



DESCRIPTION

Students investigate actions that individuals can take to decrease their carbon emissions and mitigate climate change. They consider a strategy from several perspectives and analyze the associated benefits and challenges. Students then create a poster to present their analysis of a mitigation strategy and the pros and cons of implementing it.

PHENOMENON

There are many proposed strategies individuals can take to mitigate climate change, but implementing them comes with pros and cons that should be considered.

GRADE LEVEL 9-12

OBJECTIVES

Students will:

- Explain how mitigation strategies can slow or lessen the effects of climate change
- Analyze the challenges and benefits of an individual action to mitigate climate change
- Develop solutions to overcoming the challenges in implementation of an individual mitigation strategy

TIME 45-MINUTES

COMMON CORE STATE STANDARDS

English Language Arts

[CCSS.ELA-LITERACY.RI.9-10.8](#) Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

[CCSS.ELA-LITERACY.RI.11-12.7](#) Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

[CCSS.ELA-LITERACY.W.9-12.1](#) Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

[CCSS.ELA-LITERACY.W.9-12.2](#) Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

NEXT GENERATION SCIENCE STANDARDS

Performance Expectation

[HS-ESS3-4](#) Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions	ESS3.C Human Impacts on Earth Systems ESS3.D Global Climate Change ETS1.B Developing Possible Solutions	Stability and Change

BACKGROUND

Since the Industrial Revolution, fossil fuel extraction and combustion have resulted in significant fluxes of fossil carbon to the atmosphere, thus causing a human-induced perturbation in the carbon cycle (Ciais et al., 2013). Increasing atmospheric carbon is resulting in climate change. Several technologies already exist that, when used in combination, can mitigate the effects by reducing or eliminating carbon emissions while meeting the world's energy needs. These include increased vehicle efficiency, building efficiency, power plant carbon capture and storage, wind power, and solar power (Pacala and Socolow, 2004). Scientists have also identified strategies that individuals can implement to reduce their carbon emissions, including having one fewer child, switching to a hybrid car or car-free life, limiting air travel, and eating a plant-based diet (Wynes and Nicholas, 2017). Students evaluate these actions for their feasibility, effectiveness of mitigating climate change, and their social and economic impacts.

MATERIALS

- [PowerPoint presentation](#)
- Computer and projector for educator
- Copies of Mitigation Strategy pages, [black and white](#) or [color](#) [1 set per group]
- [Copies of Mini-poster](#) [1 set per group]
- *Optional:* [Copy of Stakeholder Cards](#), copied onto cardstock and cut [1 per class]

PREPARATION

1. Set up a computer and projector and display the PowerPoint presentation.
2. If your students do not have a basic understanding of climate change and the greenhouse effect before starting this activity, you may wish to show or assign one or more of the videos in the extensions section at the end of this guide.
3. Make one Mini-poster for every group of students. Cut each page along the dotted line, align the pages, and tape them together. Alternatively, you may plan to have students assemble their Mini-posters if time permits.
4. If you are using the Stakeholder Cards, copy one set of cards onto cardstock (if available), and cut on the dotted lines.

PRESENTATION

INTRODUCTION

1. **Slide 2:** carbon moves around the planet via the carbon cycle. Humans have modified the carbon cycle by burning fossil fuels, which release carbon, in the form of carbon dioxide, into the atmosphere.
2. **Slide 3:** carbon dioxide is a greenhouse gas that traps heat inside the atmosphere. This causes many changes to the earth's climate and also results in feedback loops, which release even more carbon dioxide into the atmosphere. For example, warming the atmosphere melts the polar ice caps, causing sea levels to rise. Sea level rise destroys coastal ecosystems, which take up carbon dioxide from the
3. **Slide 4:** give students a minute to brainstorm major ways humans release carbon into atmosphere and ways that humans reduce or prevent the release of carbon into the atmosphere. [Answers for releasing carbon may include: using cars and other transportation, burning coal and gas for electricity, cutting down trees, and raising livestock. Answers for reducing carbon emissions might include: driving less, biking, walking, using

atmosphere more quickly than most other ecosystems, resulting in more carbon dioxide in the atmosphere. If time permits, discuss one or more of the other examples listed on the slide:

- **Disease spread:** The distribution of disease vectors such as mosquitos, fleas, and ticks is limited by climate. A changing climate may allow these animals to spread to new habitats and increase disease risks.
- **Growing season changes:** Warmer temperatures earlier in the year are expanding plant growing seasons, which may be beneficial in agriculture.
- **Habitat loss:** For some species, changes in temperature and precipitation are making their current habitats uninhabitable. Many marine mammals are moving towards the poles in search of cooler water as ocean temperatures rise.
- **Extreme weather patterns:** Changing ocean and air temperatures lead to stronger and more frequent hurricanes and tornadoes. Climate change models also predict more intense droughts and winter storms in the future.

renewable energy, conserving energy, planting trees, and reducing, reusing, and recycling.]

MITIGATION

1. **Slide 5:** mitigation is any action that reduces the severity of something. Climate change mitigation strategies slow or lessen the effects of climate change by reducing the amount of greenhouse gases entering the atmosphere or by removing them from the atmosphere. The data in this infographic is from a study (Wynes and Nicholas, 2017) that investigated the most effective ways for individuals to reduce their carbon emissions. Today, you will choose one of the strategies to analyze and refine.
2. **Slide 6:** mitigation of any problem is complicated, with sound arguments that can be raised for or against any action. The strategies in the previous slide have been researched extensively, and implementing them can reduce carbon emissions. However, there are social, cultural, economic, and safety challenges with all of them. It is your job to think critically about these challenges, try to address them, and determine if the strategy is feasible.
3. **Slide 7:** as a class, you will analyze one strategy together. Solar energy is electricity generated by solar panels. Scientists have estimated that carbon emissions would be reduced by 0.5 Pg/year (Pg or petagram is equal to 10¹⁵ grams, or approximately the weight of 6 million blue whales) if we replaced 1000 GW of coal-generated electricity with solar-generated electricity. This would require three billion solar panels. A few

challenges to implementing solar energy and a few steps that could help to make it happen are listed on the slide.

- a. [Optional] To encourage students to examine this strategy from a variety of perspectives, you can pass out one Stakeholder Card to each student. Ask them to think about the idea of using solar energy from the perspective on their card. Give students a minute to read their card and discuss with their neighbor the opinions their stakeholder might have about solar energy.
4. **Slide 8:** what are the biggest challenges to using solar energy? [Possible answers: the space needed for solar panels, the initial set up costs, resistance from the fossil fuel industry, the difference between peak energy production times and peak energy use times, and a limited supply of materials for solar panels and batteries.]
 - a. [Optional, if using Stakeholder Cards] Which stakeholders in the room have a strong argument against using solar energy?
5. **Slide 9:** whose responsibility is it to lead the effort to transition to solar energy? Is it up to individuals, corporations, governments, or someone else? Where in the world could this happen? Can poor countries implement solar energy? Are there parts of the world where it would be a bad idea to build solar farms? For example, it rains and it overcast a lot in Seattle, so that is probably not a good place for solar farms. There is plenty of space in Antarctica, but there is little sunlight there during half of the year.
 - a. [Optional, if using Stakeholder Cards] Which stakeholders have a responsibility to lead the effort to transition to solar energy?
6. **Slide 10:** who will pay for installing solar panels? Should it be individual people who want them, the

- government, or power companies? Who will benefit? [Possible answers: everyone gets cleaner air; power companies don't have to mine coal anymore; businesses that build solar panels will expand.] Who will be hurt by it? [Possible answers: people who currently work in the fossil fuel industry may lose their jobs. Places where the materials for solar panels are mined could be harmed.]
- a. [Optional, if using Stakeholder Cards] Can/would any of the stakeholders take responsibility to help pay for solar panels?
 7. **Slide 11:** what are the pros and cons of switching to solar energy? [Possible answers for pros: cleaner air and water, less expensive energy in the long run, will slow climate change, and will save people money. Possible answers for cons: will cost a lot of money up front, thousands of people rely on the coal and gas industry for jobs, and solar panels are made with materials that have to be mined, harming the environment.] Does investing in solar energy mean that you are ignoring another type of renewable energy that could be more effective? Hydroelectric, tidal, geothermal, and wind energy might be better options in some places.
 - a. [Optional, if using Stakeholder Cards] Are there any stakeholders that would like to share the pros and cons of switching to solar energy from their perspective?
 8. **Slide 12:** if you were in charge of making sure we switch to solar energy, how would you do it? Where would you find space? How would you address the cost? Would you need to change people's habits or the law to make sure it happens?
 9. **Slide 13:** this slide is an example of a Mini-poster that summarizes our evaluation of the strategy. Question 7 on the poster asks how to address the challenges that the class identified.

