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BENDING THE CURVE

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Climate Change Education for All
Bending the Curve Education Project

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Summary

The quest for a sustainable planet and for a sustainable humanity must include cradle-to-grave climate literacy for everyone, including children in kindergarten, college students, and grown-ups all the way to senior citizens. In this chapter, we outline such a cradle-to-grave education protocol called Bending the Curve *that has been initiated by academics and researchers at the 10-campus University of California.* Bending the Curve *is an accessible, adaptable and highly scalable set of educational tools that can increase climate literacy for all in this moment of climate urgency.*

Solutions to the climate problem require a multi-dimensional approach to bend the curve of global warming. Such an approach was articulated in 2015 in a report titled Bending the Curve: Ten Scalable Solutions published by the University of California (UC)[1]. The report was a collaboration between 50 researchers from the natural, technological, and social sciences, as well as the humanities. The report calls for solutions that integrate science, technology, societal transformation, governance, market instruments, and ecosystem management perspectives. In this Chapter, we describe an education effort that is designed after this multi-faceted and integrated approach to climate solutions.

Education and Climate Change: All societies endeavor to transfer skills, competencies, virtues and values to the next generation. The work of educating children and youth is culturally constituted, highly varied across societies, and ever evolving[2]. Schools should reflect—and reflect upon—the cultural and socioeconomic realities of the communities of which they form an essential part. The curiosity and joy of learning at a young age opens the door to the gold standard of any education system: the molding of life-long learners who have the tools and savoir-faire to continue learning long after formal schooling stops.

Today schools the world over must be at the forefront of preparing the next generation to engage and flourish in problematic times and in catastrophic contexts. A growing global challenge today is unchecked climate change and its effects—known and yet to be discovered—on nature, on health, on economy and society.

Climate Education for All: This Chapter presents an overview of a host of climate change educational programs and tools designed to engage all kinds of learners in different contexts. Each program is mindful of age differences and various social considerations in making learning and teaching about climate change engaging, age-appropriate, and culturally consonant. Our fundamental claim is that climate change education, carefully conceived and well executed has inherent value and furthermore leads to measurable desirable outcomes. A recent study (2020) found that climate change education programs have the potential to change individual behaviors and attitudes, resulting in reductions in carbon emissions of similar magnitude to other large-scale mitigation strategies[3]. The quest for a sustainable planet and for a sustainable humanity must include climate literacy for all, including pre-K-12 children and youth, college students, and adults all the way to senior citizens. The chapter outlines such a cradle-to-grave education project called *Bending the Curve*. The goal of this project is to educate and empower millions of climate champions across the world who will help solve the problem before it is too late.

I. The Climate Crisis

Unsustainable consumption of fossil fuels and other natural resources and the waste produced by this continually growing consumption pathway is a fundamental cause for polluting the air, the water, and the land. This pollution of the planetary climate and ecosystem has unleashed two catastrophic forces: climate disruption and species extinction, both of which pose existential threats to all of humanity and the ecosystems. With unchecked climate change and air pollution the very fabric of life on Earth is at grave risk[4].

We human beings are creating a new and dangerous phase of Earth's history that has been termed the Anthropocene. The term refers to the immense effects of human activity on all aspects of the Earth's physical systems and on life on the planet. With accelerating climate change, we put ourselves at risk of massive crop failures, new and re-emerging infectious diseases, heat extremes, droughts, mega-storms, floods and sharply rising sea levels. The economic activities that contribute to global warming are also wreaking other profound damages, including air and water pollution, deforestation, and massive land degradation, causing a rate of species extinction unprecedented for the past 65 million years, and a dire threat to human health through increases in heart disease, stroke, pulmonary disease, mental health, infections and cancer. Climate change threatens to exacerbate the current unprecedented flow of displacement of people and add to human misery by stoking violence and conflict. The poorest of the planet, who are still relying on 19th century technologies to meet basic needs such as cooking and heating, are bearing a heavy brunt of the damages caused by the economic activities of the rich[1].

There is a shrinking window of time to implement climate solutions and avoid further catastrophic impacts. Climate change is a major problem that today's youth and generations unborn will have to confront and manage, as they will not have the luxury of ignoring the science and delay actions any further. The impacts of climate change are both inter- and intragenerational, and have deep ethical implications with respect to how we care about each other and about how we care about creation. Society needs to embrace Pope Francis' call for an integral ecology, which recognizes the intrinsic link between environmental justice and social justice. We must hear both the "cry of the earth and the cry of the poor."

II. Role of Education

A 21st Century education for climate change, environmental and human sustainability must be rooted in the best science, social science, humanities thinking, and pedagogical practice. Furthermore, it must be:

1. Relevant to local concerns while embedded on a larger global ethic of solidarity, equity and care;
2. Developmentally and age-appropriate (how a five-year-old thinks about air pollution and how a ten-year-old thinks about climate change will differ by socio-emotional and cognitive readiness to internalize and process and make meaning of facts, concepts and ideas);
3. Culturally appropriate as to the knowledge, values, sensibilities, and practices required to participate effectively within multiple, nested ecologies (local, national, and transnational) environments and communities while understanding, valuing, and respecting cultural differences;
4. Rooted in the realities of historic and systemic environmental injustices that must be understood and addressed to make progress toward equity; and
5. Focused on teacher and student inquiry, agency, leadership, and civic activism.

Climate change education, from pre-kindergarten, primary school through adulthood, must play a central role in the societal transformation that is necessary to address the current crisis. Education for climate change has proven to be effective in reducing carbon emissions[3].

