

# The Social Footprint of Carbon

## *Implications for Environmental Management and Policy*

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Dan Stokols

*Departments of Psychological Science  
Urban Planning and Public Policy  
School of Social Ecology  
UC Irvine*

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# The Great Acceleration

*From the 1950s Through the Early 2000s*



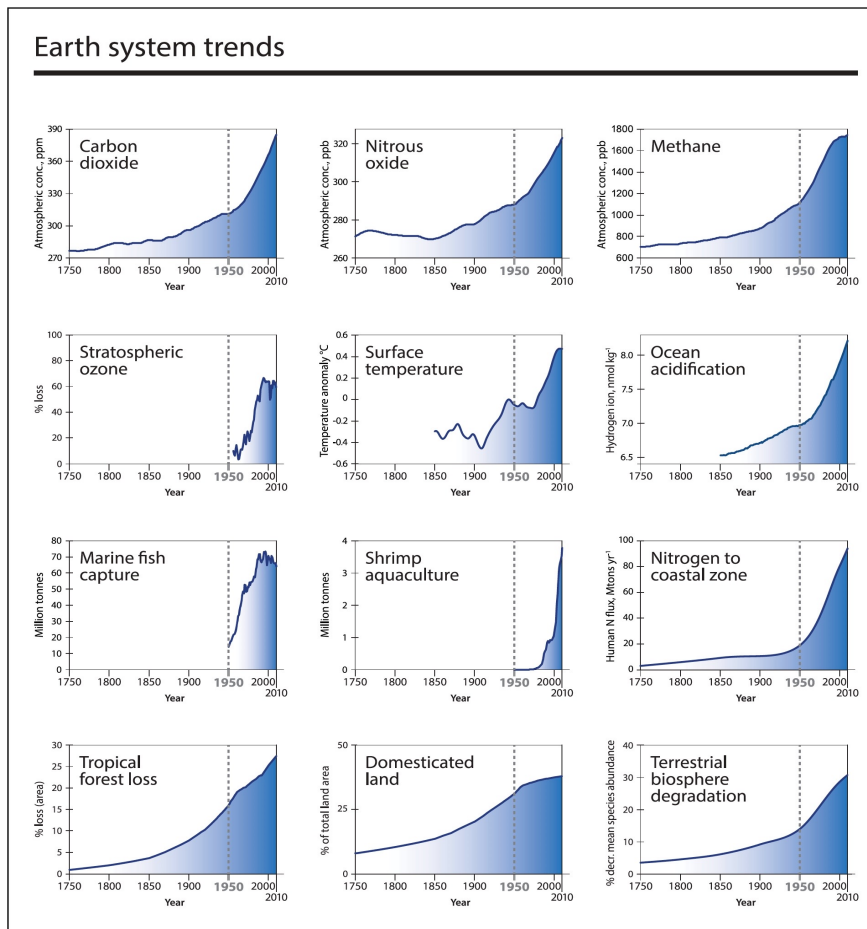
- *A period of tremendous urban development, economic growth, and technological advances that lifted millions out of poverty, enabled human exploration of outer space, and ushered in the Digital Age.*



(Steffen et al., 2015)

# Trajectory of the Anthropocene

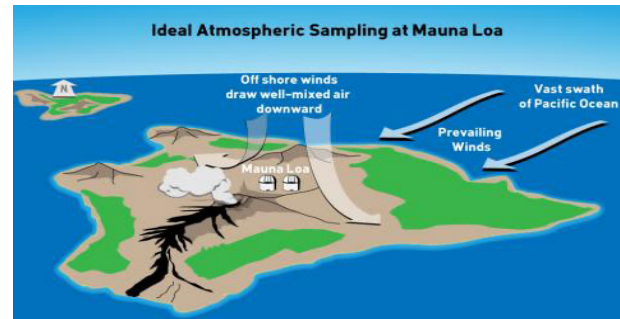
## *Aftermath of the Great Acceleration, 1950-2010*



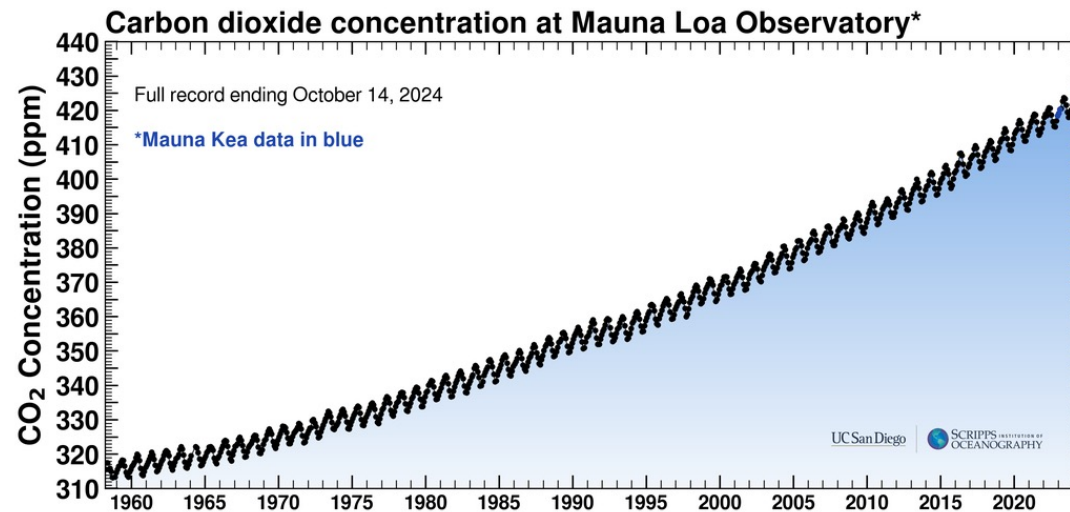
*(Crutzen & Stoermer, 2000; Steffen et al., 2015)*

# The Keeling Curve – Tracking Atmospheric CO<sub>2</sub> Levels

Charles Keeling



Mauna Loa Testing Station



(<https://keelingcurve.ucsd.edu>)

# Ecological Footprint

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- The amount of biologically productive land and marine area required to produce the resources a population consumes and absorb the corresponding waste using prevailing technology
- *Planet equivalent* – the number of earths it would take to support humanity's ecological footprint; as of 2024, the world's average ecological footprint was 1.75 planet equivalents.