ANALYZE A MITIGATION STRATEGY

1. Divide students into small groups, pairs, or choose to have them work individually.
2. Pass out a set of Mitigation Strategy pages and a copy of the Mini-poster to each group.
3. **Slide 14:** each group will choose one of the five mitigation strategies from the Mitigation Strategy pages to analyze and refine.
 - a. Each group will create their own Mini-poster like the one for solar energy on the previous slide. The Mini-poster has several questions to help you consider different aspects of your proposed strategy.
 - b. You can use the Mitigation Strategy pages to get started, but most of the information you will fill out on your poster will not be included on the pages. You will have to think critically about the world to come up with a strategy you think will work to mitigate climate change.
 - c. Try to consider the strategy from many different perspectives, just like we did in the solar energy example.
 - i. [Optional] If you chose to use the Stakeholder Cards for the class example discussion of solar panels, students will not be using them for this activity. Simply instruct them to keep in mind the perspectives of all the stakeholders as they complete the activity.
 - d. Discuss and answer all of the questions on the poster before answering question 7 because you might come up with ways to improve the strategy as you discuss and think about the challenges, pros, and cons.
4. **Slide 15:** this slide shows all the mitigation strategies proposed in the paper mentioned earlier. Leave this up as students

begin their work. You may give students the rest of class to work, or you may stop them 10 minutes before the end of class to share their strategies and have a class discussion about which strategies will be most successful and are most feasible.

EXTENSIONS

1. If you have access to computers, students can do their own research on their mitigation strategy to find other challenges and solutions they have not considered or to search for examples of successful implementation of the strategy.
2. Display the infographic on slide 5 and have students choose one of the mitigation actions and conduct one or both of the following:
 - a. Create a plan for how they could incorporate one of the mitigation actions into their own lives.
 - b. Develop a public education effort in their community to
3. If students need more background on climate change, you may want to show or assign one of these videos:
 - CIRES videos- Our Shared Climate Future <https://www.youtube.com/watch?v=sGrQdLH1K74>
 - This video explains the greenhouse effect, the science of measuring atmospheric carbon dioxide, and the impacts of warming on the planet.
 - Global Weirding- Southern Great Plains & Southwest <https://www.youtube.com/watch?v=wd6w6mTQGwc>
 - This video explains the

region-specific impacts of climate change, including extreme weather events, drought, wildfire, and enhanced climate variability. It does not include an explanation of the greenhouse effect.

The Global Weirding with Kathrine Hayhoe YouTube Channel is created by PBS Digital Studios and Texas Tech University Public Media and has videos on every region of the US.

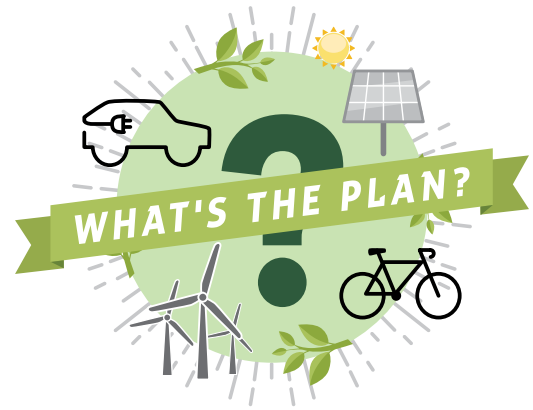
- Intergovernmental Panel on Climate Change (IPCC)- Climate Change 2013: The Physical Science Basis. https://www.youtube.com/watch?v=6yiTZm0y1YA&feature=player_detailpage
 - This video is fairly technical. It is appropriate for older students who have some familiarity with climate change and the greenhouse effect.

ADDITIONAL RESOURCES

- Pacala, S. and R. Socolow. 2004. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science* 305: 968-972.
- Wynes, S. and K.A. Nicholas. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*: 12.

MITIGATION STRATEGY: FUEL EFFICIENT CARS

The fuel efficiency of an average car is 30 miles per gallon (mpg), but the popular hybrid car below is estimated to achieve up to 58 mpg. A typical passenger car emits 4.6 metric tons of carbon dioxide per year (EPA, 2018). It is estimated that there are currently over 1 billion vehicles in the world, and there will be 2 billion by 2035. Owners of hybrid cars usually spend less on gas because the car is more efficient, but hybrid cars usually cost more than average cars, making it hard for some to afford them. Scientists have calculated that carbon emissions would be reduced by 1 Pg/year if we replaced 2 billion average cars with fuel efficient cars.¹ One person can reduce their carbon emissions by 0.52 metric tons of carbon per year by switching from a traditional to hybrid car.²



WHAT COULD HELP MAKE THIS HAPPEN:

- Governments could offer a tax credit to offset the cost of the car.
- A new law could require new cars to be more fuel efficient.
- Allow fuel efficient cars to use the carpool or HOV lanes to avoid traffic.

CHALLENGES:

- Hybrid and electric cars are more expensive.
- Fuel efficient cars are usually smaller and less powerful than standard cars.
- Car manufacturing plants are set up to make standard cars; making new types of cars requires them to change their factory set up and equipment.

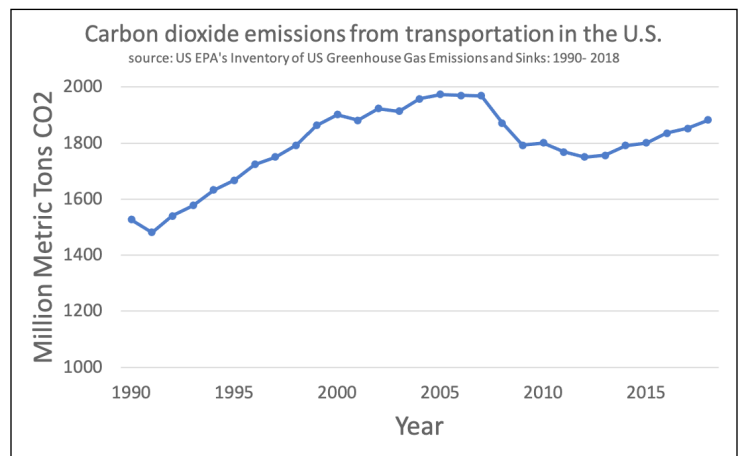
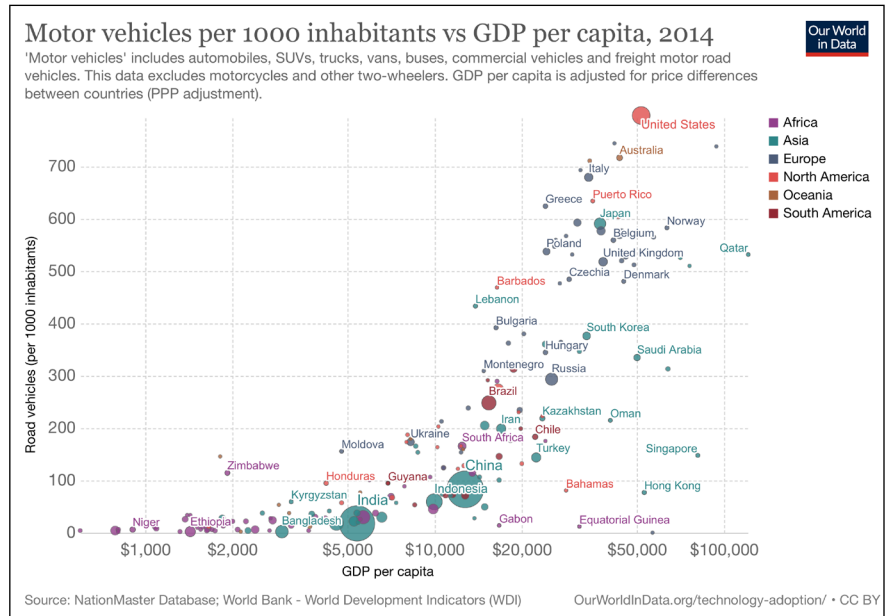


Photo credit: Toyota (toyota.com/search/search.html?keyword=prius)

Image credit (right): Our World in Data (https://ourworldindata.org/grapher/road-vehicles-per-1000-inhabitants-vs-gdp-per-capita?time=latest&country=USA~BRB)



1. Pacala, S. and R. Socolow. 2004. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science* 305: 968-972.

2. Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*: 12.

