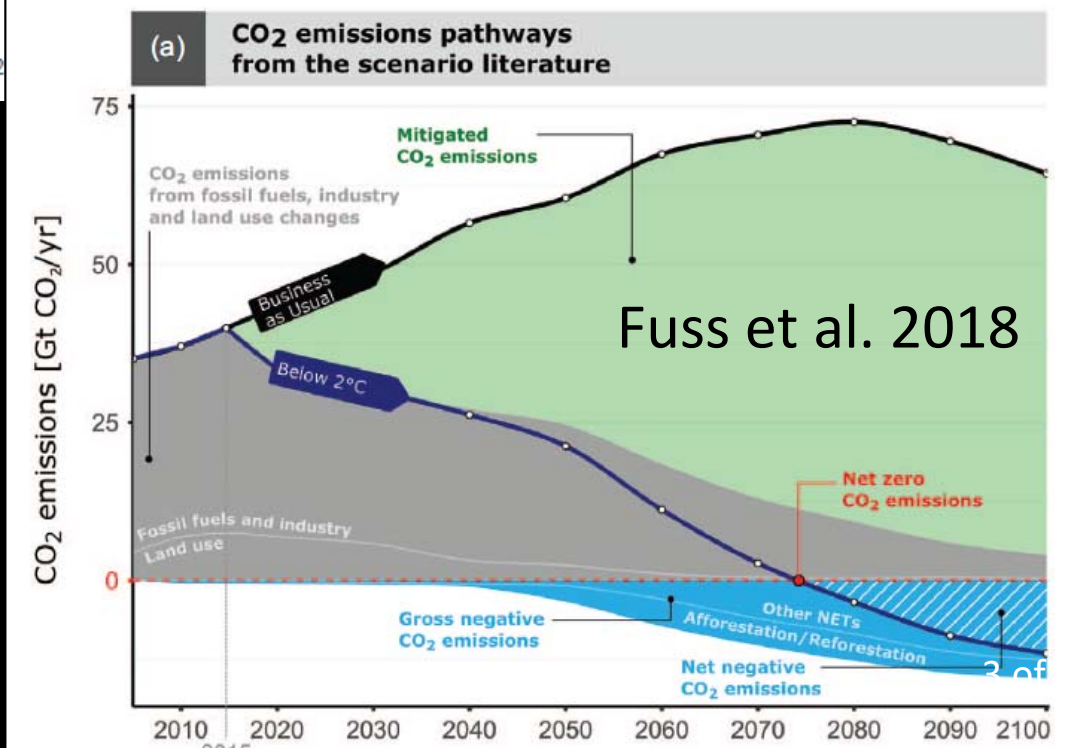
Decrement carbon: Stripe's negative emissions commitment

Christian Anderson on August 15, 2019

This leads to Stripe's Negative Emissions Commitment. **We will seek to purchase negative CO_2 emissions at any price per tCO_2, starting immediately.** We expect that [illegible] tCO_2