(Wackernagel & Rees, 1996)

# ECOLOGICAL FOOTPRINT

*Determines how fast humans consume and produce waste compared to how fast nature can absorb and produce resources*

Energy



Carbon  
Footprint

Shelter / Housing



Land

Lumber & Paper



Forest

Sustenance



Farmland  
& Pastures

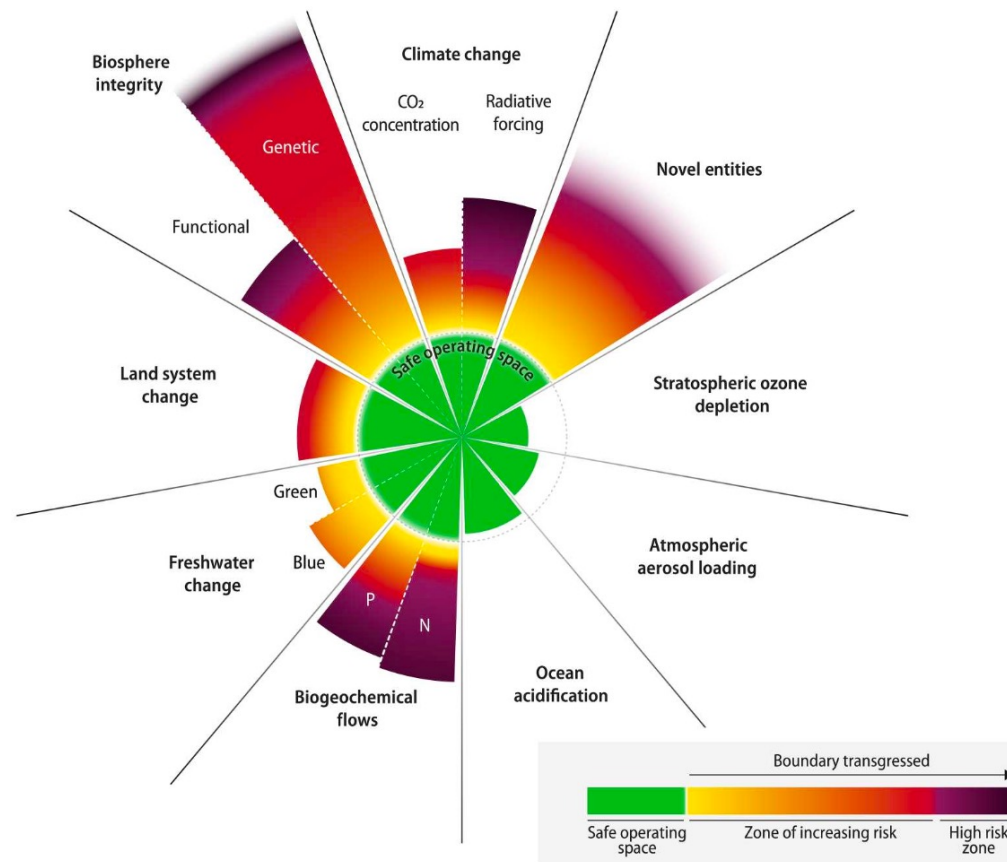
Fisheries



Oceans  
& Rivers

(<https://8billiontrees.com>)

# Humans Are Exceeding Planetary Boundaries



(Richardson et al, 2023; Steffen, Rockstrom et al., 2015)

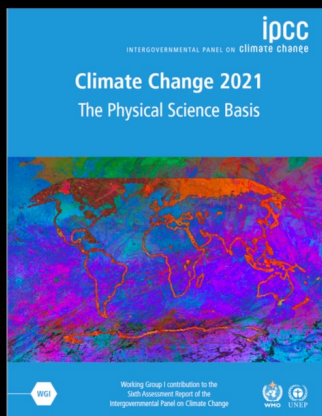
IPCC reports (1990-2023) and quantitative measures of climate change and global overshoot (such as the Keeling Curve, ecological footprint analyses, and assessments of planetary boundaries) have focused predominantly on earth system science models and measures. But there's now growing recognition of the need for more social science perspectives on climate change and remediation.

*“The first step toward reducing our ecological impact is to recognize that the “environmental crisis” is less an environmental and technical problem than it is a behavioral and social one. It can therefore be resolved only with the help of behavioral and social solutions.”*

William Rees, Preface to *Our Ecological Footprint*, 1996)

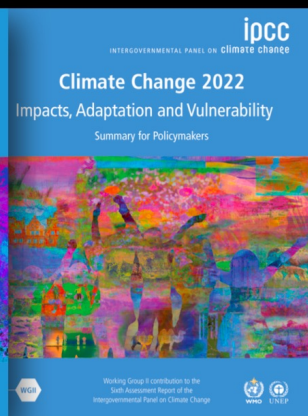
# The State of Knowledge about Climate Change

WGI



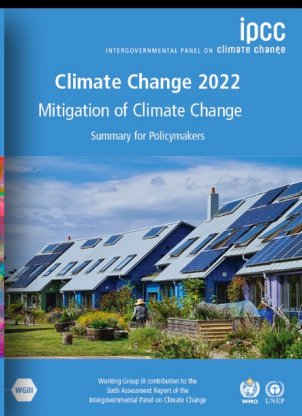
AR6 Climate Change 2021:  
The Physical Science Basis