3. Environmental Protection Agency. 2020. *Inventory of US Greenhouse Gas Emissions and Sinks 1990-2018*

MITIGATION STRATEGY: DECREASE AIR TRAVEL

Traveling by airplane emits large amounts of carbon into the atmosphere due to burning fuel. The United Nations (2019) predicts CO₂ emissions from air travel could triple by 2050. A round trip from New York to San Francisco generates approximately 1 metric ton of CO₂ per passenger. Eliminating or minimizing air travel is often claimed to be one of the most effective ways an individual can decrease their carbon emissions. Compared to traveling by car, the greenhouse gas emissions per passenger traveling by plane are much higher, especially for shorter distances. A family of four driving from Los Angeles to San Francisco generates about a third of the CO₂ that flying would generate. According to a NASA (2010) study, most of the emissions generated by planes are from take off and landing. Scientists have calculated that avoiding one transatlantic flight per year will save 1.6 metric tons of CO₂,¹ or decrease the average American's carbon emissions by 10%.

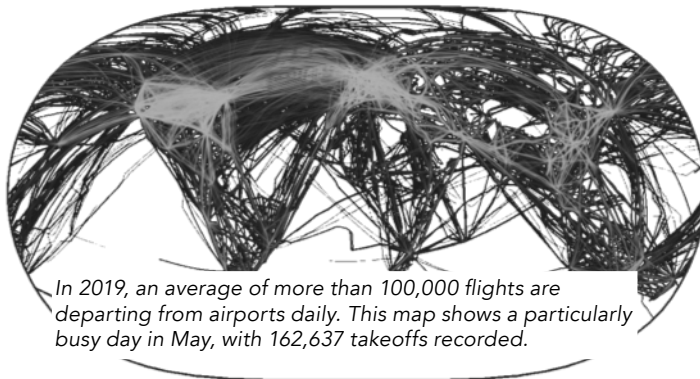
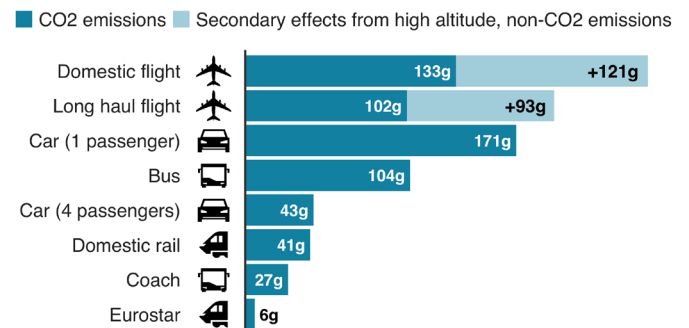


Image Credit: The Guardian (<https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year>)

Emissions from different modes of transport

Emissions per passenger per km travelled



Note: Car refers to average diesel car

Image Credit: BBC (<https://www.bbc.com/news/science-environment-49349566>)

WHAT COULD HELP MAKE THIS HAPPEN:

- Normalizing telework and work-from-home so traveling for business becomes less necessary.
- Using alternate methods of travel - more long distance and fast buses and trains.
- Choosing nonstop flights to decrease the number of take offs and landings during a trip.
- Educate people about the carbon costs of travel (e.g. an app that tells you how much carbon a trip releases).
- Purchase carbon offsets if flights are required.
- Discourage private jet flights.

CHALLENGES:

- 30% of American air travel is business-related travel, not personal choices.³
- When there is only one person in the car, carbon emissions from a long road trip are actually higher than from flying.²
- Flying is convenient and fast.
- There are not easy alternatives to flying (e.g., high speed trains) in the U.S.

1. Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*: 12.

2. Borken-Kleefeld, J., Fuglestvedt, J. and T. Berntsen. 2013. Mode, load, and specific climate impact from passenger trips. *Environ. Sci. Technol.* 47: 7608–7614.

3. Airlines for America. 2016. Air travel is affordable, accessible, and vast majority of travelers satisfied with overall experience according to new national survey

Flying from Los Angeles (LAX) to New York John F. Kennedy (JFK)

Flying from Los Angeles to New York John F. Kennedy and back generates about 697 kg CO₂. There are 50 countries where the average person produces less CO₂ in a year.



Image Credit: The Guardian (<https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year>)

MITIGATION STRATEGY: PLANT-BASED MEAT

People have relied on livestock, like cattle, as a food source for thousands of years. Many domestic animals are able to eat the plants that grow in dry environments, allowing people to live in places where they cannot grow many crops. However, raising cattle requires a lot of land, water and food. According to the United Nations (2013), livestock produce 14.5% of global greenhouse gas emissions. Many people suggest reducing the amount of meat you eat as a way to decrease greenhouse gas emissions. There are multiple companies that sell plant-based meat, a food designed to taste and look like meat but actually made from plants. These products, such as the Impossible Burger and Beyond Meat, require less land and water to produce, and making them releases less carbon dioxide and other greenhouse gasses into the atmosphere than raising livestock. Scientists have calculated that one person choosing a plant-based diet can save 0.82 metric tons of carbon per year.¹



WHAT COULD HELP MAKE THIS HAPPEN:

- People choosing to eat plant-based meat over real meat.
- Companies continuing to develop better tasting and healthier plant-based meats.
- Scientists researching how to make healthy, environmentally friendly plant-based meats.
- Large restaurant chains could switch to plant-based meats. McDonalds, Burger King, KFC and Carl's Jr. have all added plant-based meats to their menus.

CHALLENGES:

- Thousands of people make a living through the meat industry: raising, feeding, slaughtering and selling livestock.
- Many people like to eat meat.
- Scientists are researching whether new plant-based meats are healthier than meat products.^{2,3}
- Plant-based meat, especially burgers and chicken, is generally more expensive than real meat.⁴
- Many people rely on fast food, like hamburgers and chicken nuggets, that is inexpensive and easy to get.

1. Wynes, S. and Nicholas, K.A. 2017. *The climate mitigation gap: education and government recommendations miss the most effective individual actions.* *Environmental Research Letters*: 12

2. *Plant-based meat lowers some cardiovascular risk factors compared with red meat, study finds*/Journal of Clinical Nutrition

3. Harvard Health Publishing. 2019. *Impossible and Beyond: How healthy are these meatless burgers?*

4. Vox. 2020. *The next challenge for plant-based meat: Winning the price war against animal meat*

That takes the brisket 2019 or latest available			
	Greenhouse-gas emissions kg of CO ₂ equivalent per kg	Freshwater withdrawals litres per kg	Land use m ² per kg
Meat*			
Beef (herd)	99.5	1,451	326
Pork	12.3	1,796	7.8
Chicken	9.9	660	6.7
Beyond Burger	3.5	9.7	2.7
Impossible Burger	3.5	107	2.5

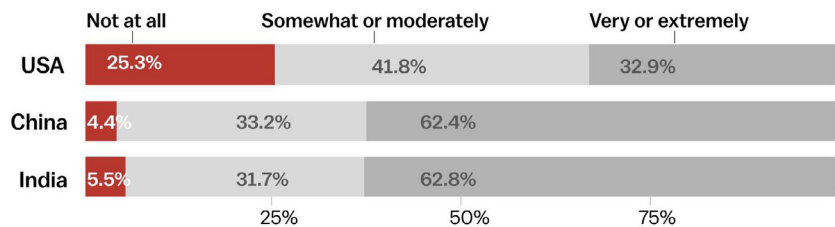
Source: Ron Milo, Weizmann Institute and Alon Shepon, Harvard University *Global average, 1kg of fat and bone-free meat and edible offal

The Economist

Image Credit: The Economist

(<https://www.economist.com/international/2019/10/12/plant-based-meat-could-create-a-radically-different-food-chain>)

How likely are you to purchase plant-based meat?



