Integrated assessment model DICE and Clean Power Plan

ASA Workshop, 14-15 Mar, 2018

How can advanced mathematical modeling tools be useful to address sustainability challenges?

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Outline

- Intro to the DICE model
- Social Cost of Carbon (SCC)
- Clean Power Plan (CPP)

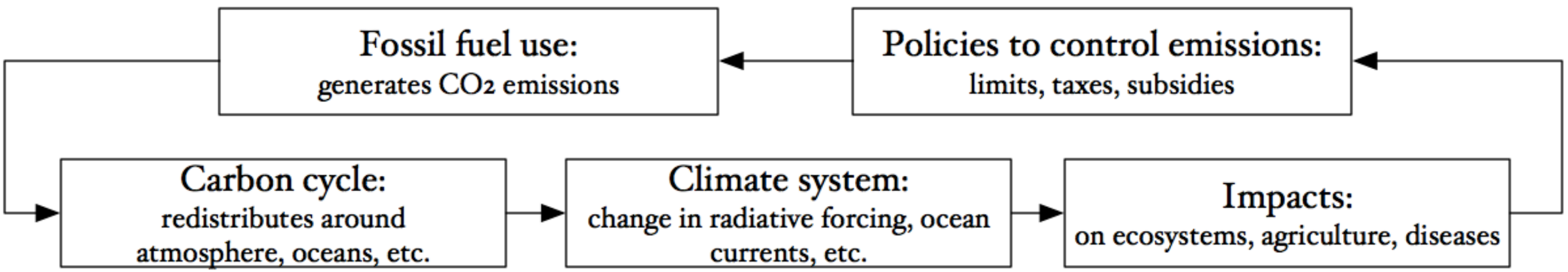
Economics of climate change

Climate is a global public good

The main questions posed by economic approach:

- How should CO2 emissions be reduced?
- How should the reductions be distributed across industries and countries?

DICE model 1992-2018



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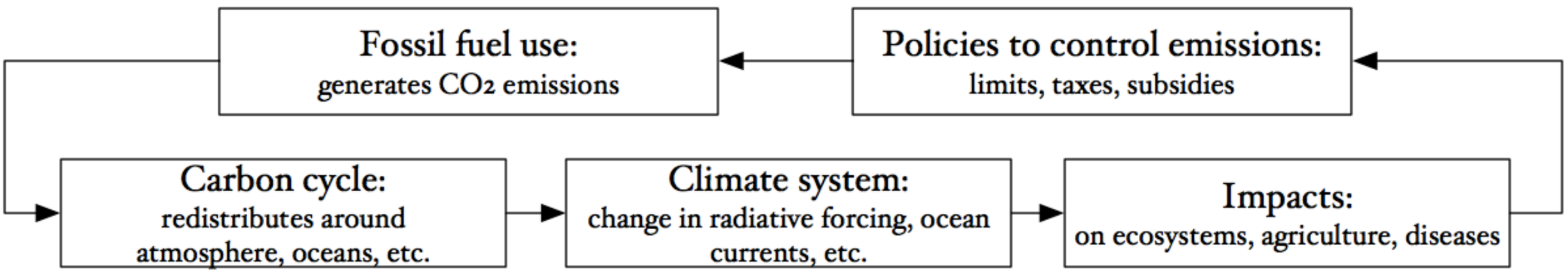