WGII



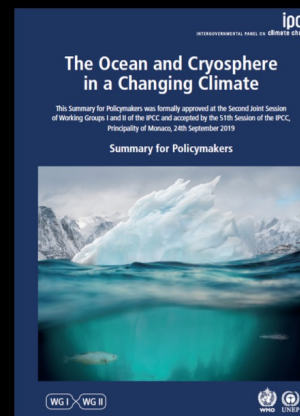
Climate Change 2022:  
Impacts, Adaptation and  
Vulnerability

WGIII



Climate Change 2022:  
Mitigation of Climate Change

Special Report



Ocean and Cryosphere in a  
Changing Climate



Climate Change and Land



Global Warming of 1.5 °C

Sixth Assessment Report | Synthesis Report

# Enablers for effective climate action

Political  
commitment

Inclusive  
governance

International  
cooperation

Effective  
ecosystem  
stewardship

Sharing of  
diverse  
knowledge

# The Social Footprint of Carbon (SFC)

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Institutionalized social patterns (e.g., interpersonal, economic, cultural, political influences) that drive carbon use or enable its reduction, and the societal impacts of carbonization and decarbonization

*“Carbon is modeled not simply as an input-output relation but as an institution, supported in practice and discourse in each society.”*

Explicit focus on the social sources and impacts of carbon production and mitigation is needed. Efforts to stem carbon emissions must address not only technological remedies but also the social and cultural underpinnings of carbon consumption.

(Lejano & Stokols, 2024)

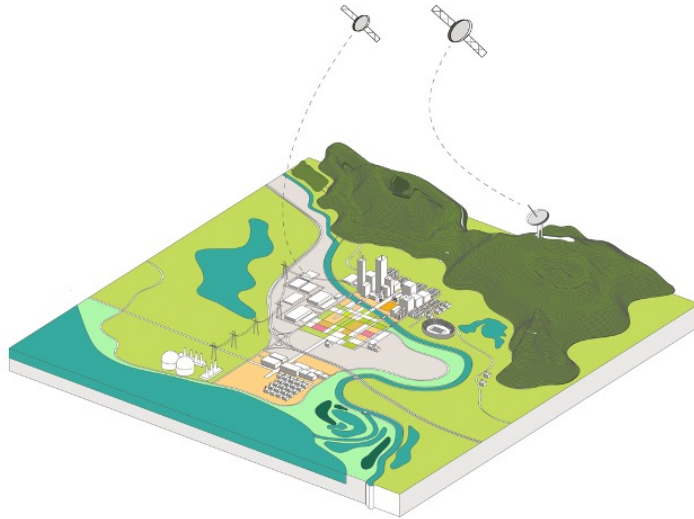
# Carbon Footprint of Society (CFS) and Social Footprint of Carbon (SFC) Perspectives

Key theme	CFS framework	SFC framework
Meaning of carbon	Carbon as a material substance	Carbon as an institution
Analysis of carbon	Patterns of carbon usage and emission	Social-cultural origins and impacts of carbon usage
Focus of intervention	Technologies for decarbonization	Institutions for decarbonization
Equity concerns	Distributive allocation of carbon reductions	Social-cultural and economic impacts of carbon reduction

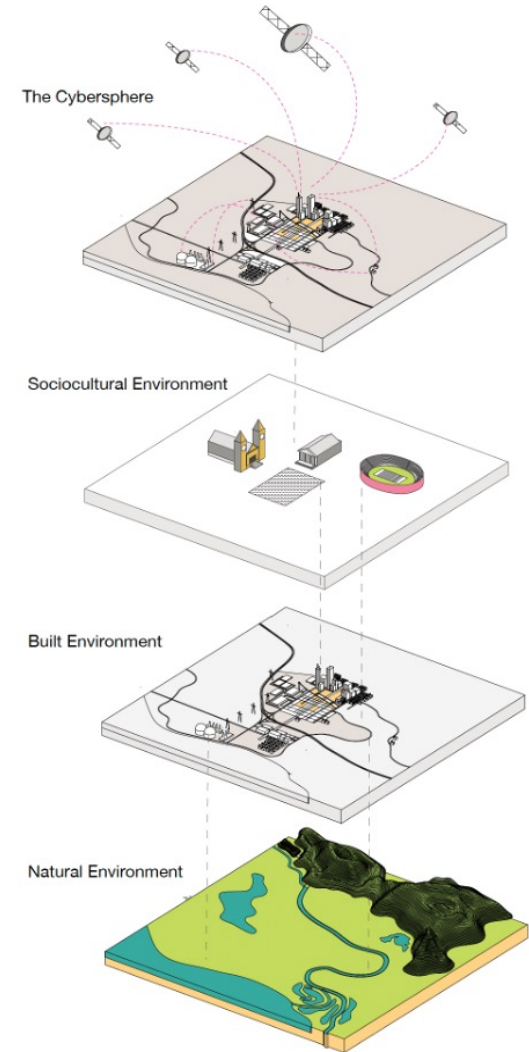
(Lejano & Stokols, 2024)

## A Social Ecological Perspective

Human communities today are a composite of natural, built, sociocultural, and virtual spheres. These different facets of our surroundings are closely interrelated and jointly influence human behavior and well-being.