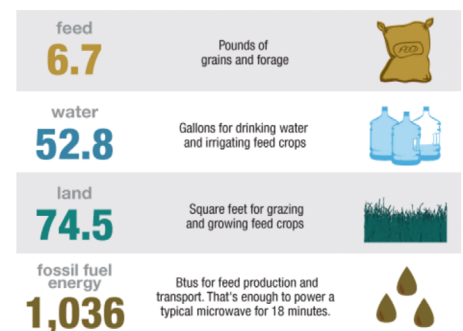
Source: Frontiers

Image Credit: Vox

(<https://www.vox.com/2019/5/28/18626859/meatless-meat-explained-vegan-impossible-burger>)

Vox

What it takes to make a quarter-pound hamburger



Source: J.L. Capper, *Journal of Animal Science*, December, 2011.

Credit: Producers: Eliza Barclay, Jessica Stoller-Conrad; Designer: Kevin Uhrmacher/NPR

MITIGATION STRATEGY: LIVE CAR FREE

A typical passenger car emits 4.6 metric tons of carbon dioxide per year (EPA, 2018). It is estimated that there are currently over 1 billion vehicles in the world. Living without a car challenges people to find alternative transportation options like walking, biking, or taking trains and buses. People without a car tend to travel shorter distances in their daily lives. Fewer cars on the road means that the remaining drivers will waste less gas sitting in traffic, and infrastructure like roads and bridges will last longer and need less maintenance due to lighter use. Scientists have estimated that one person switching from an average car to a car-free life-style will save 2.4 metric tons of CO₂ per year.¹



WHAT COULD HELP MAKE THIS HAPPEN:

- Investing in more public transportation, like buses and trains.
- Car, bike, and scooter sharing apps.
- Making cities more pedestrian and bike friendly.
- Building stores in residential areas so people can walk to them.
- More people working from home.
- Higher gasoline prices to make driving less affordable.

CHALLENGES:

- Easiest to do in cities where homes, stores, and work places are close together; hard to do in rural or suburban areas.
- Much of the country lacks efficient public transportation.
- It's hard to travel outside of your city or hometown without a car.
- There are many jobs that rely on car owners (sales, mechanics, car detailers, etc.).
- Not having a car limits how far you can go to find work, health care, and other necessities.

1. Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*: 12.

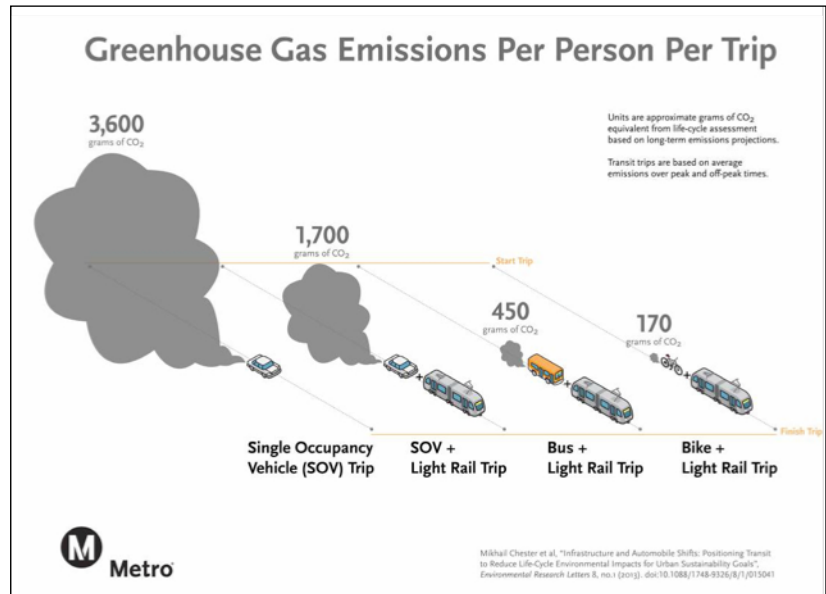


Image Credit: Metro

(<https://thesource.metro.net/2017/03/20/seven-ways-riding-a-bike-can-improve-your-life/>)

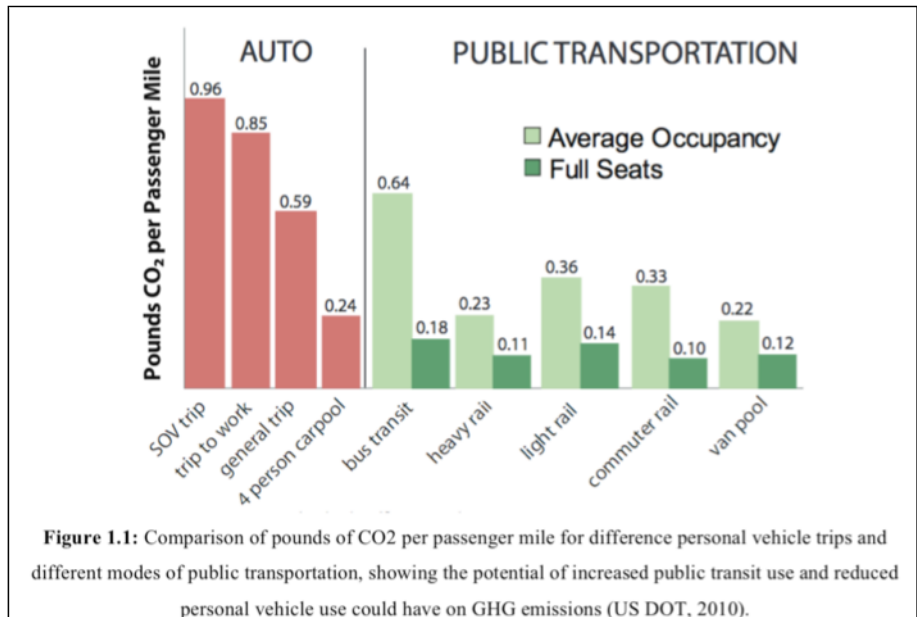
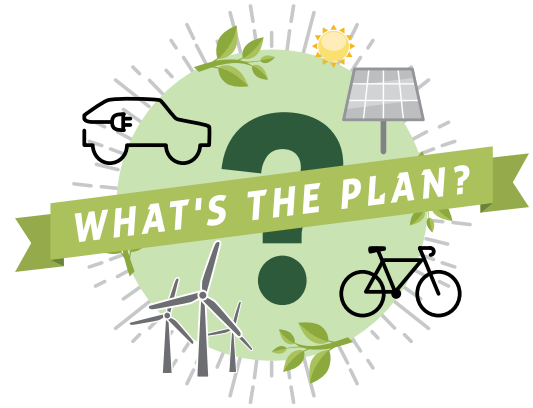


Image Credit: Metro

(<https://thesource.metro.net/2017/03/20/seven-ways-riding-a-bike-can-improve-your-life/>)

MITIGATION STRATEGY: HAVE ONE FEWER CHILD

Population growth is often named one of the greatest environmental challenges. As the global population has grown, production of food, energy, and goods has increased to meet the needs of the population. This also leads to an increase in waste and pollution. By making the decision to have one fewer child, parents are decreasing their current carbon emissions and their carbon legacy, the future carbon emissions of their descendants. By slowing population growth, resource consumption and pollution emissions also slow down. Scientists have estimated that having one fewer child will save 58.6 metric tons of carbon over a lifetime.¹