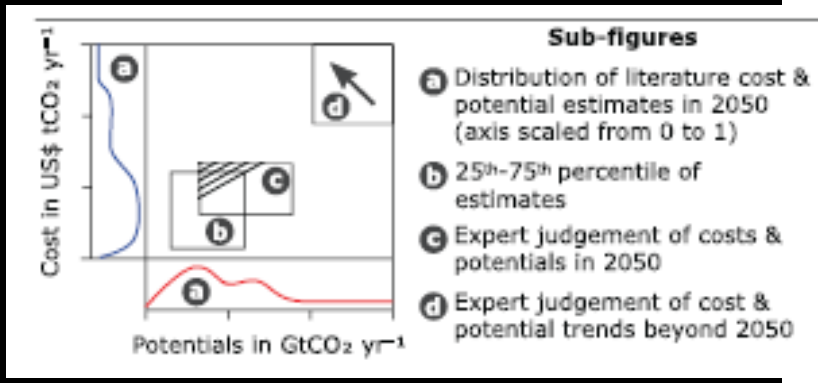


IPCC 2018

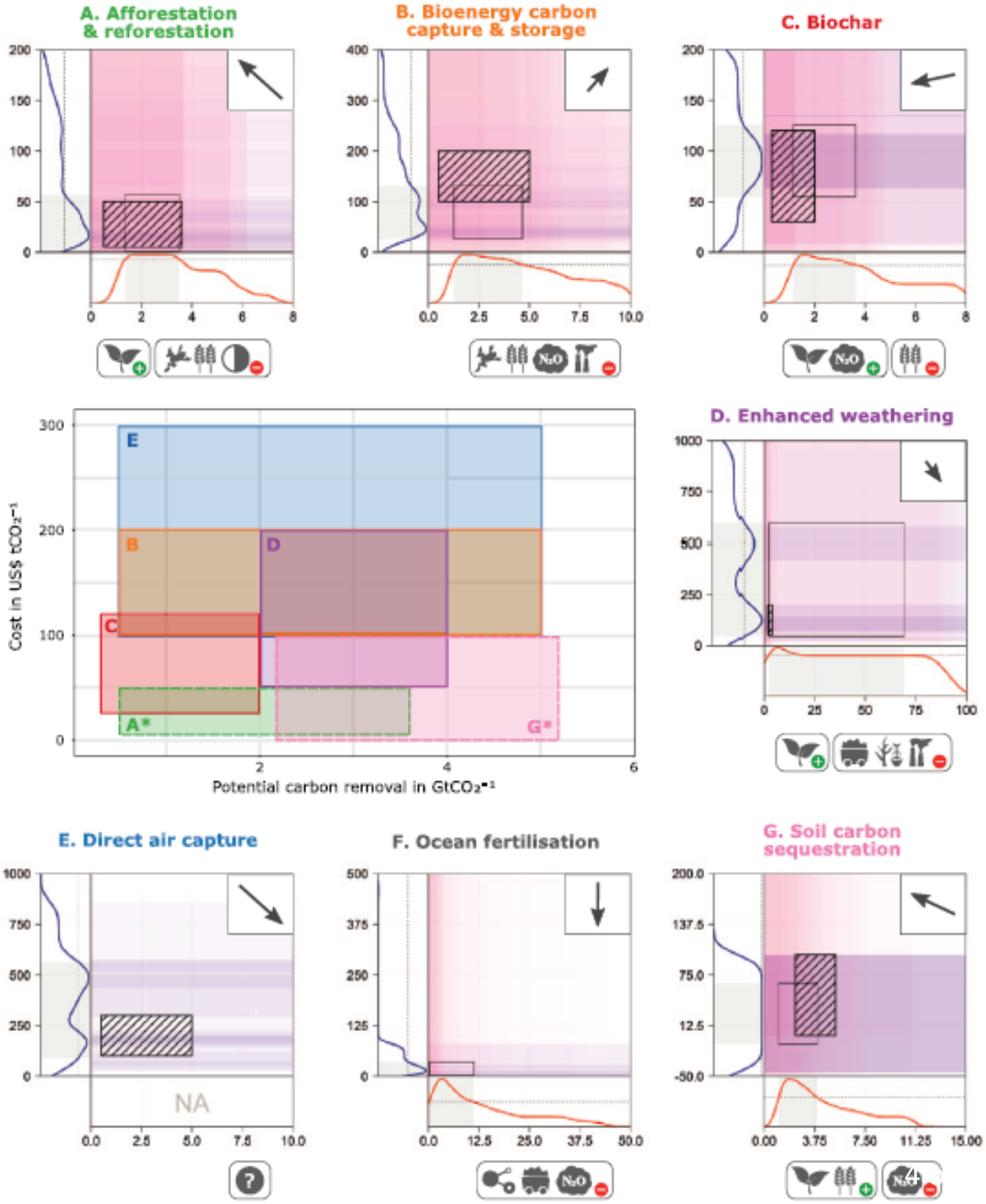


Fuss et al. 2018

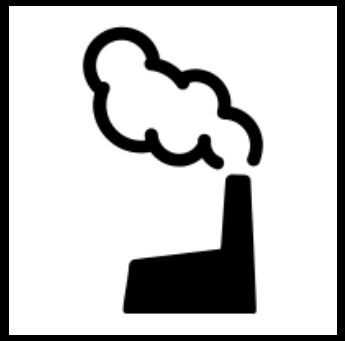
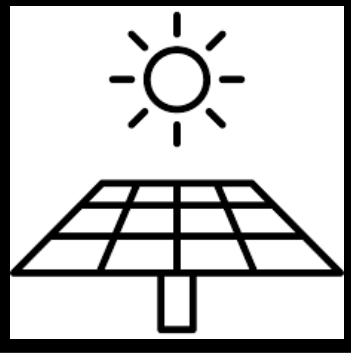
There are many ways to remove carbon from the atmosphere.