(Stokols, 2018)  
*Social Ecology in the Digital Age*



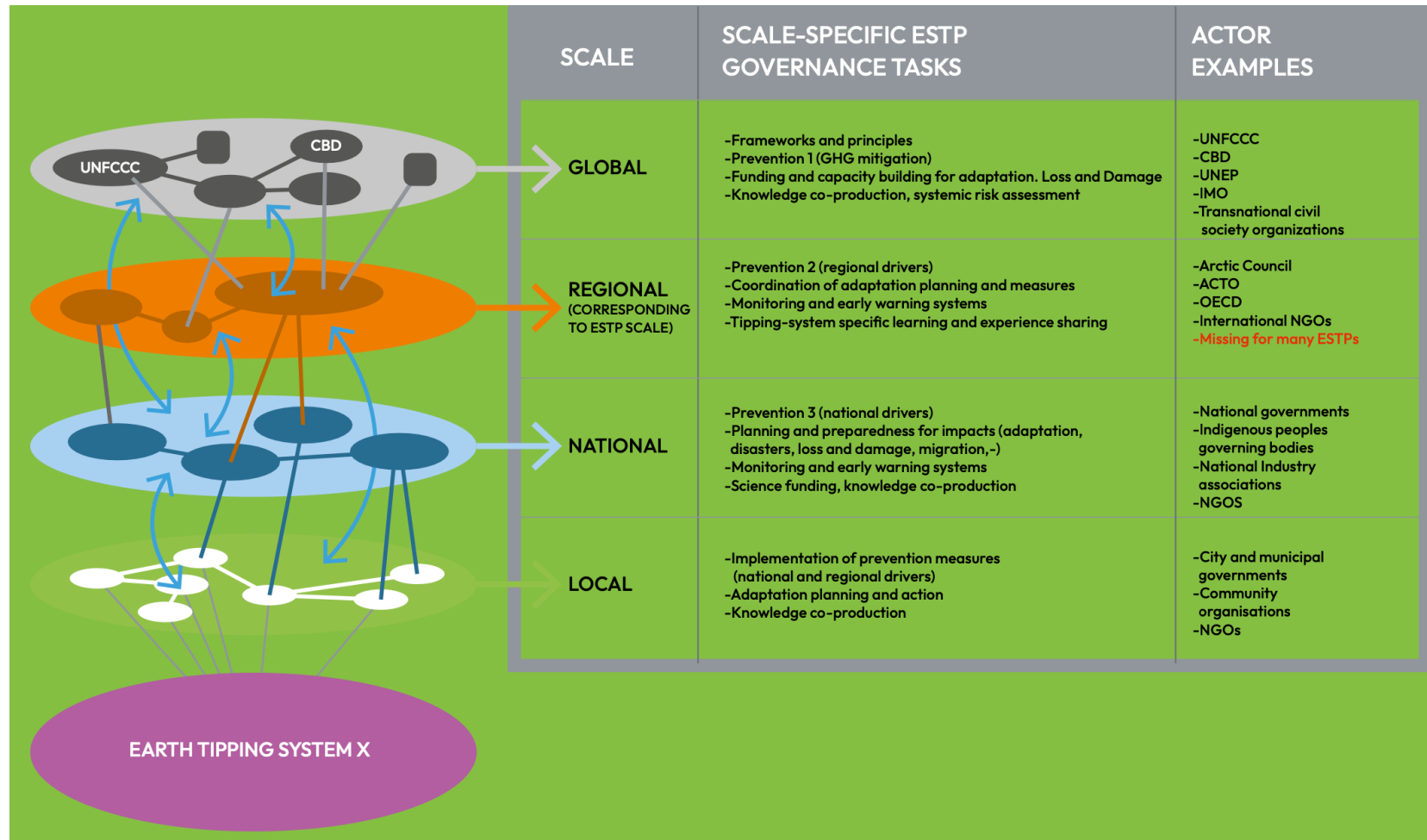
# Influences of Urban Infrastructure and Social Norms on Commuting Behavior, Energy Use, and GHG Emissions

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Zurich, Switzerland

# Multi-scale, Polycentric Governance of Planetary Resources



(Global Tipping Points Report 2023, University of Exeter; Dietz, Ostrom, & Stern, 2023)

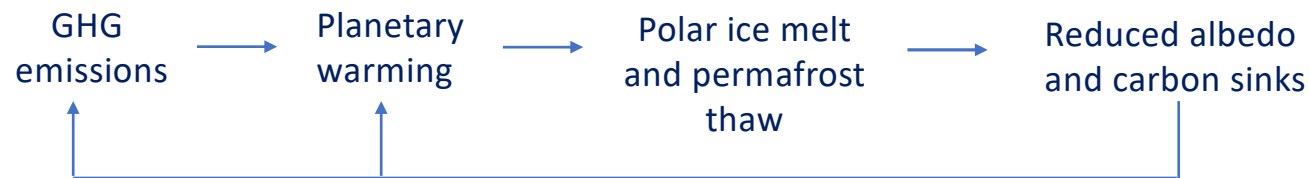
# Earth System Tipping Processes

Rising anthropogenic GHG emissions and planetary warming suggest that *Earth System Tipping Points* (ESTP's) could be passed within the Paris Climate Agreement's 2100 temperature goal range of 1.5 – 2.0 degrees Celsius.

*Earth system tipping processes* are rapid, non-linear, self-perpetuating, and often irreversible shifts in major components of the Earth system.

(Milkoreit et al., 2024; Armstrong Mackay et al, 2022)

Earth system tipping processes are often driven by positive feedback loops as in the following example:



# Map of Climate Tipping Elements



(Rockstrom et al, 2024)

# Social Tipping Points and Processes

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*Social Tipping Points (STPs)* – points within a social ecological system (SES) at which a small quantitative change triggers a non-linear change in the social component of the SES, driven by self-reinforcing positive feedbacks, that inevitably and often irreversibly lead to a qualitatively different state of the social system

(Milkoreit et al., 2018; Otto, 2020)