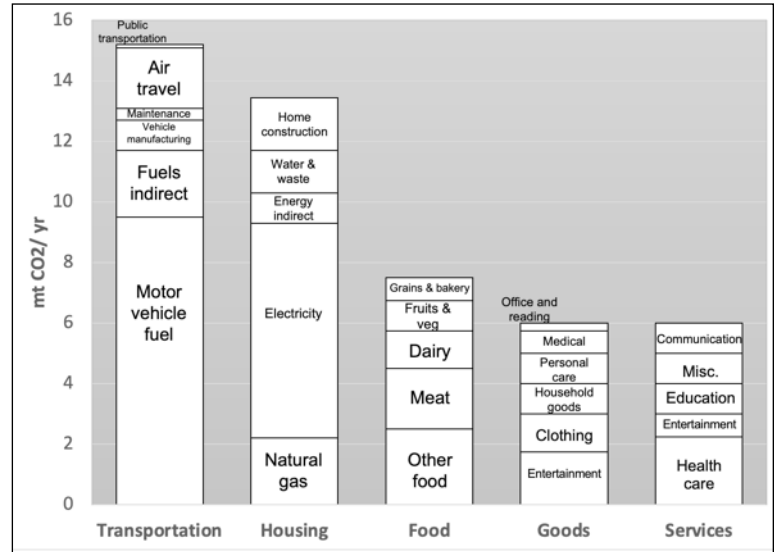


WHAT COULD HELP MAKE THIS HAPPEN:

- Educating people about the impacts of individuals on climate change.
- Research shows providing women with easy access to education and health care results in them having fewer children.²

CHALLENGES:

- How do you enforce or encourage people to keep their family size small?
- Many people have a cultural or personal preference for large families.
- Many people have a cultural, religious, or personal belief against contraception.
- Is it a violation of human rights to enforce this?
- When the Chinese government set a one child rule, a preference for sons led to a gender imbalance and poor treatment of daughters.³
- Younger generations support older generations through social security, Medicaid, etc. When there are more older than younger people, there are fewer resources to support the elderly.



Total carbon emissions of a typical US household 48 tons (CO₂/year)
Jones, C. M., & D. M. Kammen 2011. *Environmental Science & Technology*.

Population and CO₂ emissions, 1730-2015

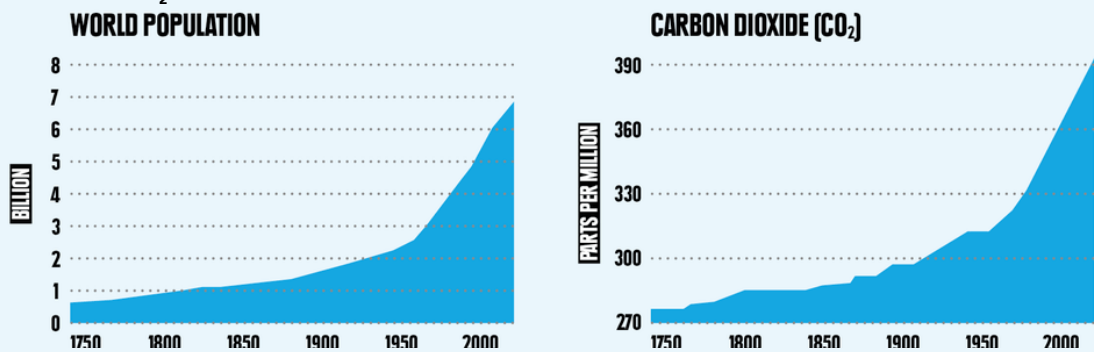


Image Credit: The Medium

Source: United Nations, 2017

(<https://medium.com/altering-climate/population-control-the-most-effective-way-to-reduce-carbon-emissions-altering-climate-a6efe56db2b>)

1. Wynes, S. and Nicholas, K.A. 2017. *The climate mitigation gap: education and government recommendations miss the most effective individual actions. Environmental Research Letters: 12.*

2. Wodon, Q., C. Montenegro, H. Nguyen, and A. Onagoruwa. 2018, *Missed Opportunities: The High Cost of Not Educating Girls. The Cost of Not Educating Girls Notes Series. Washington, DC: The World Bank.*

3. Johnson, Kay Ann (2016). *China's hidden children: Abandonment, adoption, and the human costs of the one-child policy. Chicago: University of Chicago Press. 2016.*

MITIGATION STRATEGY: FUEL EFFICIENT CARS

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WHAT COULD HELP MAKE THIS HAPPEN:

- Governments could offer a tax credit to offset the cost of the car.
- A new law could require new cars to be more fuel efficient.
- Allow fuel efficient cars to use the carpool or HOV lanes to avoid traffic.

CHALLENGES:

- Hybrid and electric cars are more expensive.
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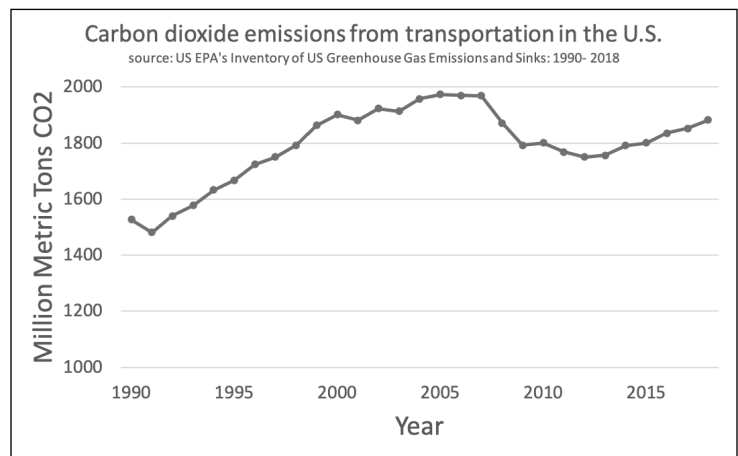
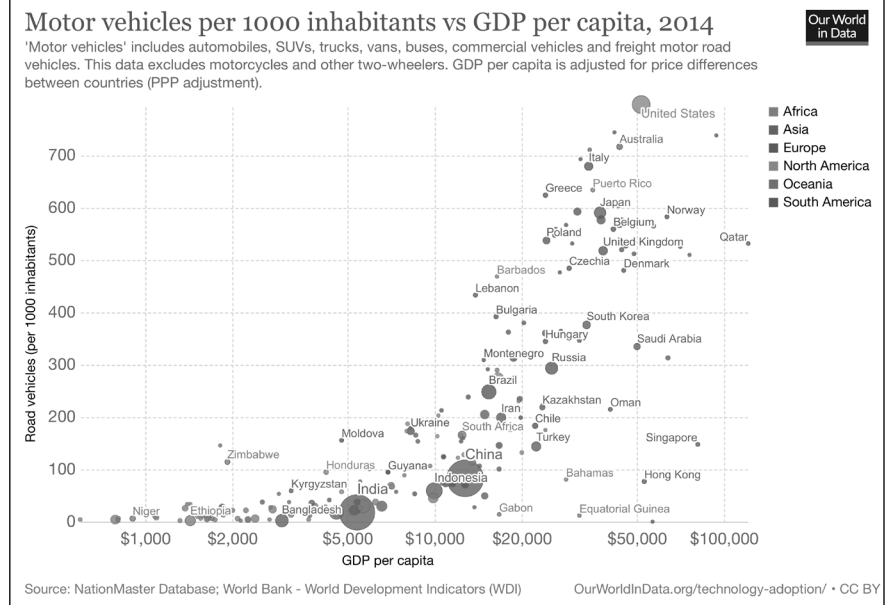


Photo credit: Toyota (toyota.com/search/search.html?keyword=prius)

Image credit (right): Our World in Data (<https://ourworldindata.org/grapher/road-vehicles-per-1000-inhabitants-vs-gdp-per-capita?time=latest&country=USA~BRB>)



1. Pacala, S. and R. Socolow. 2004. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science* 305: 968-972.

2. Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*: 12.