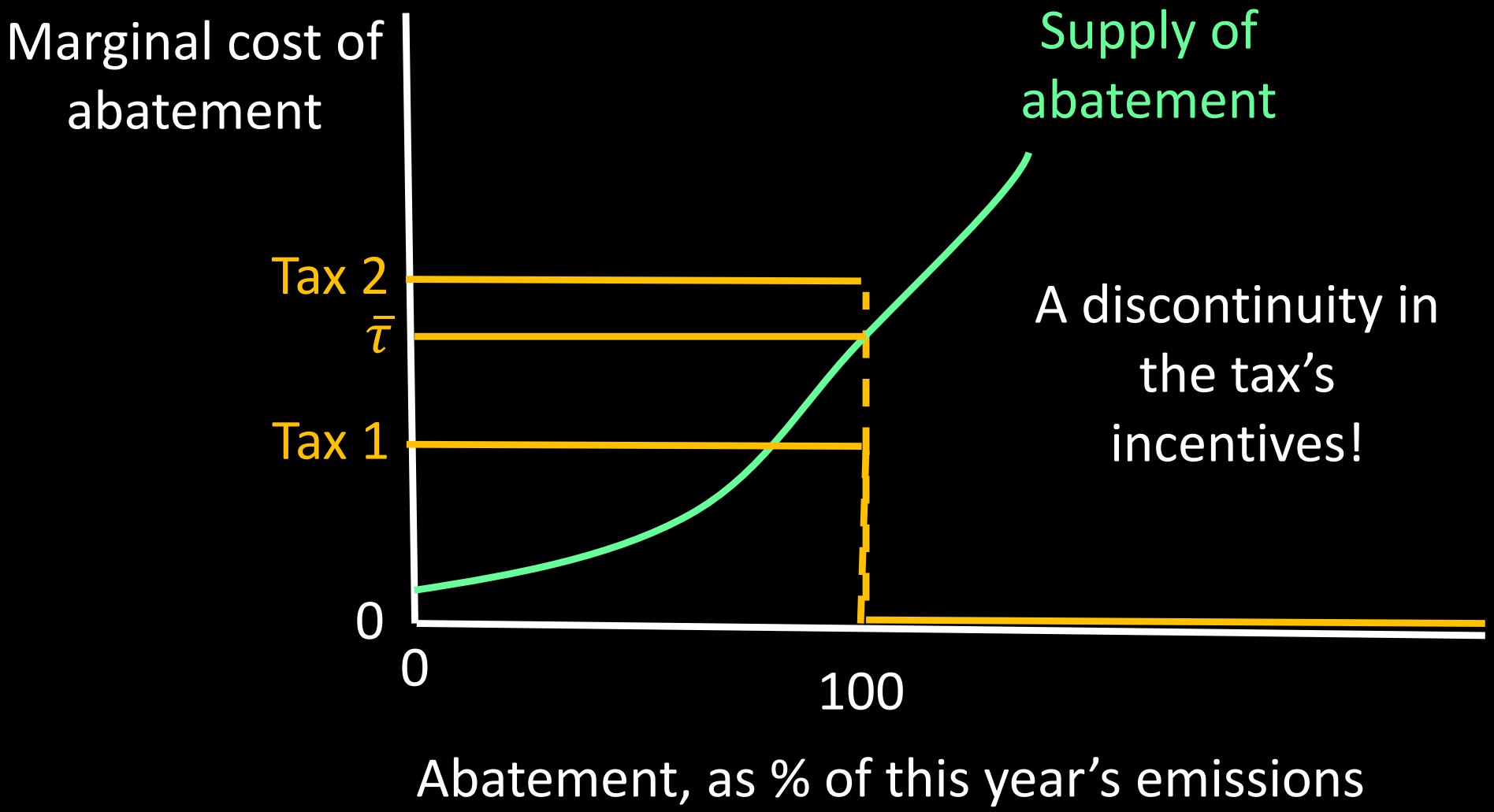
Fuss et al., 2018



Economists recommend pricing emissions, but such prices do not incentivize negative emissions.

