

## **Ocean Acidification!**

### **What is it? Why does it matter? What can I do about it?**

#### **Synopsis of the Activity**

Learners investigate what ocean acidification is, what causes it, and how it affects marine organisms through a series of hands-on activities, discussions and short exploration of text.

#### **Audience**

This activity is designed for the general public and is best accessed by learners in middle school or older. It is best done with small groups of visitors.

#### **Setting**

This activity works well as a cart anywhere in an informal science setting.

#### **Activity Goals**

Learners will gain a deeper understanding of:

- a. What is ocean acidification?
- b. What causes ocean acidification?
- c. What organisms are affected by ocean acidification?
- d. Where is ocean acidification happening?
- e. What actions they can take to decrease ocean acidification in the future?

#### **Concepts**

1. Since the start of the Industrial Revolution, the ocean has gotten about 25% more acidic. This has been caused by excess CO<sub>2</sub> entering the atmosphere and then being absorbed by the ocean. The extra CO<sub>2</sub> comes from the burning of fossil fuels from human industry.
2. Some organisms with exoskeletons and shells will have difficulty building hard parts and others' hard parts may dissolve due to ocean acidification. This will harm those species and other organisms that rely on the affected organisms within a food web.
3. Ocean acidification is happening globally, but some areas are experiencing higher levels of ocean acidification than others.
4. By taking steps to decrease our individual and collective carbon footprints, we can decrease the extent of ocean acidification in the future.

#### **Ocean & Climate Literacy Principles**

Some of the following Principles will be more relevant to different audiences, depending on their prior knowledge and the direction of the conversation between the audience and the facilitator.

##### *Ocean Literacy*

1. The Earth has one big ocean with many features.
  - e. Most of Earth's water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.

## Promoting Climate Literacy College Course Outreach Activity

2. The ocean and life in the ocean shape the features of the Earth.
  - d. The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.
3. The ocean is a major influence on weather and climate.
  - e. The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.
  - f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
  - g. Changes in the ocean-atmosphere system can result in changes to the climate that, in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.
6. The ocean and humans are inextricably interconnected.
  - d. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non- point source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
  - e. Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).
  - g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

### *Climate Literacy*

6. Human activities are impacting the climate system.
  - c. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.
  - d. Growing evidence shows that changes in many physical and biological systems are linked to human-caused global warming. Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience.
7. Climate change will have consequences for the earth system and human lives.
  - d. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part.

## Vocabulary

*Ocean acidification*: The process by which ocean water, which is naturally basic, increases in acidity (decreases in alkalinity) due to increased absorption of carbon dioxide from Earth's atmosphere.

*Carbon dioxide (CO<sub>2</sub>)*: A naturally occurring chemical compound composed of two oxygen atoms and one carbon atom. It is an important part of Earth's carbon cycle and its concentration has significantly increased in Earth's atmosphere since the start of the Industrial Revolution.

*Calcium carbonate (CaCO<sub>3</sub>)*: A carbon-based compound that shell building organisms use to make their shells.

## Materials

1. Whole Activity
  - Large Poster Display for cart: Ocean acidification: *What is it? What causes it? Why does it matter? Where is it happening? What can you do about it?*
  - scissors
2. Exploration Activity 1
  - Exploration Activity #1 Questions sheet
  - Figures A-D
  - Computer opened to Carbon Cycle Interactive: <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68/unit2>; scroll down to session 2.7 to download the appropriate version for your computer (optional)
  - Bottle of bromothymol blue (BTB)
  - distilled water
  - 1 cafeteria-style tray
  - 4 jars with screw-top lids
  - straws (one for each anticipated visitor); cut small holes in the straws so that participants have a harder time accidentally sucking water back up from cups.)
3. Exploration Activity 2
  - Exploration Activity #2 Questions sheet
  - Distilled water
  - Limewater: Calcium hydroxide (1/4 tsp dissolved in 1000 mL of distilled water—may need to dilute further so that water becomes relatively clear; test the prepared limewater and limewater with a few drops of vinegar in cups side by side to make sure the difference is visible when you blow into each cup for 15 seconds.)
  - Straws (one for each anticipated visitor); cut small holes in the straws so that participants have a harder time accidentally sucking water back up from cups.
  - 2 dropper bottles filled with white vinegar labeled "high CO<sub>2</sub> water"
  - 2 petri dishes divided into four parts each with a permanent marker (label each section with one of the following: rocks, shells/corals, seaweed, jellyfish)
  - calcium carbonate powder
  - collagen powder wetted down with tap water until it's wet throughout and

## Promoting Climate Literacy College Course Outreach Activity

- gelatinous looking
  - 2 spoons
  - Dark colored permanent marker
  - Seaweed (small pieces)
  - pebbles or gravel
  - shell and coral samples
  - Figure D
  - Organism information sheets: shellfish, pterapods, jellyfish, ocean food web, corals, plankton that build shells, less acidic → more acidic
  - Direction sheet for Exploration Activity 2
  - Four 6-8 oz. plastic Solo cups with lids
4. Exploration Activity 3
- Exploration Activity #3 Questions sheet
  - Color ocean acidification map
  - Computer (animations from: <http://sos.noaa.gov/videos/pH.mov> and <http://sos.noaa.gov/videos/saturation.mov>)
5. Exploration Activity 4
- Exploration Activity #4 Questions sheet
  - "What can you do?" sheet
  - EPA information sheets (home, school, office, on the road)

### Procedure and Set-up

Arrange the 4 exploration question trays on the table with all relevant materials on each tray. Each tray should display an exploration question, the folders of information sheets and other written materials relevant to that exploration question, and the hands-on materials and directions for activities related to that exploration question.