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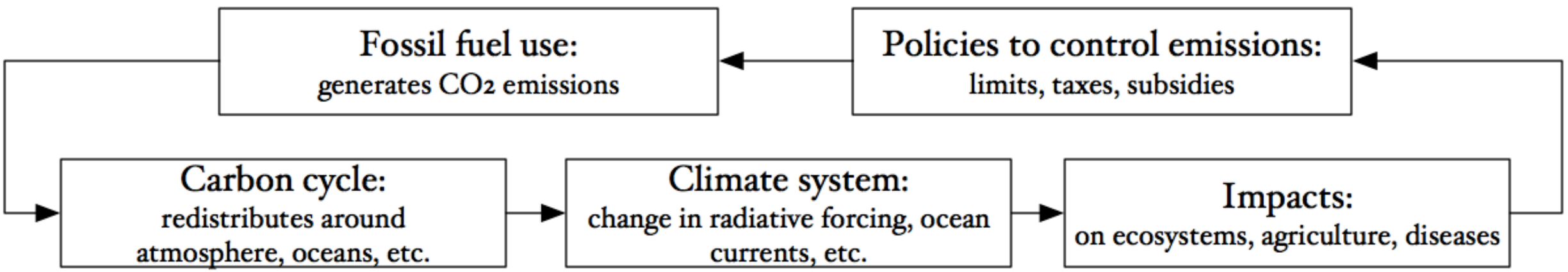

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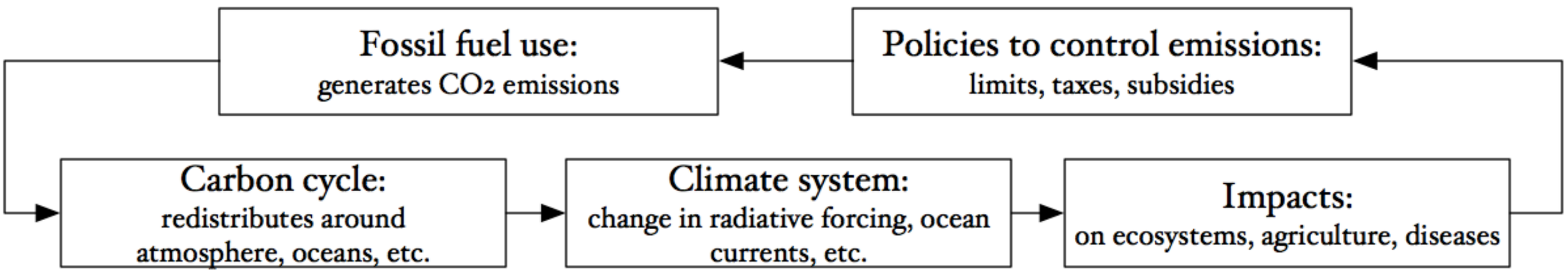

By devoting output to emissions reductions, economies reduce consumption today

BUT prevent economically harmful climate change

thereby increase consumption possibilities in the future.

[Nordhaus 2013]

DICE 1994

$$\frac{dK(t)}{dt} = \frac{s(t)(1 - b_1\mu(t)^{b_2})A(t)L(t)^{1-\gamma}K(t)^{\gamma}}{1 + \theta_1 T^U(t)^{\theta_2}} - \delta_K K(t),$$

$$\frac{dM(t)}{dt} = \alpha(1 - \mu(t))\sigma(t)A(t)L(t)^{1-\gamma}K(t)^{\gamma} - \delta_M(M(t) - \tilde{M}),$$

$$\frac{dT^U(t)}{dt} = \frac{1}{R_1}\left(\eta \log_2\left(\frac{M(t)}{\tilde{M}}\right) + O(t) - \lambda T^U(t) - \frac{R_2}{\tau_{12}}(T^U(t) - T^L(t))\right),$$

$$\frac{dT^L(t)}{dt} = \frac{1}{\tau_{12}}(T^U(t) - T^L(t)),$$

$$M(T_0) = M_0, \quad K(T_0) = K_0, \quad T^U(T_0) = T_0^U, \quad T^L(T_0) = T_0^L,$$

$$\mu(t) \in [0, 1], \quad s(t) \in [0, 1],$$

$$\text{maximize } W = \int_{T_0}^{\infty} e^{-\rho(t-T_0)} L(t) \ln\left(\frac{(1 - s(t))(1 - b_1\mu(t)^{b_2})A(t)K(t)^{\gamma}L(t)^{1-\gamma}}{\left(1 + \theta_1 T^U(t)^{\theta_2}\right) L(t)}\right) dt.$$

[Nordhaus 1994; Smirnov 2005]

Policies in DICE

We design climate policy for the next **200 years.**

Then every control is a sequence of **40 values** in [0, 1].