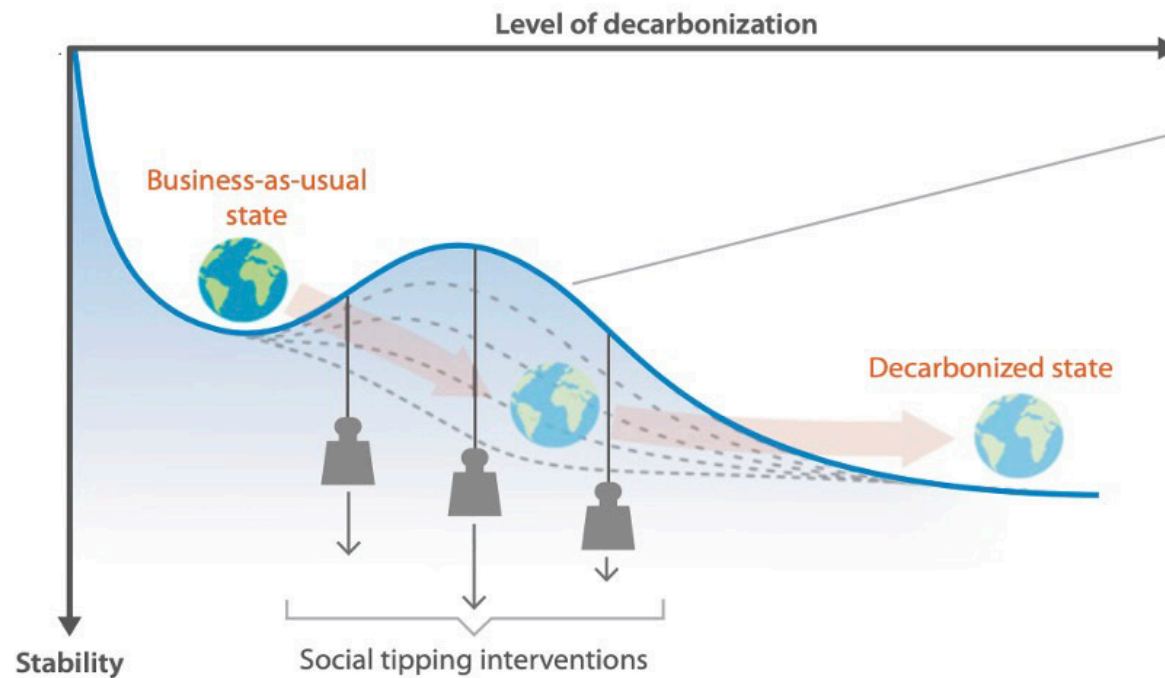
*Social Tipping Interventions (STIs)* – changes originating in social components of a social-ecological system that contribute to rapid transition of the world system toward a state of net zero anthropogenic GHG emissions

(Otto, 2020)

*Example of an STI* – introduction of tariffs, subsidies, and mandates to incentivize the growth of renewable energy production, leading to mutually reinforcing market growth and technology cost improvement

(Otto, 2020)

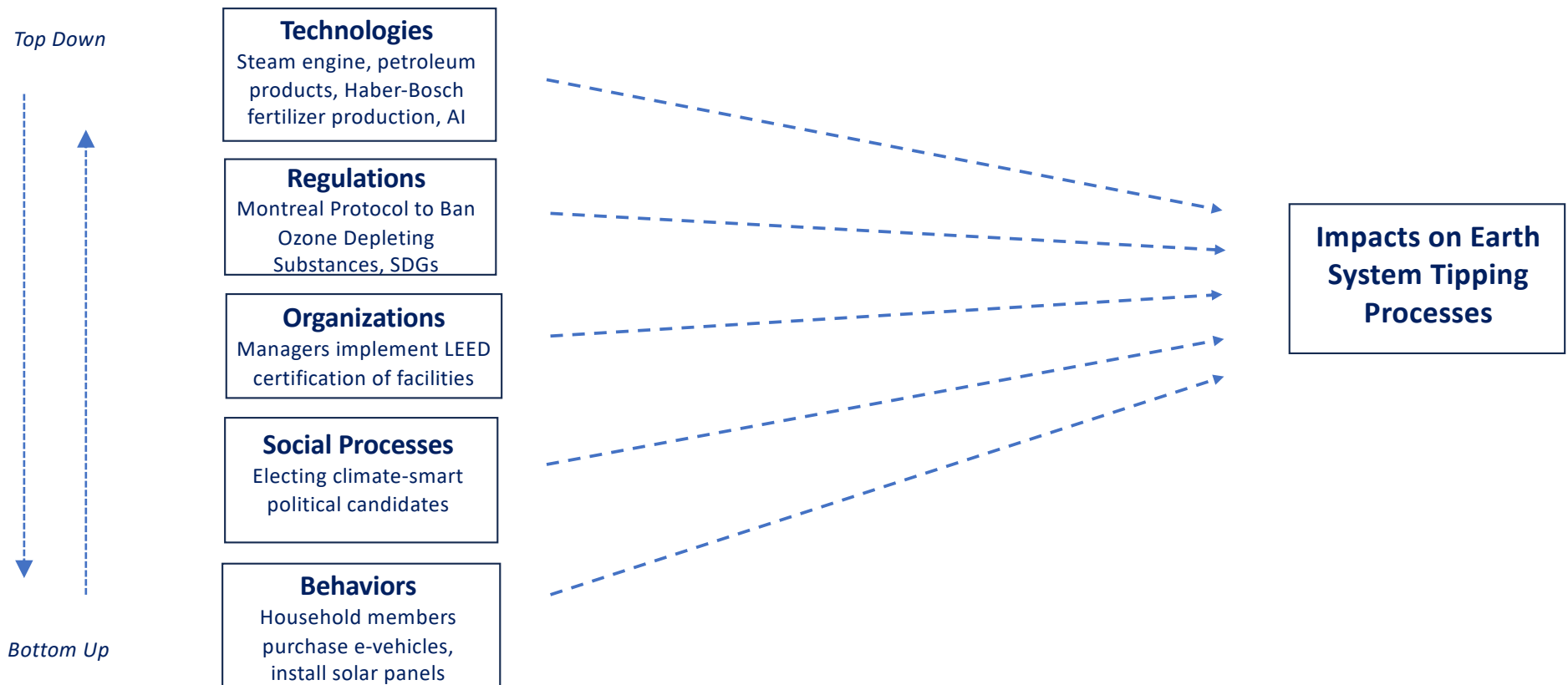
# Social Tipping Interventions



(Otto et al, 2020)

# Behavioral, Social, Organizational, Regulatory, and Technological Tipping Processes Influence ESTPs

*A variety of behavioral, social, institutional, regulatory, and technological factors influence on Earth system tipping points and processes.*