	2020	2050
2020 emissions:	 - 	
	or 	or 
2050 emissions:		same options, plus  - 

Carbon is a stock pollutant: its harm follows from leaving it in the atmosphere, not merely from emitting it.



A Pigouvian emission price cannot attain first-best if damages (marginal benefit) might end up high!

Governments could directly subsidize carbon removal, but the needed subsidies could be politically infeasible or costly (if financed by distortionary taxation.)

->Can we incentivize optimal carbon emission and removal without net outlays from the government?

Recommendation for Pigouvian taxes at point of carbon emission dates to at least Nordhaus (1977).

There is a mountain of literature on negative emissions, but seemingly nothing on how to incentivize negative emissions.

One solution: Tax the stock of carbon remaining in the atmosphere, not the flow of carbon released to the atmosphere.

->An atmospheric rental charge

<u>2020</u> <u>2050</u>

2020 emissions:

-

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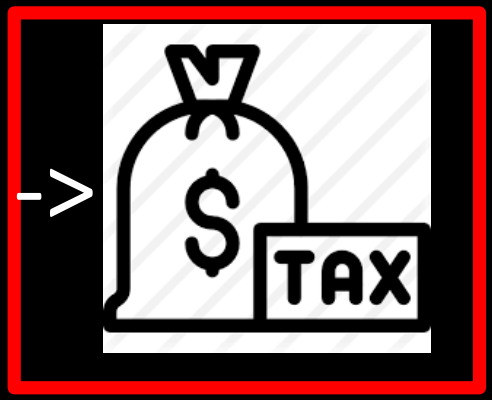

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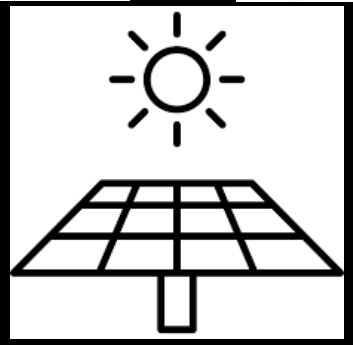

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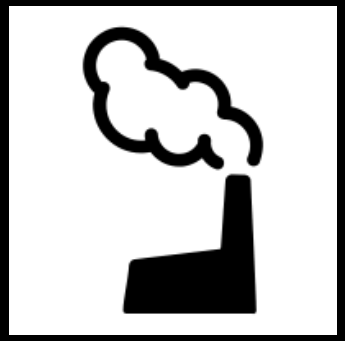
But this might be infeasible! Emitters might no longer be around by the time negative emissions become optimal.

2020 2050

2020 emissions:  - 

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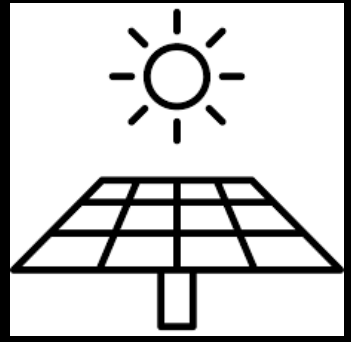
or 

or 

or 

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Negative emissions limited

And reduced incentive to abate in the first place

A feasible policy: Carbon shares, attached to each unit of carbon emitted

"Carbon share"
Value: $\Omega_{t,t}$

Bond
B_t

xferable

Incentive to reduce emissions:
$B_t - \Omega_{t,t}$

(1) If time *t* carbon is still in the atmosphere at time *t+s*, the value of the share is drawn down based on realized damages from climate change

Time *t+s* face value: $\theta_{t,t+s}$
with $\theta_{t,t} = B_t$

Damage charge $\kappa_{t,t+s}$

Dividend $\delta_{t,t+s}$

$$\theta_{t,t+s+1} = (1+r)(\theta_{t,t+s} - \delta_{t,t+s} - \kappa_{t,t+s})$$

(2) If the shareholder removes the carbon from the atmosphere in time *t+s*, they receive all remaining funds attached to the share.