Every value is a share of emissions that we plan to avoid during the period of **5 years**.

Avoided emissions lead to less goods produced; this slows down economic growth but reduces economic damages from global warming.

"an economic analysis of climate change weighs the costs of slowing climate change against the damages of more rapid climate change" [Nordhaus 2014]

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- Intro to the DICE model
- **Social Cost of Carbon (SCC)**
- Clean Power Plan (CPP)

Social cost of carbon and carbon tax

The Social Cost of Carbon (SCC) is the damage of an additional ton of carbon along a certain emission path.

W. Nordhaus argues that the most effective way to incentivise the transition to a low-carbon future is to impose ‘carbon’ tax.

The optimal carbon tax equals the SCC when calculated along the optimal policy path in, e.g., the DICE model.

DICE and SCC

- DICE not only produces optimal policy but estimates the SCC!

- DICE is used by the United States Government *(Interagency Working Group on Social Cost of Carbon)* to estimate the SCC for regulatory impact analysis.

Technical Support Document: -
Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis -
Under Executive Order 12866 -

Interagency Working Group on Social Cost of Carbon, United States Government

August 2016

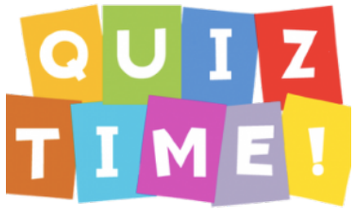
See Appendix B for Details on Revisions since May 2013

Credits

Perhaps the most important contribution *[of IAMs]* is the ability of systematic modeling to highlight the critical issues (such as discounting and damages)… [Nordhaus 2014]

There was essentially no awareness of the importance of carbon pricing two decades ago… Today, in part because of developments in IAMs, carbon prices and estimates of the SCC are actually integrated into the regulatory decisions of major countries." [Nordhaus, 2013]

Outline



- Intro to the DICE model
- Social Cost of Carbon (SCC)
- **Discount rate and SCC**
- Clean Power Plan (CPP)

Animated explanation of discount rate

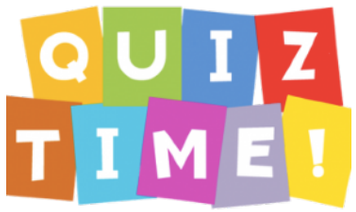
https://www.youtube.com/watch?v=Mol1yT7tczY

SCC depends on discount rate

The SCC is <u>the stream of damages</u> of an additional ton of carbon along a certain emission path.

How much does the annual damage of **$1 for the next 200 years** cost you today?

Is it $200? More? Less? How much <u>exactly</u>?



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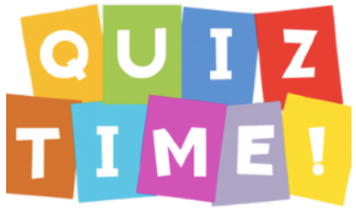


It depends on **the discount rate*** *on goods* that quantifies a relative price of goods at different time points.

*the real return on capital, the real interest rate, the opportunity cost of capital and the real return.

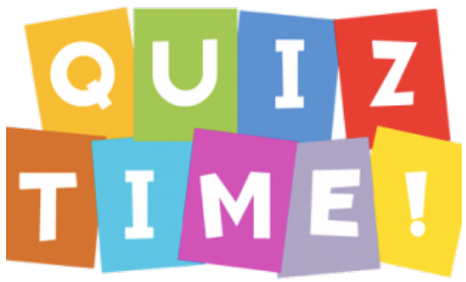
When do you care more about future profits/losses?