It is imperative that we nurture a generation of climate-literate and empowered young people. Further, interdisciplinary climate education must also be woven into the fabric of undergraduate education, to ensure that the world's future decision-makers are equipped with the knowledge to design and implement solutions to the crisis we have left them. And lastly, education via trusted community leaders can help today's generation of adults better understand the crisis before us, and to make better decisions.

We live in an integral ecology; we inhabit a common home and we share the planet like one family. We need the relevant stakeholders to do their part: teachers will need climate scientists as partners. In turn scientists will need faith leaders to take part in the transformational moves required to communicate fact-and-science curated messages to mobilize public opinion. Scientists will need community leaders to help them carry the message of climate change science, impacts, and solutions to the public. Policy makers will need to translate the best science and best education to articulate smart new policy frameworks. We all need enlightened business leaders to lead a revolution on sustainable business practices and products for a sustainable word.

III. Six Clusters, Ten Solutions

Scientists and technological innovators have identified key solutions to the climate change crisis, and the implementation of many of them is already underway. A collection of these solutions was produced in 2015 in *Bending the Curve: Ten Scalable Solutions*, a landmark report by the University of California (UC)[4].

We outline ten scalable solutions that have made California a global leader in climate solutions over the last decades. These solutions are organized into six clusters: science, societal transformation, governance, markets and regulation, technology, and natural and managed ecosystems (fig.1, below). The ten solutions represent an integrated approach to climate change across a wide range of expertise and sectors, and are described as *scalable* because they can be implemented in local or regional "living laboratories" and then adapted to the changing needs or demands of a variety of contexts and scaled up to national and global levels.
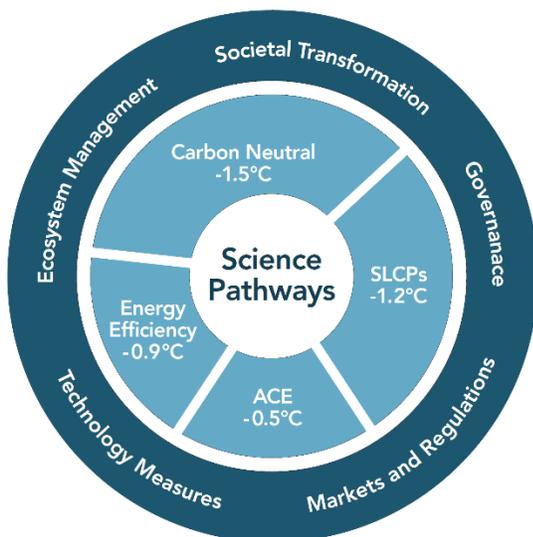
Figure 1 - The magnitude of potential cooling by 2100 that can be achieved by implementing carbon neutrality, phasing out Short Lived Climate Pollutants (SLCPs), and actively extracting atmospheric carbon (ACE) if implemented well before 2030. Energy efficiency by itself can cool only by 0.9°C. Reaching these goals require interdisciplinary action of the six clusters: science pathways, societal transformation, governance, markets and regulations, technology measures, and ecosystem management. The magnitude of the cooling for the science pathways is taken from Xu and Ramanathan[5].

IV. Societal Transformation

For the poorest three billion of Earth's population, 2°C (3.6°F) of global warming, expected before 2050, would pose catastrophic existential threats, in effect raising an unprecedented intra-generational equity issue, which will become worse as it lingers for centuries affecting generations unborn[1].

In the first quarter of the 21st Century, the world witnessed the largest number of forcibly displaced human beings in history. While precise numbers are both elusive and changing 2019 United Nations High Commissioner for Refugees data report that more than 70 million people—the equivalent of every man, woman, and child in Lagos, São Paulo, Seoul, London, Lima, New York, and Guadalajara—are escaping home into the unknown. While migration is a shared condition of humanity, it is increasingly catastrophic: "The majority of new displacements in 2016 took place in environments characterized by a high exposure to natural and human-made hazards, high levels of socioeconomic vulnerability, and low coping capacity of both institutions and infrastructure[6]."

The Science cluster identifies what our targets should be; it prescribes which climate pollutants we should target and defines the pathways and timelines for society to remain under 2°C of warming. The remaining clusters explore the diverse levers we need to pull to achieve these targets.

Innovations in policy and governance, business practices, and technologies are necessary for these solutions to take effect. But developing the broad societal will and motivation to take advantage of these levers will require the work of education. Implementing solutions to climate change demands that we foster societal understanding of the challenge, and a global culture of climate action. Bending the curve requires societal transformation—a radical shift in attitudes and behaviors. We must learn to think about and behave differently in our own lives, in our interactions with each other, and in our interactions with nature. We need a bold humanistic vision of education, as articulated by Stefania Giannini in this volume, with "based on human rights, social justice, dignity, cultural and social diversity, and intellectual solidarity. This vision reaffirms a set of universal ethical principles and the need to strengthen moral values in education and society. It starts with people of all ages and the analysis of development contexts. It is inclusive and equitable, and informed by interdisciplinary research across the sciences, arts and humanities. Finally, it is participatory and international in scope."

As Pope Francis put it societal transformation requires shifting "hearts, heads, and hands."