Time *t+s* face value: $\theta_{t,t+s}$

Cost p_{t+s} of carbon removal

$\theta_{t,t+s}$

Removing carbon is exercising an option. Do it iff payoff from removing $(\theta_{t,t+s} - p_{t+s})$ exceeds value of keeping the option $(\delta_{t,t+s} + \frac{1}{1+r} E_{t+s}[\Omega_{t,t+s+1}])$

The value of a carbon share is the present value of expected dividends.

Proposition 5. *In a competitive equilibrium,*

$$\Omega_{t,t+s} = \sum_{j=0}^{\infty} \frac{1}{(1+r)^j} E_{t+s}[\delta_{t,t+s+j}].$$

Value is positive: somebody always wants to hold it. So bankruptcy not an issue for this policy.

Optimal Policy

What should the time *t+s* damage charge $\kappa_{t,t+s}$ be?

- That period's realized marginal damage from time *t* emissions
  - Can hope to empirically estimate! e.g. via attribution studies

What should the time *t* bond B_t be?

- Time *t* worst-case social cost of carbon
  - Need to be able to fund any realized sequence of damage charges

What should the time *t+s* dividend $\delta_{t,t+s}$ be?

- Difference between time *t+s* realized marginal damage and time *t+s* worst-case marginal damage
  - As go along, are refunding based on not being in the worst case

Incentives Under Optimal Policy

First-best emission incentives: I show that the marginal cost of emissions is equal to the expected social cost of carbon

$$B_t - \Omega_{t,t} = \sum_{j=0}^{\infty} \frac{1}{(1+r)^j} E_t[\kappa_{t,t+j}]$$

- Like the optimal emission tax!

First-best removal incentives: I show that shareholder's removal decisions equate the marginal cost of removal to the present value of future expected damage charges

$$p_{t+s} = \sum_{j=0}^{\infty} \frac{1}{(1+r)^j} E_{t+s}[\kappa_{t,t+s+j}]$$

- Remove if removal costs turn out low or damages turn out high
- Damage trends provide early market signal that it's worth developing new removal techs

When is it important to begin issuing carbon shares?

1) When negative emissions will not be optimal for a while

- Waiting increases the fraction of carbon lacking removal incentives

2) When current emission controls are too lax

- Negative emissions more likely to become optimal if we emit a lot today

Implication: Especially important to begin now because emission controls are probably too lax and negative emissions still far away

Possible Objections (1)

1) Will bonds challenge firms' liquidity?

- But optimal net outlays are equivalent to optimal emission taxes, which we don't describe as challenging liquidity

2) Will regulatory incentives (hold-up, taxation of inelastic factors) lead to overly high damage charges?

- But there will be lobbies for and against high charges
- And policy could constrain rate of change in these charges

Possible Objections (2)

3) Informationally too demanding?

- But is less so than conventional emission taxes, which require specifying a probability distribution over marginal damages in every future period.
- Here need only estimate realized marginal damages and develop a worst-case scenario for future marginal damages.

4) But private actors still need to project future damage charges

- We would expect shareholders to become quite informed about climate change and derivatives markets to emerge that could anchor expectations

This policy could be implemented through a quantity instrument.

Instead of announcing damage charges period by period, regulator would announce a cap on cumulative emissions period by period.

Each shareholder would bid in the damage charge above which they would remove their underlying unit of carbon from the atmosphere.

Regulator would deduct market-clearing charges from the face value of each outstanding share.

Could think more about whether could discover the bond through a quantity instrument.

Quantitative Questions:

How large might the bond be?

How large are the welfare gains from using carbon shares instead of conventional emission prices?

Numerical experiments adapt DICE-2016R (Nordhaus, 2017) to allow uncertainty and learning about damages (with updated carbon and climate modules).