A. Given a high discount rate.

B. Given a lower discount rate.

C. I do not care anyway.

A paradox of low discount rates in IAMs



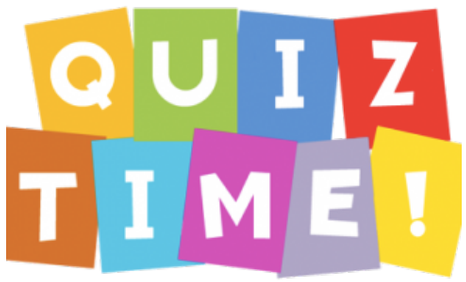
Assume that starting in 2200, we have annual damages equal to 0.1 percent of net consumption.

Equilibrium real interest rate is 1.4%.

What one-time investment is justified today to remove the wrinkle that starts in two centuries?

[A Wrinkle Experiment, Nordhaus 2007]

A paradox of low discount rates in IAMs



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56% of one year's world consumption to fix a tiny problem that starts in 2200!

[A Wrinkle Experiment, Nordhaus 2007]

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- **Clean Power Plan (CPP)**

Clean Power Plan (CPP)

- is a policy aimed at combating climate change and focused on reducing emissions from coal-burning power plants, as well as increasing the use of renewable energy, and energy conservation;
- proposed by the U.S. Environmental Protection Agency (EPA) in June 2014;
- under the Obama administration.

Clean Power Plan (CPP)

- March 28, 2017, president Trump orders to EPA to immediately review CPP.
- October 16, 2017, the repeal of CPP is proposed by the Trump EPA;

Media coverage

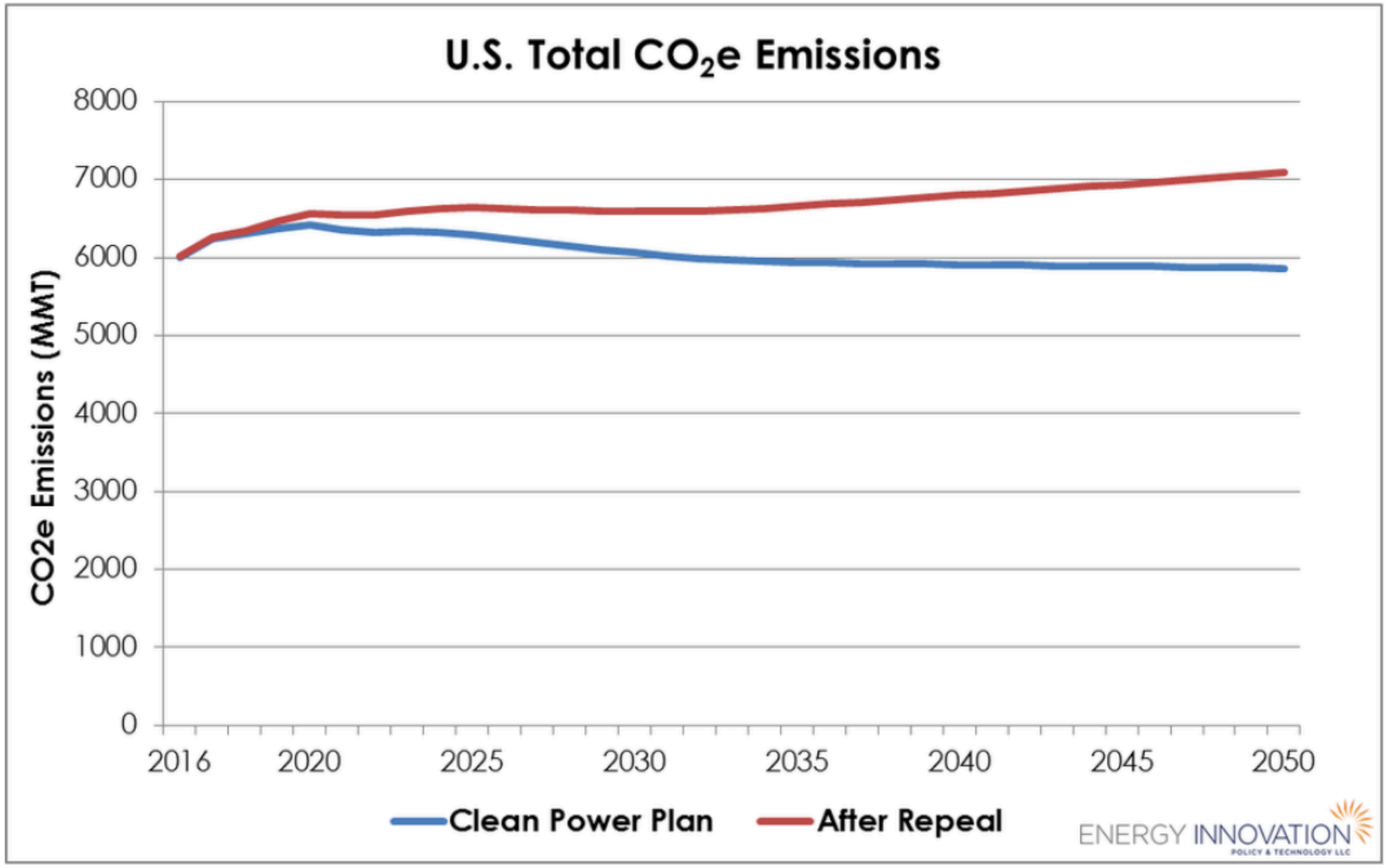
- New EPA document reveals sharply lower estimate of the cost of climate change
  The Washington Post