3. Environmental Protection Agency. 2020. *Inventory of US Greenhouse Gas Emissions and Sinks 1990-2018*

MITIGATION STRATEGY: DECREASE AIR TRAVEL

Traveling by airplane emits large amounts of carbon into the atmosphere due to burning fuel. The United Nations (2019) predicts CO₂ emissions from air travel could triple by 2050. A round trip from New York to San Francisco generates approximately 1 metric ton of CO₂ per passenger. Eliminating or minimizing air travel is often claimed to be one of the most effective ways an individual can decrease their carbon emissions. Compared to traveling by car, the greenhouse gas emissions per passenger traveling by plane are much higher, especially for shorter distances. A family of four driving from Los Angeles to San Francisco generates about a third of the CO₂ that flying would generate. According to a NASA (2010) study, most of the emissions generated by planes are from take off and landing. Scientists have calculated that avoiding one transatlantic flight per year will save 1.6 metric tons of CO₂,¹ or decrease the average American's carbon emissions by 10%.

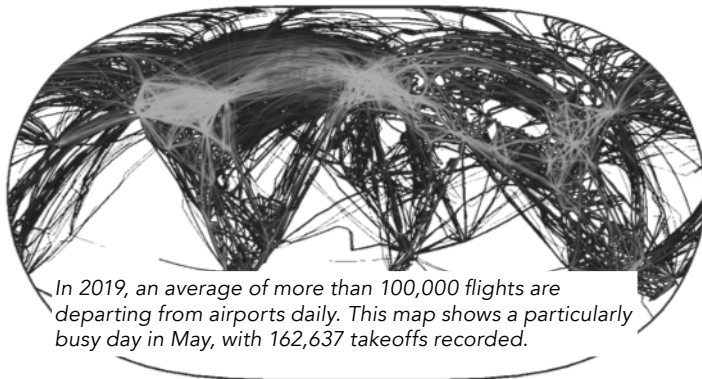
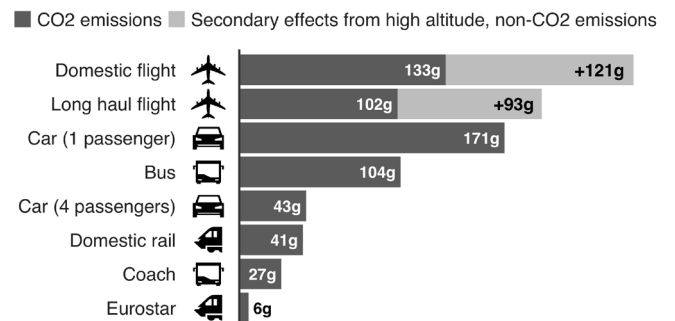


Image Credit: The Guardian (<https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year>)

Emissions from different modes of transport Emissions per passenger per km travelled



Note: Car refers to average diesel car

Image Credit: BBC (<https://www.bbc.com/news/science-environment-49349566>)

WHAT COULD HELP MAKE THIS HAPPEN:

- Normalizing telework and work-from-home so traveling for business becomes less necessary.
- Using alternate methods of travel - more long distance and fast buses and trains.
- Choosing nonstop flights to decrease the number of take offs and landings during a trip.
- Educate people about the carbon costs of travel (e.g. an app that tells you how much carbon a trip releases).
- Purchase carbon offsets if flights are required.
- Discourage private jet flights.

CHALLENGES:

- 30% of American air travel is business-related travel, not personal choices.³
- When there is only one person in the car, carbon emissions from a long road trip are actually higher than from flying.²
- Flying is convenient and fast.
- There are not easy alternatives to flying (e.g., high speed trains) in the U.S.

1. Wynes, S. and Nicholas, K.A. 2017. The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*: 12.

2. Borken-Kleefeld, J., Fuglestvedt, J. and T. Berntsen. 2013. Mode, load, and specific climate impact from passenger trips. *Environ. Sci. Technol.* 47: 7608–7614.

3. Airlines for America. 2016. Air travel is affordable, accessible, and vast majority of travelers satisfied with overall experience according to new national survey

Flying from Los Angeles (LAX) to New York John F. Kennedy (JFK)

Flying from Los Angeles to New York John F. Kennedy and back generates about 697 kg CO₂. There are 50 countries where the average person produces less CO₂ in a year.



Image Credit: The Guardian (<https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year>)

MITIGATION STRATEGY: PLANT-BASED MEAT

People have relied on livestock, like cattle, as a food source for thousands of years. Many domestic animals are able to eat the plants that grow in dry environments, allowing people to live in places where they cannot grow many crops. However, raising cattle requires a lot of land, water and food. According to the United Nations (2013), livestock produce 14.5% of global greenhouse gas emissions. Many people suggest reducing the amount of meat you eat as a way to decrease greenhouse gas emissions. There are multiple companies that sell plant-based meat, a food designed to taste and look like meat but actually made from plants. These products, such as the Impossible Burger and Beyond Meat, require less land and water to produce, and making them releases less carbon dioxide and other greenhouse gasses into the atmosphere than raising livestock. Scientists have calculated that one person choosing a plant-based diet can save 0.82 metric tons of carbon per year.¹



WHAT COULD HELP MAKE THIS HAPPEN:

- People choosing to eat plant-based meat over real meat.
- Companies continuing to develop better tasting and healthier plant-based meats.
- Scientists researching how to make healthy, environmentally friendly plant-based meats.
- Large restaurant chains could switch to plant-based meats. McDonalds, Burger King, KFC and Carl's Jr. have all added plant-based meats to their menus.

CHALLENGES:

- Thousands of people make a living through the meat industry: raising, feeding, slaughtering and selling livestock.
- Many people like to eat meat.
- Scientists are researching whether new plant-based meats are healthier than meat products.^{2,3}
- Plant-based meat, especially burgers and chicken, is generally more expensive than real meat.⁴
- Many people rely on fast food, like hamburgers and chicken nuggets, that is inexpensive and easy to get.

1. Wynes, S. and Nicholas, K.A. 2017. *The climate mitigation gap: education and government recommendations miss the most effective individual actions.* *Environmental Research Letters*: 12

2. *Plant-based meat lowers some cardiovascular risk factors compared with red meat, study finds*/Journal of Clinical Nutrition

3. Harvard Health Publishing. 2019. *Impossible and Beyond: How healthy are these meatless burgers?*

4. Vox. 2020. *The next challenge for plant-based meat: Winning the price war against animal meat*

That takes the brisket 2019 or latest available			
	Greenhouse-gas emissions kg of CO ₂ equivalent per kg	Freshwater withdrawals litres per kg	Land use m ² per kg
Meat*	Beef (herd) 99.5	1,451	326
	Pork 12.3	1,796	7.8
	Chicken 9.9	660	6.7
Beyond Burger	3.5	9.7	2.7
Impossible Burger	3.5	107	2.5

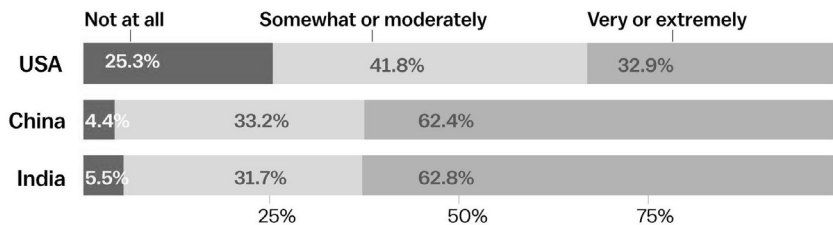
Source: Ron Milo, Weizmann Institute and Alon Shepon, Harvard University *Global average, 1kg of fat and bone-free meat and edible offal

The Economist

Image Credit: The Economist

(<https://www.economist.com/international/2019/10/12/plant-based-meat-could-create-a-radically-different-food-chain>)

How likely are you to purchase plant-based meat?



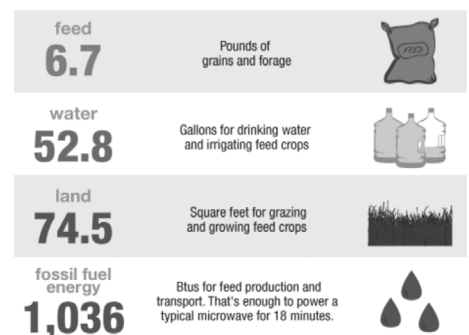
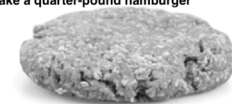
Source: Frontiers

Image Credit: Vox

(<https://www.vox.com/2019/5/28/18626859/meatless-meat-explained-vegan-impossible-burger>)

Vox

What it takes to make a quarter-pound hamburger



Source: J.L. Capper, *Journal of Animal Science*, December, 2011.