Have posted a MATLAB version of DICE-2016R at https://github.com/dlemoine1/DICE-2016R-Matlab

Warming reduces economic output Y to $Y(1 - d\ T_t^2)$

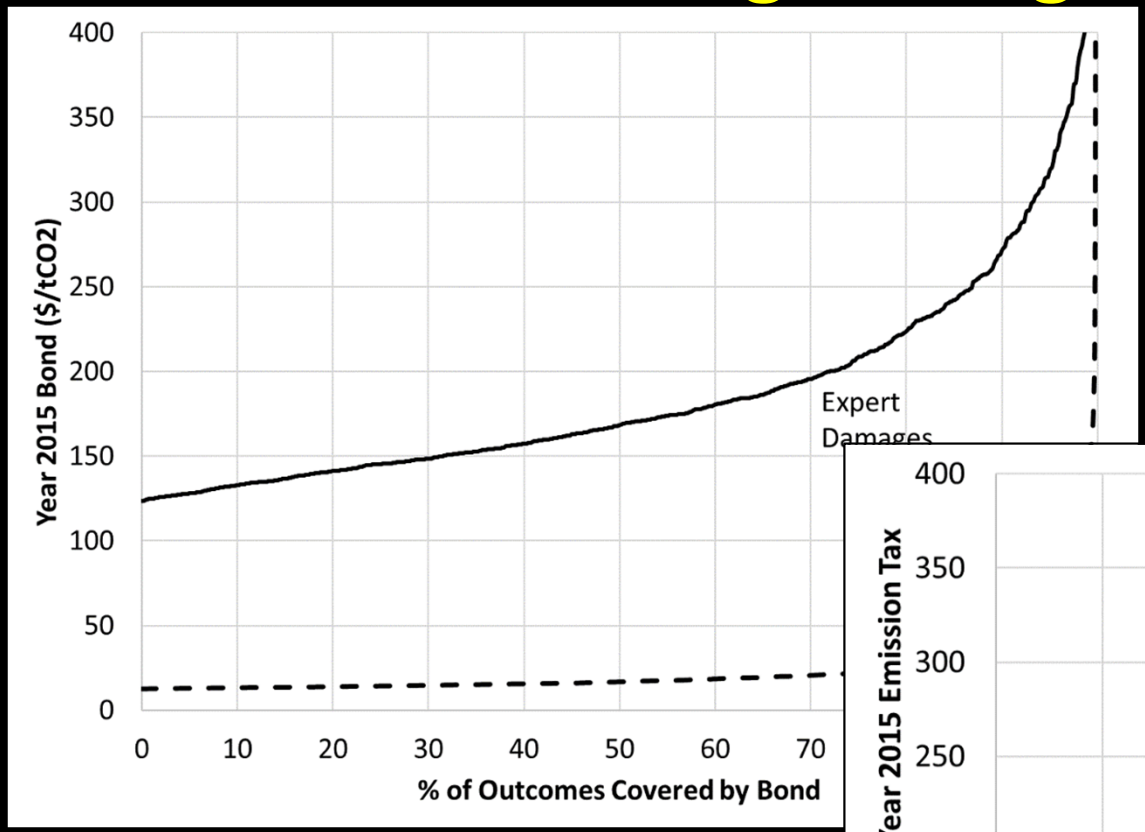
We know very little about damages. I allow long-run d to be a random variable.

Policymaker learns its value after 50 years (in 2065) and then sets policy accordingly. In nearer-term is fixed to mean of the distribution.