## Destruction of the Earth's Stratospheric Ozone Layer by Chlorofluorocarbons (CFCs) and Other Ozone-Depleting Substances

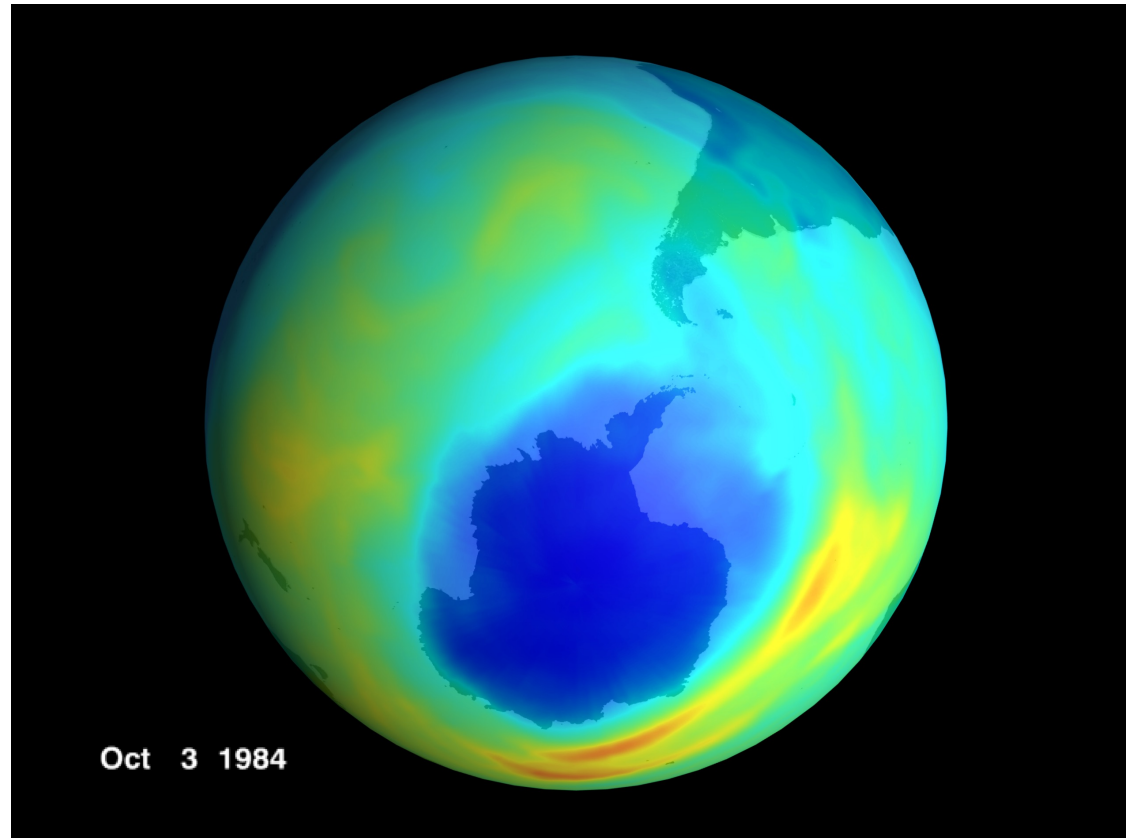



Photo of Antarctic Ozone Hole in 1984, NASA

# The Montreal Protocol

## *A Multilateral Intervention to Reverse the Destruction of the Earth's Stratospheric Ozone Layer*

**OZONE SECRETARIAT**

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THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEplete THE OZONE LAYER

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HANDBOOK FOR THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEplete THE OZONE LAYER					
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The Montreal Protocol on Substances that Deplete the Ozone Layer was designed to reduce the production and consumption of ozone depleting substances in order to reduce their abundance in the atmosphere, and thereby protect the earth's fragile ozone Layer. The original Montreal Protocol was agreed on 16 September 1987 and entered into force on 1 January 1989.

The Montreal Protocol includes a unique adjustment provision that enables the Parties to the Protocol to respond quickly to new scientific information and agree to accelerate the reductions required on chemicals already covered by the Protocol. These adjustments are then automatically applicable to all countries that ratified the Protocol. Since its initial adoption, the Montreal Protocol has been adjusted six times. Specifically, the Second, Fourth, Seventh, Ninth, Eleventh and Nineteenth Meetings of the Parties to the Montreal Protocol adopted, in accordance with the procedure laid down in paragraph 9 of Article 2 of the Montreal Protocol, certain adjustments and reductions of production and consumption of the controlled substances listed in the Annexes of the Protocol. These adjustments entered into force, for all the Parties, on 7 March 1991, 23 September 1993, 5 August 1996, 4 June 1998, 28 July 2000 and 14 May 2008, respectively.

The Parties to the Montreal Protocol have amended the Protocol to enable, among other things, the control of new chemicals and the creation of a financial mechanism to enable developing countries to comply. Specifically, the Second, Fourth, Ninth and Eleventh Meetings of the Parties to the Montreal Protocol adopted, in accordance with the procedure laid down in paragraph 4 of Article 9 of the Vienna Convention, four Amendments to the Protocol – the London Amendment (1990), the Copenhagen Amendment (1992), the Montreal Amendment (1997) and the Beijing Amendment (1999). Unlike adjustments to the Protocol, amendments must be ratified by countries before their requirements are applicable to those countries. The London, Copenhagen, Montreal and Beijing Amendments entered into force on 10 August 1992, 14 June 1994 10 November 1999 and 25 February 2002 respectively, only for those Parties which ratified the particular amendments.