- The Flawed Analysis Behind Trump Administration's Proposed Repeal of the Clean Power Plan
  World Resources Institute

- Should the Social Cost of Carbon Be Higher?
  Scientific American

Why is it important?

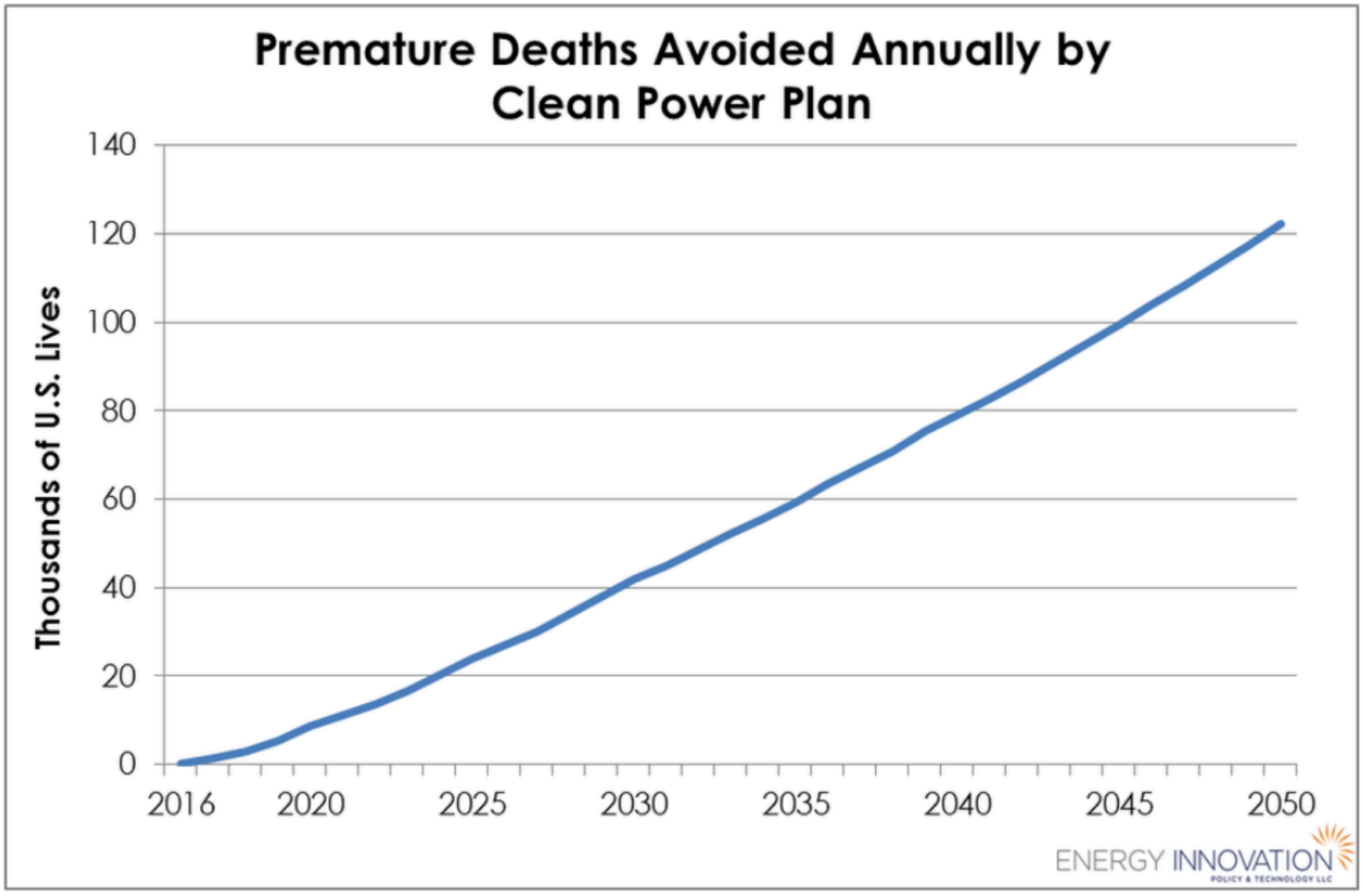
CPP combats global warming.