Education must serve to develop climate communication strategies that invest people personally in the challenge, and help everyone think about their individual and collective lives differently. Effective climate communication is not simply a matter of transmitting scientific knowledge. Having better science information, while important, does not seem to be the main reason why people accept that climate change is happening, or change their behaviors. People change their attitudes and behaviors when the social becomes personal and familial: they come to care about climate change as a relevant to the "me" and the "us." Climate communication should help us understand the impacts that climate change will have on things that are up close and matter to us: our personal well-being, and the well-being of our families and communities: the beloved creek where we first discovered shells and conches, the mysterious forest where we first encountered wild-life; the ageless glaciers where we learned the many shades, shapes, and colors of ice all now threatened by climate change. Climate communication is most successful creating social motivation for change when it is tailored to audiences and their unique contexts, needs, and aspirations[7].

We also need to harness the power of social movements, to cultivate early the collective will needed to make the change we see as essential. Social movements are unlike other forms of social change in that

they are designed to bring individual and collective motivation to make change into alignment with the authority to do so. Sometimes the people who have the authority to make change are also motivated. Sometimes they are not. When they are not, those who have the motivation must learn to transform the resources they have into the power they need to make the change they want. That is what social movements do. They work, thus, by teaching people to realize their own role as agents of change—what can I do, as one person, to put my hands on the levers of change? By developing people's capacities and teaching people to work with others, social movements transform people to transform the world[8].

The foundation of societal transformation is education at every age, from pre-kindergarten through college, from early adulthood and beyond. Like climate communication more broadly, climate education should not be understood as a passive activity of absorbing science information, but must seek to connect the learner to the challenge.

Climate education is most effective when it employs integral, inquiry-based, community-rooted strategies that invest young and adult learners in climate action. It should endeavor to help all learners understand what's at stake for them personally, but at the same time cultivate empathy for one's fellows born and unborn, and for vulnerable populations who are disproportionately impacted by climate disruption. Climate education must instill a sense of agency and generational purpose – the best antidotes of learned helplessness and anomic withdrawal[9]. The *Bending the Curve* project does all of this, targeting three distinct audiences: higher-education students and professionals; pre-kindergarten to high school and teachers; and adults of all ages, with or without college education.

Bending the Curve is a set of educational tools and protocols that present climate disruption as a complex but solvable problem requiring solutions that integrate science, technology, governance, finance, ecosystem management, ethics, and societal transformation. Students of *Bending the Curve: Climate Education Solutions* courses become active learners, and are challenged to apply their knowledge to community-based experiential learning laboratories and online dashboards.

IV. Bending the Curve Education for All

A. College Students and Professionals

The education protocol consists of four components, outline below.

1. Bending the Curve: Climate Change Solutions (BtC_CCS) hybrid course

The *Bending the Curve: Climate Change Solutions* (BtC_CCS) hybrid course was produced with the specific goal of educating students at the university level in academic contexts. The course is designed as a hybrid course, combining the best elements of a traditional in-person class with those of online learning environments and flipped classrooms. Students watch video lectures at home and attend in-person classes that are devoted to discussions and group capstone project work, facilitated by an instructor.

The course was launched in the winter of 2018, and includes over 20 recorded lectures presented by 23 expert faculty from across the UC system and beyond, covering multi-dimensional aspects of the climate problem[10]. By focusing on scalable solutions for carbon neutrality and climate stability, *Bending the Curve: Climate Change Solutions* challenges students to take matters into their own hands and identify solutions at different scales.

The BtC_CCS hybrid course introduces students to the social and natural history of climate change and the impact that climate change has on the world from various dimensions: scientific, technological, economic and social justice perspectives. Students then learn about various solutions for carbon neutrality

and climate stability, and the essential interrelationships between various solutions. They examine current living laboratories of climate solutions and critique them from a multitude of perspectives. Students are encouraged to personalize the challenge, to create a vision for leadership and action within their own various communities. They come to understanding through doing that personal values and a commitment to climate change mitigation can guide personal decisions and actions. Lastly, students experiment with diverse solutions and scenarios to reduce the carbon footprint of society. Together, these are the learning outcomes of the course.

The course culminates in a capstone project, through which interdisciplinary student teams apply new knowledge. The capstone project assignment consists of designing an integral set of solutions on a particular challenge – for example wildfires in California, or climate vulnerability among island inhabitants in the Pacific. Students research the challenge, and come to understand that no one discipline or approach alone can "solve" the problem. They are encouraged to identify a set of solutions, drawn from across the six clusters of the *Bending the Curve* report. Another variation of the capstone project assignment is that student teams investigate "living laboratories" – case studies of particularly successful integral climate action. Through their research, they come to understand why solutions require integral cooperation and action across knowledges and sectors. At the end of the course, instructors can select the most successful group capstone projects for open access publication through the California Digital Library. Opportunities for undergraduate students to publish their work are rare, and several student group projects have been published already and are now publicly accessible.

Through the 2019-20 academic year, the hybrid course has been offered on a total of 11 campuses, including seven UC campuses (some multiple times), two additional California campuses beyond the UC and universities in Taiwan and Sweden.

> 2. *Bending the Curve: Climate Change Solutions (BtC_CCS) online course*

Additionally, *Bending the Curve: Climate Change Solutions* has launched an online version, which provides an opportunity for individuals to take the course without having to be physically present in a classroom. The online version of the course uses the hybrid course as its base and optimizes the design for a fully digital learning environment, emphasizing student engagement and interactivity. Lecture videos remain the foundation of the course's content, and students are required to work together to prepare for and actively participate in live sessions hosted via video conference. Students in the online course are also expected to complete a final capstone project, imagining solutions to the climate change problem in ways that demonstrate their ability to synthesize key issues across a diverse range of disciplines, and creatively apply what they have learned.