In addition to adjustments and amendments to the Montreal Protocol, the Parties to the Protocol meet annually and take a variety of decisions aimed at enabling effective implementation of this important legal instrument. Through the 22nd Meeting of the Parties to the Montreal Protocol, the Parties have taken over 720 decisions. The decisions adopted by the Parties are included in the reports of the Meetings of the Parties and, along with other documents considered during the meetings, can be accessed under the meetings' links

(<https://ozone.unep.org/treaties/montreal-protocol>)

# Government Incentives to Promote Private Sector Investment in Renewable Energy Technologies

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*Solar Energy*



*Wind Power*



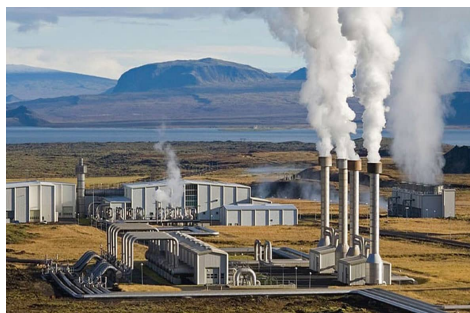
*Hydropower*



*Bioenergy and Biofuels*



*Geothermal Energy*

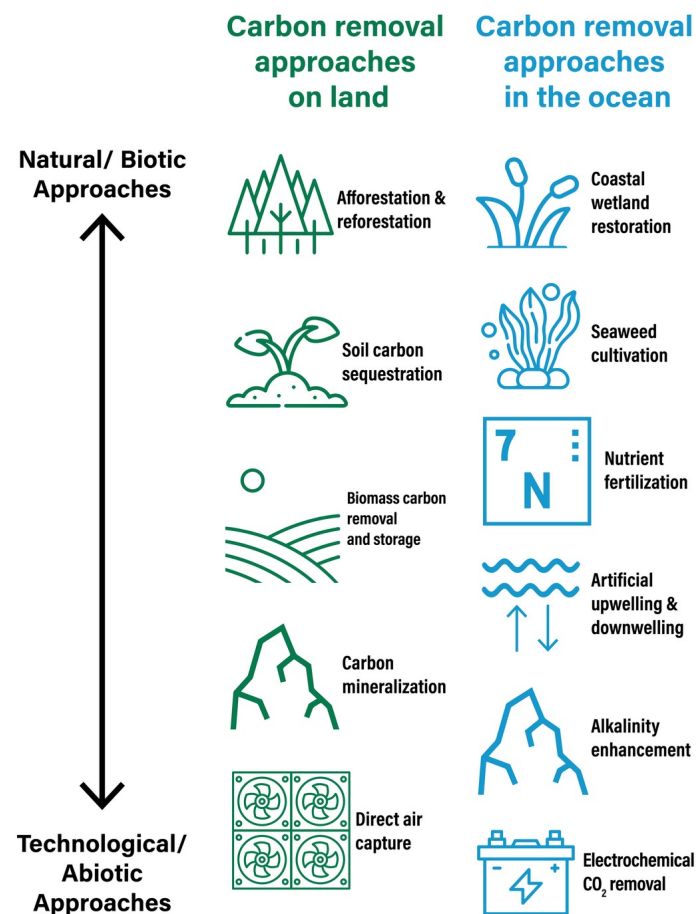


*Ocean Energy*



(International Renewable Energy Agency, 2016)

# Investments in Carbon Dioxide Removal (CDR) Strategies



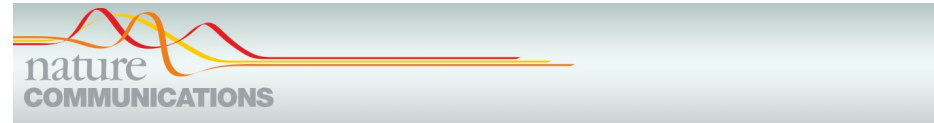
(<https://www.wri.org>)

# Targeting High-Impact Environmental Behaviors

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Sustainable behaviors and lifestyles encompass so many different actions (e.g., resource consumption in homes and workplaces, waste disposal and recycling, transportation choices), so it's important to consider *which* and *whose* activities have greatest impact on environmental outcomes.

## Recent Largescale Studies of Interventions to Change Climate Beliefs and Behavior



ARTICLE

<https://doi.org/10.1038/s41467-019-12457-2>

OPEN

Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change

Nisa et al., 2019

SCIENCE ADVANCES | RESEARCH ARTICLE

**SOCIAL SCIENCES**

**Addressing climate change with behavioral science: A global intervention tournament in 63 countries**

Vlasceanu et al., 2024

# Target One-Time Purchases of Energy Saving Devices



Efforts to promote environmentally protective behavior should *target the actions of individuals and groups that afford greatest leverage in reducing energy use and emissions.*

(Dietz et al. 2009; Gardner & Stern, 2008)

# Curtailment vs. Efficiency Behaviors

## *Curtailment*



Turn off/unplug



Walk or take bus  
rather than car



Turn off lights

## *Efficiency*



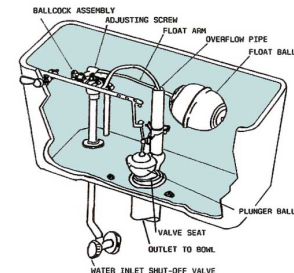
Insulate home



Use energy efficient  
appliances



Check for  
thermal leaks



Check toilet  
for leaks

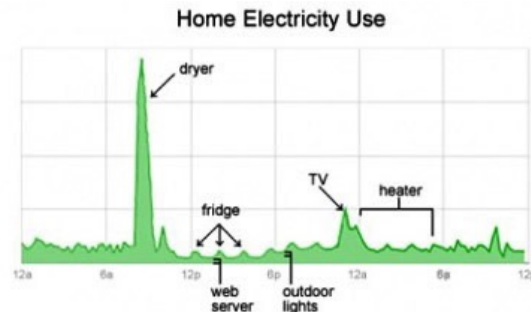
(Gardner & Stern, 2008)

# Technology-Enabled Feedback to Curb Household Energy Use

*People are more likely to use energy-efficient appliances if they are provided with immediate energy use feedback*