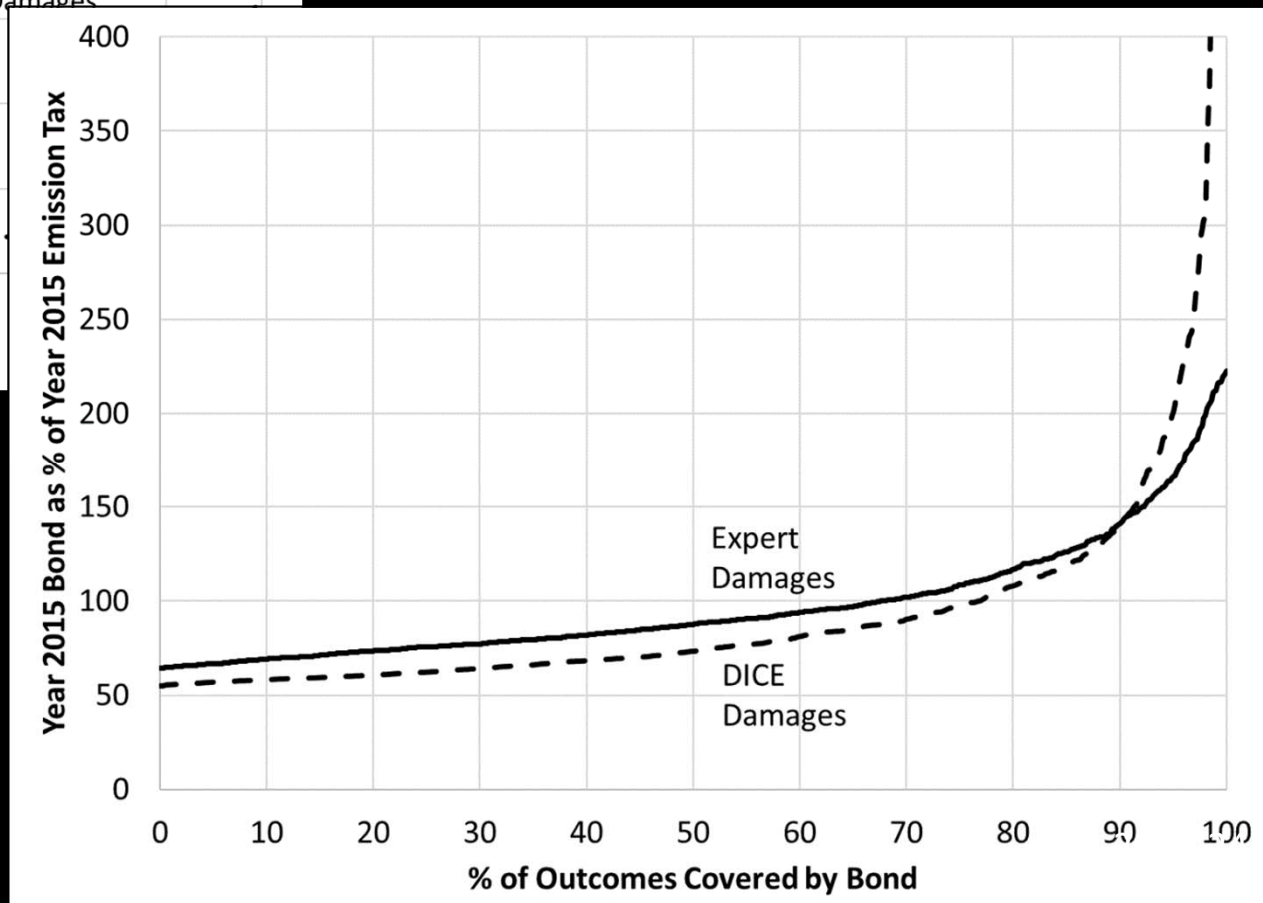
Damage distribution from expert survey in Pindyck (2019), via my forthcoming JAERE paper (which adjusts for uncertainty about warming).

- DICE has d=0.00236
- Mean of calibrated distribution is d=0.0228

A bond equal to twice the optimal emission tax would cover damage charges in nearly all cases.



Level of bond



As % of emission tax

Failing to incentivize negative emissions reduces the expected value of policy by nearly 10%.

Table 1: Balanced growth equivalent gain from optimal and constrained-optimal policy.

	Expert Damages		DICE Damages	
	BGE (%)	Loss (% of BGE)	BGE (%)	Loss (% of BGE)
Optimal	40.3	-	1.51	-
No Negative Emissions	37.6	6.8	1.37	9.1

Balanced growth equivalent gain (BGE) is relative to a case with abatement fixed at zero (but savings optimized). The BGE translates changes in welfare into the constant relative difference in consumption between two counterfactual consumption trajectories that grow at the same constant rate (Mirrlees and Stern, 1972).

->Using a carbon share policy instead of an emission tax policy generates nontrivial benefits in expectation

Conclusions

Pigouvian emission taxation is not first-best when negative emissions could be optimal ex post, as is the case today.

Taxing the stock of CO_2 can attain first-best, but the likelihood of market churn makes such a policy infeasible.

We can recover first-best by requiring emitters to post a bond that finances a transferable asset, called a “carbon share”.

The face value of each share declines as damages are realized.

Shareholders can choose to recover the face value by removing the underlying unit of carbon.

The upfront bond should be equal to the worst-case social cost of carbon, perhaps around twice the optimal emission tax.