> 3. *The Bending the Curve: Climate Change Solutions digital textbook*

The *Bending the Curve: Climate Change Solutions* digital textbook was designed to accompany the course, and is focused on solutions[11]. The 19 chapters tell us that the deep emission cuts that are required to bend the curve are well within our technical capabilities. This book demonstrates, however, that deploying the technological solutions demands a broad understanding of the multidimensional aspects of the climate change problem. It shows how we can quicken the pace of technological innovation and create the social, political, and economic impetus to implement solutions that are already available. And it explains how we can do so in a way that helps, not harms, the most disadvantaged people in society. The book's central theme is this: climate change is not a question of political beliefs but a dominant scientific and societal issue. Without fast actions to bend the curve, it can quickly morph into an issue of enormous human tragedy.

The book itself is an open-educational resource (OER) published by the Regents of the University of California that is intended for multiple audiences. It can be used as a companion text with all versions of the *Bending the Curve* course, including the hybrid and fully online courses and the MOOC series (described below). It can also be used in non-academic contexts by civic, religious and community organizations in a variety of contexts. A [companion guide](#) helps all audiences guide conversations related to the themes found in the textbook. Both the digital textbook and the companion guide are available worldwide as a free PDF download through a Creative Commons license via the California Digital Library.

The book consists of three parts. The first part sets the stage for the entire book by introducing concepts and solutions. The second part consists of chapters organized into six solution clusters that capture the multi-dimensional aspects of climate solutions. The third part focuses on special topics that are vital for developing mitigation solutions but do not properly fit into the six clusters structure.

While the book is designed to accompany the *Bending the Curve* courses, it is also written for anyone who cares about the future of the planet and human well-being. The chapters are designed to help individuals, community groups, businesses, religious leaders, mayors, heads of state—in short, everyone—to bend the emissions curve. The chapters are written for a generalist audience—nonexpert readers at the level of a second-year undergraduate student—with little assumed in the way of prior knowledge.

4. *Audience of Learners Pursuing Climate Knowledge: The BtC_CCS educational protocol*

The *Audience of Learners Pursuing Climate Knowledge: The BtC_CCS educational protocol* also targets professionals, concerned stakeholders and life-long learners from all over the world through a series of four massive open online courses (MOOCs).

Available on [UC San Diego Online](#) beginning the first half of 2020, the MOOC program of the *Bending the Curve: Climate Change Solutions* initiative consists of four self-paced courses available for learners around the world to enroll in anytime, from anywhere. The same content covered in the *BtC_CCS online course* is distributed across the first three MOOC courses so that each stand-alone course can be completed in approximately 30 hours. These MOOC courses provide access to video lectures, homework exercises, the digital textbook, and community discussion forums that allow learners to engage with each other. In the fourth and final capstone course, learners use their acquired knowledge from the first three courses to create and share an action-plan for climate change solutions in their local community. Learners can enroll in each course for free, or pay a fee to access the assessments and earn a Statement of Accomplishment issued by UC San Diego.

B. Kindergarten to High School Teachers

We propose an educational narrative building on the idea of the sustainable planet. Our starting point is the child's innate moral sensibilities and the natural and emerging scientific curiosities of youth. It should build on their solidarity, providing a sense of connection to peers in one's local environment and community as well as with youth from around the world. The sustainable planet serves to expand the sense of "me" into "us" and the "us-vs-them" into the "us-with-them group." It endeavors to provide a compelling moral imperative that can set youth on an active search for Bending the Curve solutions to interrupt and reverse harmful disruptions in their environment. Above all, the purpose is to expand the opportunities for every student to learn about climate change and to act on what she is learning effectively and for the common good.

The UC and California State University (CSU) systems are presently partnering with key stakeholders to advance environmental and climate change literacy for prekindergarten to grade 12. Together, the UC-CSU system encompasses 33 campuses and over 760,000 students, and trains 56 percent of the pre-kindergarten to grade 12 teachers in California.

In September 2019, the leadership of the UC and CSU systems signed a declaration of climate emergency sponsored by the United Nations. Following this declaration, the Environmental and Climate Change Literacy Project and Summit (ECCLPS), a collaborative effort helping to prepare current and future teachers to respond to climate change issues, held the *Environmental and Climate Change Literacy Summit* in December 2019. The purpose of the ECCLPS is to inform and encourage the advancement of pre-kindergarten–12 environmental and climate change literacy through the preparation, development and support of future and current teachers in California. By ensuring that California educators have the knowledge, skills, support and opportunities they need to address climate issues, the initiative aims to help more than 500,000 high school students each year to become literate in environmental and climate change issues and solutions.

The ECCLPS summit seeded a collaborative effort to prepare current and future teachers to respond to the need for climate change education. UC and CSU educators, California government representatives and other global decision-makers, representatives from the public K-12 school system, representatives of the indigenous communities, and others contributed to a report that provides a road map for ECCLPS' goals, objectives and recommendations[12]. Educating the next generation on climate change impacts and solutions requires preparing teachers for the task.

ECCLPS focuses on how to best prepare teachers for facilitating climate dialogue with their students before teaching, while teaching, and for teaching different age-groups. Three respective working groups focused their work on: 1) pre-service, which addresses the preparation of future teachers; 2) in-service, which addresses the continued support and learning of current teachers; and 3) curriculum, which addresses the course of study for all students.