Credit: Producers: Eliza Barclay, Jessica Stoller-Conrad; Designer: Kevin Uhrmacher/NPR

MITIGATION STRATEGY: LIVE CAR FREE

A typical passenger car emits 4.6 metric tons of carbon dioxide per year (EPA, 2018). It is estimated that there are currently over 1 billion vehicles in the world. Living without a car challenges people to find alternative transportation options like walking, biking, or taking trains and buses. People without a car tend to travel shorter distances in their daily lives. Fewer cars on the road means that the remaining drivers will waste less gas sitting in traffic, and infrastructure like roads and bridges will last longer and need less maintenance due to lighter use. Scientists have estimated that one person switching from an average car to a car-free life-style will save 2.4 metric tons of CO₂ per year.¹



WHAT COULD HELP MAKE THIS HAPPEN:

- Investing in more public transportation, like buses and trains.
- Car, bike, and scooter sharing apps.
- Making cities more pedestrian and bike friendly.
- Building stores in residential areas so people can walk to them.
- More people working from home.
- Higher gasoline prices to make driving less affordable.

CHALLENGES:

- Easiest to do in cities where homes, stores, and work places are close together; hard to do in rural or suburban areas.
- Much of the country lacks efficient public transportation.
- It's hard to travel outside of your city or hometown without a car.
- There are many jobs that rely on car owners (sales, mechanics, car detailers, etc.).
- Not having a car limits how far you can go to find work, health care, and other necessities.

1. Wynes, S. and Nicholas, K.A. 2017. *The climate mitigation gap: education and government recommendations miss the most effective individual actions.* *Environmental Research Letters*: 12.

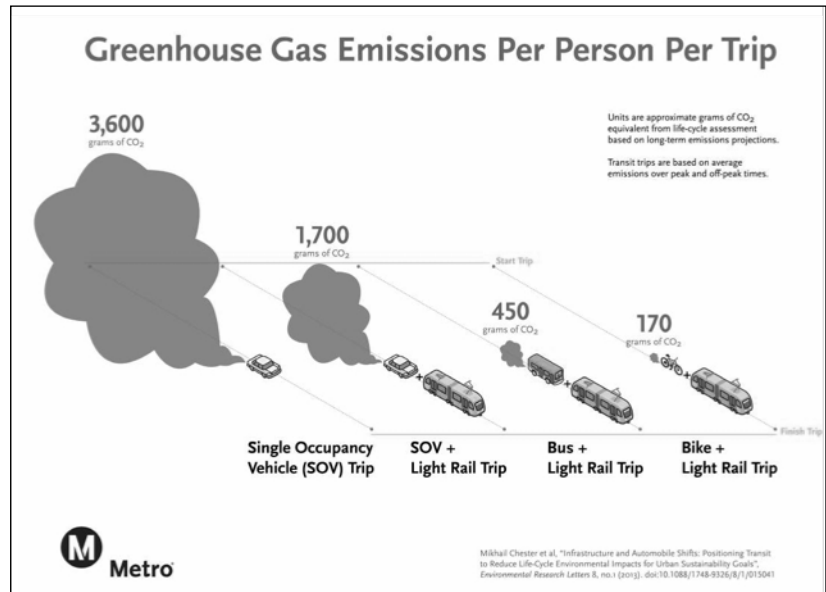


Image Credit: Metro

(<https://thesource.metro.net/2017/03/20/seven-ways-riding-a-bike-can-improve-your-life/>)

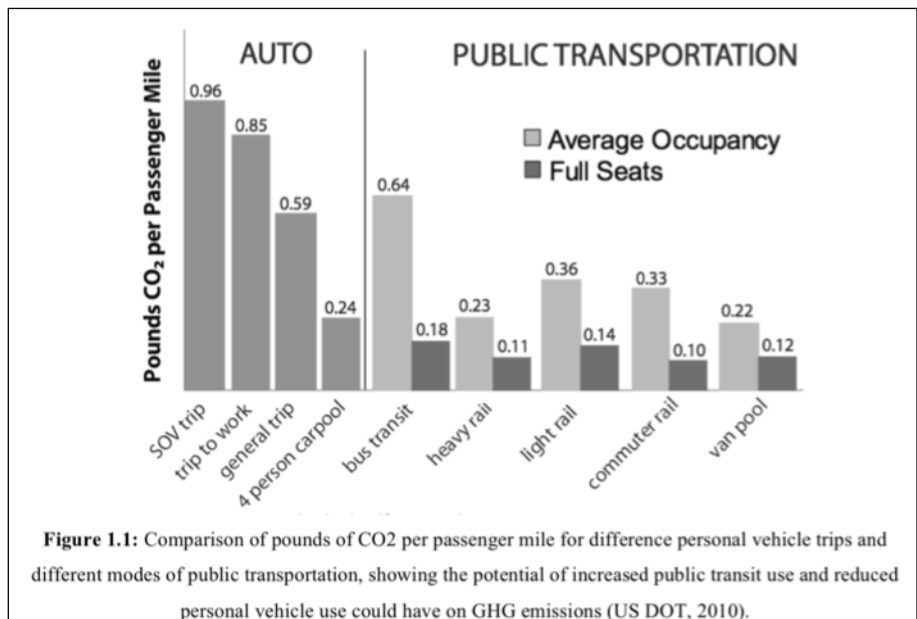


Figure 1.1: Comparison of pounds of CO₂ per passenger mile for difference personal vehicle trips and different modes of public transportation, showing the potential of increased public transit use and reduced personal vehicle use could have on GHG emissions (US DOT, 2010).

Image Credit: Metro

(<https://thesource.metro.net/2017/03/20/seven-ways-riding-a-bike-can-improve-your-life/>)

MITIGATION STRATEGY: HAVE ONE FEWER CHILD

Population growth is often named one of the greatest environmental challenges. As the global population has grown, production of food, energy, and goods has increased to meet the needs of the population. This also leads to an increase in waste and pollution. By making the decision to have one fewer child, parents are decreasing their current carbon emissions and their carbon legacy, the future carbon emissions of their descendants. By slowing population growth, resource consumption and pollution emissions also slow down. Scientists have estimated that having one fewer child will save 58.6 metric tons of carbon over a lifetime.¹

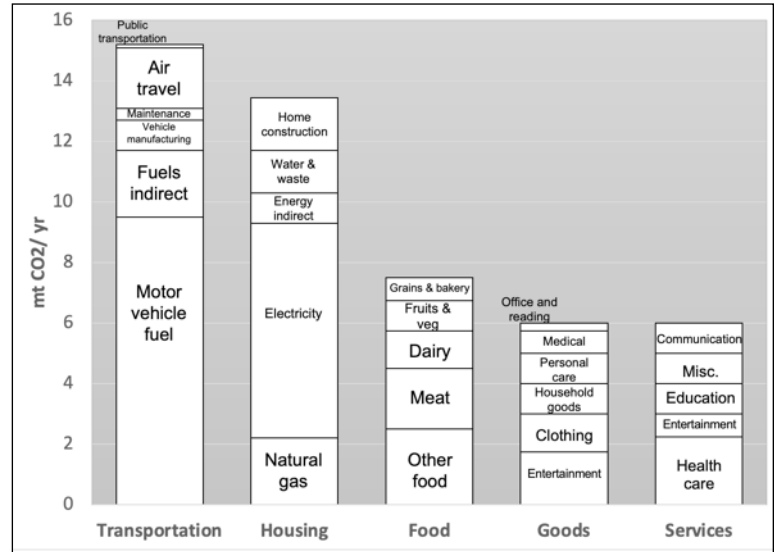


WHAT COULD HELP MAKE THIS HAPPEN:

- Educating people about the impacts of individuals on climate change.
- Research shows providing women with easy access to education and health care results in them having fewer children.²

CHALLENGES:

- How do you enforce or encourage people to keep their family size small?
- Many people have a cultural or personal preference for large families.
- Many people have a cultural, religious, or personal belief against contraception.
- Is it a violation of human rights to enforce this?
- When the Chinese government set a one child rule, a preference for sons led to a gender imbalance and poor treatment of daughters.³
- Younger generations support older generations through social security, Medicaid, etc. When there are more older than younger people, there are fewer resources to support the elderly.