Kill a Watt meter



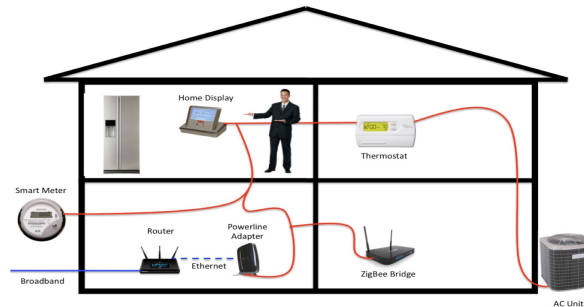
Google Power Meter



Smart Phone Apps



Smart Meter



Home Energy Monitoring and Feedback System

(Karlin, Zinger, & Ford, 2015)

# Emphasize Norm-Based Appeals for Pro-Environmental Behavior

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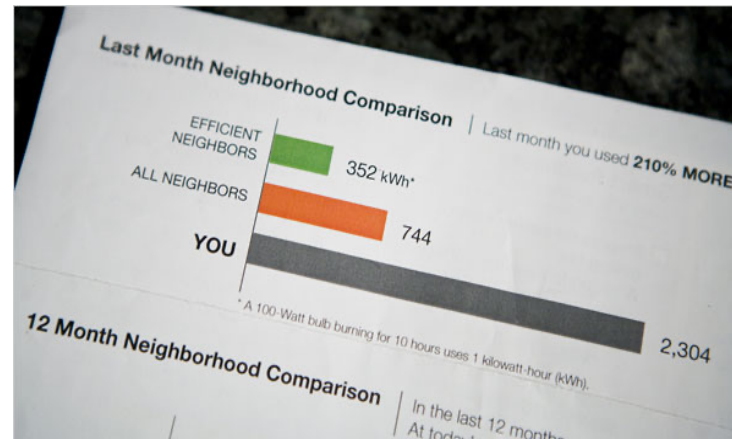
## *Pre-Behavioral Normative Appeal*



### *ASU HOTEL TOWEL REUSE STUDY*

(Goldstein, N.J., Cialdini, R.B., Griskevicius, R.B., 2008)

## *Post-Behavioral Normative Feedback*



### *SACRAMENTO MUNICIPAL UTILITY DISTRICT ...*

(New York Times, January 30, 2009)

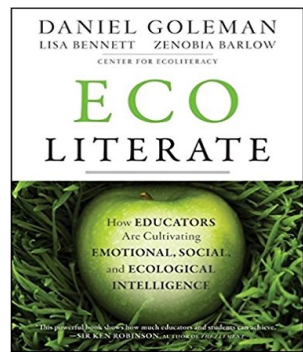
# Combining Strategies to Promote Sustainable Behaviors and Lifestyles

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1. Provision of Information
2. Financial Incentives
3. Verbal or Written Feedback
4. Social Norms and Social Marketing
5. Social Praise
6. Institutional Support

# Educational, Organizational, and Institutional Supports for Sustainable Behaviors and Lifestyles

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*Nurturing Sustainability Values*



*Environmental Stewardship Programs*



*UCI's Commitment to Carbon Neutrality and Eventual Net-Zero Emissions*

# Scaling Up Environmentally Supportive Behaviors

## *Coupling Locally Sustainable Technologies with Centralized Infrastructures*

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Energy Sector



[http://en.wikipedia.org/wiki/Fossil-fuel\\_power\\_station](http://en.wikipedia.org/wiki/Fossil-fuel_power_station)

Agribusiness



<http://www.templetonco.com/Agribusiness>

Water Sector



<http://bit.ly/1ro83WX>

Residential Solar



<http://bit.ly/WJf0I>

Urban Farming



<http://www.shareable.net/>

Home Water Capture



<http://www.rwh.in/>

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(Tomlinson, Nardi, Patterson, Richardson, Saphores, & Stokols, 2015)

# Personal and Other-Directed Environmentally Relevant Behaviors

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## Personal

- ❑ *Person Takes Action That Modifies His/Her Own Energy Use Patterns*

### Examples:

- *Employee turns off the lights in his or her office when exiting*
- *Resident participates in a municipal curbside recycling program*

## Other-Directed

- ❑ *Person or Group Takes Action That Modifies Others' Energy Use Patterns*

### Examples:

- *Managers install occupant sensors and energy conserving bulbs*
- *City council members vote to implement curbside recycling program in multiple neighborhoods*

# Public Policies at Municipal and State Levels to Promote Sustainability

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## *California Will Require Solar Power for New Homes*



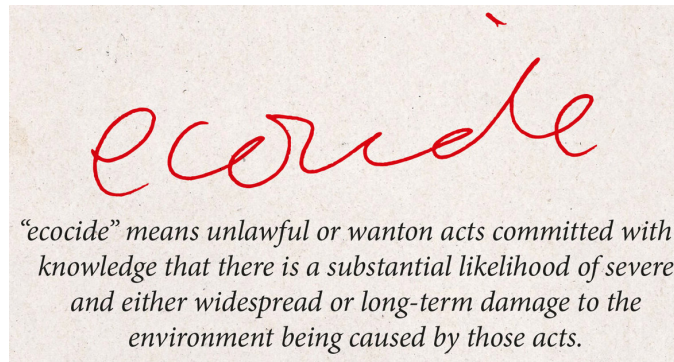
Solar panels on a Southern California home. State law requires at least 50 percent of California's electricity to come from noncarbon-producing sources by 2030. David Paul Morris/Bloomberg

(*New York Times*, May 9, 2018)



**80% of global CO2 emissions** from fossil fuel and cement production during 2016-2022 were attributable to just **57 corporate and state-owned entities**. Carbon Majors' database of historic CO2 production data extends from 1854-present and focuses on 122 of the world's largest oil, gas, coal, and cement producers.

(<https://carbonmajors.org>)



## Targeting Ecocide Crimes Through International Law



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<https://www.stopecocide.earth>; <https://www.stopecocide.earth/expert-drafting-panel>