The basic recommendation of ECCLPS is to integrate environmental and climate change literacy across all subjects[12].

Both the *Bending the Curve: Climate Change Solutions* MOOC and ECCLPS is complemented by UC-CSU's NXTerra initiative that is a resource for college teachers from across all disciplines and anyone seeking to enhance their teaching and learning about the climate crisis, critical sustainability, and climate justice studies, both inside and outside the classroom. NXTerra's online platform centralizes resources including course syllabi, assignments, bibliographies, films, videos, podcasts, and sustainability news at UC and CSU campuses.

C. Climate Literacy for Grown-Ups

Bending the Curve: Climate Education Solutions is a strong starting point in climate education since it assembles the collective wisdom of experts from many disciplines. But formal education alone, whether in the classroom or online, cannot solve the climate crisis. Climate education needs to reach the general public beyond those for whom these materials are accessible in academic contexts.

To do this, scientists and educators must form alliances with faith leaders, tribal-leaders, policymakers and like-minded influencers to articulate and disseminate climate action messages in contexts that are personal and relevant to multiple communities. One approach is to produce an inclusive and locally

relevant education program aimed at engaging the general public, including, very importantly, those who are dismissive of climate change science.

Similar to existing *Bending the Curve* materials, this education program, *Climate Literacy for Grown-Ups*, would form an alliance between four crucial sectors: academics, faith leaders, the private sector, and policy-makers, to develop a locally relevant education program for faith leaders on how climate change poses risks to communities around the United States, and opportunities for developing and implementing solutions. These materials would serve as tools for faith leaders to take and adapt as appropriate for their communities.

At present, a key obstacle that scientists and educators face when reaching out beyond academia is the politicization of the topic of climate change. There is a pressing need to depoliticize the subject and educate the public not only on the moral obligations we all have to the environment, and to each other, but to the real risks we are all facing. Though this effort is applicable globally, the present focus is on communities in the United States.

Climate Education for Grown-Ups is the culmination of brainstorming with leading theologians, religious leaders, climate and social scientists, and communicators. It also addresses an urgent issue that has long been identified by religious groups, including the Pontifical Academy of Sciences and Pope Francis, who together have advanced numerous solutions and calls to action regarding our collective responsibility to protect human health and wellness – "a moral obligation to safeguard the earth for future generations[13]."

V. Beyond California

Although the educational protocol presented here is developed primarily by experts in California, it is by no means applicable only to California, or even the United States. Certain components of the educational protocol, for example *Higher Education*, have already transcended state lines and international borders. *Bending the Curve: Climate Change Solutions* was designed with flexibility and scalability in mind as a cross-campus initiative for students at different campuses within the UC system. *Bending the Curve: Climate Education Solutions* is customizable to its audience in terms of age, culture, and region. Campus coordinators design their own approach and assemble their own subset of the available materials. They are provided with teaching guides that include detailed instruction on how to facilitate group discussions and suggestions for examinations and capstone project assignments, but they are free to be as creative as they wish with their applications of the course.

The course has been piloted successfully at universities in Sweden and Taiwan, and a pilot will soon be conducted at a university in North Carolina. The digital textbook is freely available worldwide through a Creative Commons license via the California Digital Library. With the further launch of the MOOC, this protocol will be available to a global audience.

Through the components of the protocol, current and future generations will be better prepared not only to confront climate change and its technical challenges, but also to become stewards of society, standing up for sustainable development.

A massive societal transformation on how we view our relationship with one another and with our planet must occur in tandem for true change to take place. This is why climate change education needs to be incorporated into schools, universities, and beyond traditional learning centers to engage professionals and the general public.

In September 2019, in the largest-ever youth-led demonstrations in history, young people took to the streets by the millions to articulate in hundreds of different languages and in cities big and small, on every continent on Earth, a powerful message: We must act on climate change now. Young people are struggling to make sense of the planet's finality. While all children come to contemplate the mortality of their parents and loved ones and, eventually their own, the mortality of the planet is not easily grasped. In their collective cry, they are articulating the existential terror of planetary death.

 Climate change has ignited the dynamic movement for youth agency and action in service of the common good. Climate change education for all should be a part of the solution for moving forward.

It is by nurturing socio-emotional learning, the values and virtues of engaged citizenship, and by imparting the basic skills to prepare youth for a changing world that schools and colleges become meaningful vehicles for collective empowerment and positive social action. Schools and colleges must endeavor to instill in youth humane sensibilities, empathy and compassion, communication and collaboration skills, higher-order cognitive skills for critical thinking, as well as the metacognitive abilities to become lifelong learners, civic agents and environmental literacy champions.

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Appendix 1: Bending the Curve Book Chapters

The first four chapters of the Bending the Curve: Climate Change Solutions digital textbook set the stage for the entire book by introducing concepts and solutions. Chapter 1 (Climate Change) is a broad summary of climate change science that describes what we know, how we know what we know, and the future extreme climates society will inherit this century if we do not bend the curve in time. Chapter 2 (Humans, Nature and the Quest for Climate Justice) gives a broad background on the societal behavior and history that led to the current state of affairs, while Chapter 3 (Climate Change and Human Health) describes the impacts of climate change on health—perhaps the most important motivation for urgent action. Chapter 4 (Six Clusters and Ten Solutions for Bending the Curve) gives a broad overview of the six solution clusters and ten solutions to bend the curve.