Total carbon emissions of a typical US household 48 tons (CO₂/year)
Jones, C. M., & D. M. Kammen 2011. *Environmental Science & Technology*.

Population and CO₂ emissions, 1730-2015

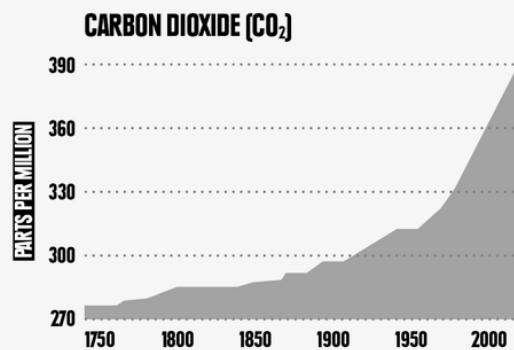
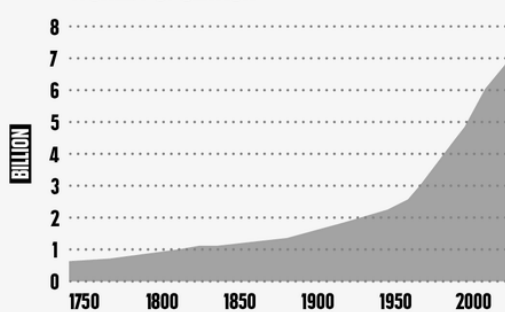


Image Credit: The Medium

Source: United Nations, 2017

(<https://medium.com/altering-climate/population-control-the-most-effective-way-to-reduce-carbon-emissions-altering-climate-a6efe56db2b>)

1. Wynes, S. and Nicholas, K.A. 2017. *The climate mitigation gap: education and government recommendations miss the most effective individual actions. Environmental Research Letters: 12.*

2. Wodon, Q., C. Montenegro, H. Nguyen, and A. Onagoruwa. 2018, *Missed Opportunities: The High Cost of Not Educating Girls. The Cost of Not Educating Girls Notes Series. Washington, DC: The World Bank.*

3. Johnson, Kay Ann (2016). *China's hidden children: Abandonment, adoption, and the human costs of the one-child policy. Chicago: University of Chicago Press. 2016.*

Names: _____

CLIMATE CHANGE M

STRATEGY: _____

1. Who will be involved in this strategy?

Think of 3-5 people or groups who would have an opinion about this strategy. Would they be for or against it?

2. Who will be in charge of making this strategy happen?



3. Where will this happen?

What does the ideal place for this to happen look like? Is there anywhere this wouldn't work?



4. What are the biggest challenges to this strategy? How will you address them?

7. Explain how you will implement this strategy. How can you address the arguments against the strategy?

CLIMATE CHANGE MITIGATION

What are the biggest challenges to implementing this strategy? How do you address these challenges?

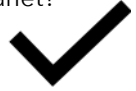


How do you implement this mitigation strategy? How do you address the challenges and the strategy?

5. Arguments for this strategy:

How could this help individuals, communities, and the planet?

1.



2.

3.

4.

6. Arguments against this strategy:

How could this harm individuals, communities, and the planet?

1.



2.

3.

4.

STAKEHOLDER CARDS

Stakeholder: Solar Engineer

You are an engineer who works for a company that builds and installs solar panels. The more solar panels in the world, the more demand there will be for your skills.

Stakeholder: Coal Miner

You live in a small town where people have been mining coal for 100 years. Most people you know work for a coal company. There isn't an endless supply of coal in the ground, so you worry about what would happen if the mine closed.

Stakeholder: Homeowner

You just bought a house and are interested in buying solar panels. You are worried that it is too expensive to buy solar panels.

Stakeholder: Homeowner

You just bought a house, and you want to install solar panels. You like that it will help slow climate change and that you won't have to pay electricity bills anymore. Your regular electricity bill is about \$100 per month, and solar panels cost about \$14,000 to install.

Stakeholder: Government Official

You work for the department of energy, and your job is to think about the big picture of energy resources in the country. You wonder where people will get their energy in 50 years and how can we prepare for that future now?

Stakeholder: Apartment Renter

You live in an apartment building with many other people. Your apartment doesn't have the space to install enough solar panels to meet the needs of your entire building.

STAKEHOLDER CARDS

Stakeholder: Environmentalist

You spend a lot of your time volunteering with groups that help protect the environment, and you are very concerned about climate change and greenhouse gasses. You think that replacing coal power plants with solar panels is a big part of the solution, but you aren't sure how to convince other people this is important.

Stakeholder: Power Company

You run a power company that provides electricity to millions of homes. Most of the electricity comes from coal-burning power plants, but the company also has some solar panels and wind turbines. You know that coal is getting more expensive and that there will probably be laws that limit the emission of greenhouse gasses in the future. You are concerned with making sure your company continues to provide electricity to customers.

Stakeholder: Lobbyist

You work for an organization with a lot of money and clients who want to decrease regulations on fossil fuel companies.

Stakeholder: Lobbyist

You work for an organization with a lot of money and clients who want to increase regulations on fossil fuel companies.

Stakeholder: Landowner

You own a big piece of land right outside a city, and a solar energy company has approached you and wants to rent your land to build solar panels.

Stakeholder: Charitable Organization Worker

You work for an organization that provides solar energy to developing countries. You recognize the importance of renewable energy for the future. However, from your experience, you've seen that developing countries cannot invest in the necessary technology.

STAKEHOLDER CARDS

Stakeholder: Meteorologist

You are a weather expert in Seattle, Washington. You know that there is an average of 152 sunny days per year where you live. Your friend wants to put solar panels on their roof. They asked you if you think it's a good idea and if it will generate much energy.

Stakeholder: Meteorologist

You are a weather expert in Phoenix, Arizona. You know that there is an average of 299 sunny days per year where you live. Your friend wants to put solar panels on their roof. They asked you if you think it's a good idea and if it will generate much energy.

Stakeholder: Coal Miner

You live in a small town where people have been mining coal for 100 years. Most people you know work for a coal company. More solar energy will mean less demand for coal. You worry that you and most of the people you know could lose jobs.

Stakeholder: Doctor

You are a doctor in a city where a lot of people have asthma. You know that clean air helps your patients, and you know that more renewable energy would decrease air pollution.

Stakeholder: Solar Company Owner

You own a company that makes solar panels. If more people used solar energy, your company would be able to expand, and you would hire more workers with the increased profits.

Stakeholder: Construction Worker

California has a new law that requires all new homes to have solar panels. You worry that this will make homes more expensive, and you don't yet have the expertise needed to install solar panels.

STAKEHOLDER CARDS

Stakeholder: Wildlife Biologist

You study the dune sagebrush lizard, a unique and endangered species that lives only in New Mexico. Its habitat is being destroyed by fossil fuel companies mining for oil and gas. You think that reducing the use of fossil fuels will protect this species.

Stakeholder: Wildlife Biologist

You study wildlife in southern New Mexico. Because fossil fuel mining harms some rare species, the fossil fuel companies have agreed to provide money and support for wildlife conservation that benefits many species you study.

Stakeholder: Economist

You know that if we switch to solar energy, in the long run, it will be less expensive than fossil fuels, which could be good for the future economy.

Stakeholder: Economist

You know that there are thousands of jobs that depend on the fossil fuel industry, and if those jobs suddenly disappear, many people will suffer financially.

Stakeholder: Water Quality Expert

You know that water will be cleaner in the long-term if we switch to solar energy due to less air and water pollution.

Stakeholder: Politician

You were elected to your state government because you promised to help represent the people's voice in the government. You know that people want jobs and resources available for a bright future in your community. What does your community think about solar energy?