Repealing the Clean Power Plan would emit an additional 1,200 million metric tons of carbon dioxide in 2050. (Credit: Energy Innovation) [-] source: Forbes

Why is it important?

CPP reduces health problems of minority and low-income communities living near power plants due to toxic emissions and air pollution



The Clean Power Plan would avoid 120,000 deaths annually by 2050. (Credit: Energy Innovation).

source: Forbes

SCC and climate benefits

- Depend on the SCC (no longer a purely academic concept!)
- The Trump EPA introduced crucial changes to the original analysis to focus on a significantly lower range of the SCC
- New estimates of the SCC allow to neglect climate benefits from emission reduction

Is there any connection between DICE and CPP?

CPP:
to be, or not to be,
that is the question

Georges Gorbet/Pool/Getty Images

CPP:
to be, or not to be,
that is the question
<u>of the SCC!</u>

Georges Gorbet/Pool/Getty Images

Crucial changes

The Obama EPA

- considered global damages
- set discount factor to 2.5%, 3%, and 5%

The Trump EPA

Crucial changes

The Obama EPA

- considered global damages
- set discount factor to 2.5%, 3%, and 5%

The Trump EPA

- considered only domestic damages; the global character of damages was ignored.
- set discount factor to 3% and 7%

SCC estimates. Summary

The Obama EPA average SCC estimates in 2030:

$17, $54, $79, and **$165.**

The Trump EPA average SCC estimates in 2030:

$1, **$7**, and $10* (domestic damages)

$7*, $53*, and $77* (global damages)

*Full analysis is not done or does not mentioned in Executive Summary.

All prices are for a metric ton CO2 in 2011$

SCC estimates. Conclusion

Is the SCC equal to $165 or just $1?

The answer makes a huge difference in calculated climate benefits of emission reductions and shapes U.S. climate policy, thus, global climate policy too.

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Join the integrated assessment modelling community to find the answer!

QUIZ
TIME!

Which SDGs are relevant to CPP?

SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
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SUSTAINABLE DEVELOPMENT GOALS

3, 7, 8, 10,13

Ethical judgements define SCC

- Discount factor
- Domestic vs global damages

Are there more objective ways to derive climate policies?