Cluster 1

Science consists of a single chapter that prescribes the emissions pathways for a safe climate. By and large, international bodies such as the United Nations Framework for Climate Change have concluded that warming in excess of 1.5°C to 2.0°C, persisting over decades to centuries, will be dangerous. Chapter 5 accepts this norm and explores pathways that will keep the warming below dangerous levels.

Cluster 2

Societal Transformation consists of three chapters. Together they argue that we need to foster a global culture of climate action that creates the will to take the measures required. Such a culture can be created by social movements (Chapter 6) and by behavioral changes through changing social norms (Chapter 7). Communication is a fundamental requirement for fostering a global culture of climate action as argued in Chapter 8 which also offers effective communication techniques to persuade those who have difficulty accepting climate change science, the data and the predictions.

Cluster 3

Governance consists of two chapters that explore policy making at vastly different scales—the local and the global. Locally and regionally, many cities and states in the United States are already well on the road to bending the curve and are acting jointly through coalitions such as C40 Cities Climate Leadership Group; the case of the state of California is analyzed in detail in Chapter 9. But these leaders—city mayors and state governors—need broad-based political support to continue to deepen their efforts, while other leaders need to be pushed into action. At the global level, Chapter 10 shows the promise of new models of international cooperation, and the potential to build on the Paris Agreement.

Cluster 4

Market Instruments consists of two chapters that analyze climate change from an economic lens. Chapters 11 and 12 discuss market-based, regulatory and policy approaches such as carbon pricing that encourage firms and individuals to switch to cleaner production methods, prioritize energy efficiency and travel more sustainably. The chapters also highlight how market instruments are working successfully in many parts of the world.

Cluster 5

Technological Measures consists of three chapters that introduce readers to the tools to solve the problem. New breakthroughs in renewable energy, vehicle electrification and smart grids, detailed in Chapters 13 and 14, will help to bring down the cost of emission reductions and help reach zero emissions shortly after 2050. But reductions in carbon emissions of 30 to 40 percent are already feasible using mature technologies that are available today. Chapter 15 shows that tackling short-lived climate pollutants—as methane, black carbon, hydrofluorocarbons and ozone—can bend the curve quickly, giving time for the carbon reduction measures to take effect.

Cluster 6

Natural and Managed Ecosystems consists of a single chapter, which argues that much of the climate change remedy has already been provided by nature. As Chapter 16 highlights, we can reduce emissions by one-quarter through tackling deforestation, regenerating damaged natural ecosystems, improving the ability of soils that store carbon, and reducing food waste.

The book also includes four additional chapters categorized under Special Topics. Chapter 7 (Religion, Ethics, and Climate Change) brings up a major tool for solving the climate change problem, of forming an alliance with leaders from a range of religious belief systems to effect large-scale societal transformation. Chapter 17 (Sea Level Rise from Melting Ice), addresses the impact of the possible disintegration of the massive ice-sheets of Antarctica and Greenland. Chapter 18 (Atmospheric Carbon Extraction: Scope, Available Technologies and Challenges), addresses a major emerging theme in climate solutions, which deals with deploying technological measures to extract carbon from the atmosphere. Chapter 19 (Local Solutions), describes a local community scale living laboratory to attempt societal transformation.

Appendix 2: Bending the Curve Video Lectures and Lecturers

Lecture Topics	Lecturer(s)
1. Climate Change	**V. Ram Ramanathan,** UC San Diego, Climate sciences
2. Six Clusters and Ten Solutions for Bending the Curve	**V. Ram Ramanathan,** UC San Diego, Climate sciences

3. Humans and Nature: How Did We Get Here?
  a. Climate Justice and Equitable Approaches
  b. The Quest for Climate Justice
	Fonna Forman, UC San Diego, Political theory and global justice
	David Pellow, UC Berkeley, Environmental justice

4. Impacts and Barriers to Solutions
  a. Obstacles to Climate Solutions
  b. Climate Change: Health Impacts
  c. Sea Level Rise from Melting Ice
	Steven Davis, UC Irvine, Low-carbon energy sources
	Gina Solomon, UC San Francisco, Health and climate change
	Eric Rignot, UC Irvine, Glaciology and Atmospheric sciences

5. Bending the Curve: Lessons from California	**Daniel Press,** UC Santa Cruz, Environmental politics and policy

6. Bending the Curve: Lessons from the University of California
  a. Carbon Neutrality Initiative of the University of California
  b. Energy Efficiency Management at UC Irvine
	Matthew St. Clair, UC Office of the President, Sustainability
	Jacob Brouwer, UC Irvine, Energy technology

7. Science and Technology Pathways for Bending the Curve
  a. Energy Technology Pathways
  b. Transportation Pathways for Bending the Curve
	Scott Samuelsen, UC Irvine, Power generation, distribution and utilization
	Daniel Sperling, UC Davis, Transportation technology and policy

8. Your Leadership: Social Movements and Social Solutions to Climate Change	**Hahrie Han,** Johns Hopkins University, Environmental politics

9. Behavioral Changes
  a. Changing Social Norms and Behavior
  b. Religion, Ethics, and Climate Change
  c. Climate Change, Christianity, and the Real Challenges
	Fonna Forman, UC San Diego, Political theory and global justice
	Mary Evelyn Tucker, Yale University, religion and ethics
	Kathryn Hayhoe, Texas Tech University, Religion and political science

10. Local Solutions: Making Urban and Rural Areas Resilient (Living Laboratory: UCSD)	**Keith Pezzoli,** UC San Diego, Planning, interactions in city-region sustainability

11. Public Opinion and Communication
  a. Climate Science Communications
  b. Climate Communication
	Richard Somerville, UC San Diego, Climate communications and atmospheric modeling
	Jon Christensen, UC Los Angeles, Environmental journalism

12. International Governance	**David Victor,** UC San Diego, Climate policies and politics
13. Consideration of Economics for Designing Climate Policy	**Max Auffhammer,** UC Berkeley, Economics
14. Cost Effective and Efficient Climate Policies	**Mark Jacobsen,** UC San Diego, Economics and environmental regulation
15. Bending the Curve with Sustainable Transportation	**Matthew Barth,** UC Riverside, Electrical and computer engineering

16. New Technologies and Innovations for Carbon Neutrality
  a. Renewable Energy
  b. Nuclear Energy
	Scott Samuelsen, UC Irvine, Power generation, distribution and utilization
	Per Peterson, UC Berkeley, Nuclear technology and waste processing

Technologies for Short-Lived Climate Pollutants (SLCP) Mitigation	**V. Ram Ramanathan,** UC San Diego, Climate science **Durwood Zaelke,** UC Santa Barbara, Environmental law and policy
Bending the Carbon Curve by Enhancing Carbon Sinks	**Whendee Silver,** UC Berkeley, Ecosystem ecology and biogeochemistry
Negative Emissions Technology	**Roger Aines,** Lawrence Berkeley National Laboratory, Negative emissions technology

Appendix 3: Bending the Curve Massive Open Online Course

Table 2 – Taught by leading experts from across the UC system, this series of 4 short courses focuses on the multidimensional aspects of the climate change problem and presents a set of scalable solutions, from technological innovation and ecosystem management to market mechanisms and behavior change, designed to disrupt the changes taking place.

	Climate Change: Science, Impacts, Human Dimension and Solutions Framework	Science and Technology Innovation and Solution	Scaling Up Solutions with Innovation	Capstone Projects [Title Pending]
Description	This first course begins the learner's journey of discovery into the climate crisis. We begin with an exploration of the science, including the human contribution to the crisis. We will develop a multi-faceted framework into which all solutions will be organized. Our first solution will focus on societal transformation, and the leadership role every climate warrior can play.	Climate change solutions must be approached from the local, regional, national and international scope. In the second course, we look at California as a case study, and analyze energy issues, power generation, and transportation. We also expand our view and investigate a variety of international efforts.	In the third course, we build on the scientific framework and multifaceted solutions approach to establish the importance of an international approach. We explore the challenges to implementation, along with practical techniques to mitigate the obstacles.	At this point in the learner's journey, they have an understanding of the complexities and necessities of bending the curve. This course provides an opportunity for the climate warriors to identify or create solutions that can be implemented in their own local, regional, national, and/or international community. The potential solutions will be analyzed and strengthened by the input of the bending the curve community.
Open for Enrollment	Mid- to Late- January, 2020			
Course Launch	March 2, 2020	May 18, 2020	July 13, 2020	September 14, 2020
Lessons Included	1-1: Climate Change - Scientific basis, physical system impacts and future changes (V. Ramanathan, UC San Diego; Eric Rignot, UC Irvine) 1-2: Social and Health Impacts - Climate Justice (Fonna Forman, UC San Diego; David Pellow, UC Santa Barbara; Gina Solomon, UC San Francisco) 1-3: Framework for Solutions: Six Clusters and Ten Solutions for Bending the Curve (V. Ramanathan, UC San Diego; Jonathan Cole, MiraCosta College) 1-4: Your Leadership: Social Movements and Social Solutions to Climate Change (Hahrie Han, Johns Hopkins University; Michelle Niemann, Independent Writing Consultant and Editor) 1-5: Societal Transformation – Changing Attitudes, Norms, and Behavior (Fonna Forman, UC San Diego) 1-6: Societal Transformation – Role of Religions (Mary Evelyn Tucker, Yale University; Katherine Hayhoe, Texas Tech University) 1-7: Societal Transformation – Communicating Climate Change (Richard C. J. Somerville, UC San Diego)	2-1: Technologies and Innovations for Carbon Neutrality: Renewable Energy / Nuclear Energy (Scott Samuelsen, UC Irvine; J. Brouwer, UC Irvine) 2-2: Transportation Solutions (Matthew Barth, UC Riverside; Daniel Sperling, UC Davis) 2-3: Technologies for SLCPs Mitigation (Daniel Sperling, UC Davis; Durwood Zaelke, UC Santa Barbara) 2-4: Enhancing Carbon Sinks: Natural Systems (Whendee L. Silver, UC Berkeley) 2-5: Extracting Carbon from the Air (Roger Aines, Lawrence Livermore national Laboratory)	3-1: Local Solutions (Keith Pezzoli, UC San Diego) 3-2: Scaling Up Solutions to Global Levels (International Governance) (David G. Victor, UC San Diego) 3-3: Economic Measures to Encourage Investment & Drive Innovation and Barriers to Scaling Up and Adoption (Maximilian Auffhammer, UC Berkeley; Stephen Davis, UC Irvine) 3-4: Market Based Climate Policy (Mark R. Jacobsen, UC San Diego) 3-5: California Climate Policy (Daniel Press, UC Santa Cruz; David G. Victor, UC San Diego) 3-6: Living Laboratories - Carbon Neutrality Initiative of the University of California (Matthew St. Clair, UC Office of the President; V. Ramanathan, UC San Diego)	The Capstone Project is still being developed. Components will likely include the following: - Reflections from learning in the other 3 Bending the Curve: Climate Change Solutions courses - Description of a possible solution that is tailored to learner's community - Analysis of how the solution fits within the multifaceted framework - Evidence of an implementation plan that includes actionable items
Book Chapters Covered	- Chapter 1: Climate Change (V. Ramanathan) - Chapter 2: Humans, Nature and the Quest for Climate Change (Fonna Forman and David Pellow) - Chapter 4: Overview of the Ten Solutions for Bending the Curve (V. Ramanathan and Jonathan Cole) - Chapter 5: Your Leadership: Social Movements and Social Solutions to Climate Change (Hahrie Han and Michelle Niemann) - Chapter 6: Social Transformation: Changing Attitudes, Norms and Behaviors (Fonna Forman) - Chapter 7: Religion, Ethics, and Climate Change (Mary Evelyn Tucker) - Chapter 8: Communicating Climate Change Science (Richard C. J. Somerville)	- Chapter 13: Two Energy Technology Pathways (Scott Samuelsen) - Chapter 14: Environmentally Sustainable Transportation (Matthew Barth and Daniel Sperling) - Chapter 15: Technologies for Super Pollutants Mitigation (V. Ramanathan, D. Zaelke, and J. Cole) - Chapter 16: Enhancing Carbon Sinks in Natural and Working Lands (Whendee L. Silver) - Chapter 18: Atmospheric Carbon Extraction: Scope, Available Technologies, and Challenges (Roger Aines)	- Chapter 9: Lessons from California (Adam Millard-Ball and Daniel Press) - Chapter 10: The Paris Agreement and Its Implementation (David G. Victor) - Chapter 11: Economics: Emissions, Impacts, and Policy (Max Auffhammer) - Chapter 12: Cost-Effective and Efficient Climate Policies (Mark R. Jacobsen) - Chapter 19: Local Solutions (Keith Pezzoli)	
Estimated Hours per week	3 – 5 hours per week *(21 - 35 hours total)*	4 – 6 hours per week *(20 - 30 hours total)*	4 – 6 hours per week *(24 - 36 hours total)*	4-6 hours per week *(24 - 36 hours total)*

Appendix 4: Authors of the Bending the Curve Effort

Veerabhadran Ramanathan (Chair), San Diego. Climate.
Fonna Forman (Vice Chair), San Diego. Global justice.
Daniel Kammen (Vice Chair), Renewable energy technologies.
Juliann E. Allison, Riverside. Environmental policy.
Maximilian Auffhammer, Berkeley. Greenhouse gas emissions forecasting.
David Auston, Santa Barbara. Carbon neutrality engineering.
Roger Bales, Merced. Critical ecosystems.
Anthony D. Barnosky, Berkeley. Ecosystems respond to climate change.
Jack Brouwer, Irvine. Alternative energy.
Jennifer Burney, San Diego. Energy, environment, climate change.
James Bushnell, Davis. Energy and environmental economics.
Lifang Chiang, Science and innovation policy.
Jon Christensen, Los Angeles. Environmental journalism.
William D. Collins, Berkeley Lab (LBNL). Coupled climate system.
Steven J. Davis, Irvine. Sustainable systems analysis.
Magali Delmas, Los Angeles. Incentives to energy efficient solutions.
Steven Denbaars, Santa Barbara. Solid state lighting and energy.
Olivier Deschênes, Santa Barbara. Climate change health and economic impacts.
David Feldman, Irvine. Water resources management and policy.
William Glassley, Davis. Geothermal energy.
Hahrie Han, Santa Barbara. Environmental politics.
Susanna Hecht, Los Angeles. Political ecology.
Cara Horowitz, Los Angeles. Climate policy.
Bryan Jenkins, Energy systems in agriculture.
C.-Y. Cynthia Lin Lawell, Davis. Environmental economics.
Teenie Matlock, Merced. Cognitive science.
Ryan McCarthy, Transportation.
Michael Mielke, Silicon Valley Leadership Program.
Jack Miles, Irvine. Religion, science and the environment.
Adam Millard-Ball, Santa Cruz. Future of travel demand.
Dorothy Miller, Science and innovation policy.
Rachel Morello-Frosch, Berkeley. Environmental health science.
Walter Munk, San Diego. Geophysics.
Per Peterson, Berkeley. High-temperature reactors.
Keith Pezzoli, San Diego. Natural-human system interactions.
Stephanie Pincetl, Los Angeles. Urban environments and transformation.
Daniel Press, Santa Cruz. Environmental politics and policy.
Ramamoorthy Ramesh, Berkeley. sustainable energy.
Ronald E. Rice, Santa Barbara. Environmental Communication.
Eric Rignot, Irvine. Glaciology.
Doug Rotman, Lawrence Livermore National Lab (LLNL). Clean energy technologies.
Scott Samuelsen, UC Irvine. Power generation, distribution, and utilization.
Gina Solomon, San Francisco. Science and health.
Daniel Sperling, Davis. Transportation technology assessment.
Venkat Srinivasan, Berkeley Lab. Next-generation batteries.
David G. Victor, San Diego. Highly regulated industries; how regulation affects operation of major energy markets.
Byron Washom, San Diego. energy storage development.
LeRoy Westerling, Merced. climate-ecosystem-wildfire interactions.
Lisa D. White, Berkeley. K-12 science education and outreach.
Junjie Zhang, San Diego. Environmental and resource economics