### Activity Description

Learners can engage in all four Exploration Activities in any order, and each Exploration Activity can be repeated, or cycled through as new visitors approach. Facilitators should gauge the areas of interest and knowledge level of learners, and help them to make connections between ideas explored in the four exploration activity stations.

### Invitation

Ask, **"Have you heard anything about ocean acidification?"** If yes, **"What have you heard about ocean acidification?"** and **"Would you like to find out more? We're exploring these questions (show exploration questions). Are any of them interesting to you? Would you like to explore one or more of them?"**

If the learner has never heard of ocean acidification, you might say, **"We're exploring these questions about ocean acidification (show big questions). Would you like to explore one or more of them?"**

Start with whichever exploration question the learner is interested in. If learners are immediately interested in "Where is ocean acidification happening?" encourage them to at least do Exploration Activity #2 first. After they have explored the first question they find interesting, ask if they would

like to explore one of the others. Ask after each subsequent exploration until all exploration questions are completed or the learner would prefer to move on to something else.

**Exploration Activity #1: What is ocean acidification? And what causes it?**

- 1. Share a quick definition.** Since the start of the Industrial Revolution, the ocean has gotten about 25% more acidic. This has been caused by excess CO<sub>2</sub> entering the atmosphere and then being absorbed (taken in) by the ocean. The extra CO<sub>2</sub> comes from the burning of fossil fuels—from cars, trucks, airplanes, factories, making cement, clear cutting forests and other sources.

**Share information on sources of atmospheric CO<sub>2</sub> (Optional).** Many learners may already know how excess CO<sub>2</sub> gets into the atmosphere. However, if learners are interested in learning more about sources of CO<sub>2</sub>, you may either direct them to the Carbon Cycle game station if there is one or share any or all of figures A-C as they seem relevant to the learners' interests. Give learners a little time to explore the figures. **Ask if they are surprised by any of the information in the figures.** Allow learners to discuss what surprises them and why. If there are multiple learners at the activity station, help them connect their ideas to others' by asking questions like, "Were other people surprised by that? What do you think about what \_\_\_\_\_ just said?" Tell learners that atmospheric CO<sub>2</sub> levels have been steadily increasing since the Industrial Revolution. They can find more information about this at the Carbon Cycle game station.

If you have the Carbon Cycle Interactive open on a computer, learners might wish to engage with that as well, or instead of Figures A-C. For the Carbon Cycle Interactive, show the learners how to click on the choices at the top of the page. Most people find the natural flows in and out of the atmosphere and the human industry tabs interesting. Point out that if they were to do the math, the natural flows in and out of the atmosphere would be balanced. However, the human industry flows put more carbon into the atmosphere than is being removed. Show learners how to click on any of the flows or reservoirs to find out more.

- 2. Introduce the first investigation question.** Tell learners that so far you've just discussed what happens to CO<sub>2</sub> in the atmosphere, but excess CO<sub>2</sub> in the atmosphere can have big effects on the ocean. Tell learners that you have some materials that they can use to help them explore the effects of excess atmospheric CO<sub>2</sub> on the ocean, but first they'll need to understand a little bit about how the CO<sub>2</sub> gets into the ocean. Let learners know that CO<sub>2</sub> is naturally found in ocean water, and that it is important for organisms in the ocean. Tell learners that in this investigation they will explore how CO<sub>2</sub> gets from the atmosphere to the ocean. If they would like to know how carbon is used by ocean organisms, they can explore question #2 next.
- 3. Introduce CO<sub>2</sub> and BTB.** The investigations will use the CO<sub>2</sub> that learners exhale and a chemical indicator called BTB. Explain that BTB stands for bromothymol blue, a chemical that turns green or yellow when it's mixed with an acid. Give the learners a sealable jar of BTB water and have them describe it [it's blue]. Have them shake the jar up and describe what they see [it's still blue]. Tell the learner that this lack of color change indicates that just shaking water up does not add any acid to it. Then give the learner a straw and have them blow directly into the water until it changes color. Remind learners that they are exhaling

CO<sub>2</sub>. Have the learner describe what happens [it turned yellow or green]. Remind the learner that BTB shows whether or not an acid is present in the water and the learner exhaled CO<sub>2</sub> into the water. Ask, **“What does that tell you about CO<sub>2</sub>?”** [it makes water more acidic]. Tell the learner that, in water, carbon dioxide makes an acid called carbonic acid, so if the BTB turns green or yellow that is evidence that enough carbon dioxide is present in the water to make carbonic acid.

4. **Explore what happens when CO<sub>2</sub> is not blown directly into the water.** Give the learners another sealable jar of BTB water and have them blow ten big breaths into the air at the top of the jar. Quickly, have the learners screw on the lid. Then have them note the color of the BTB [it will likely still be blue, but sometimes it starts to change color a bit]. Have the learners shake the jar and note any color change [it should turn yellow/green at this point]. Explain that molecules in the atmosphere would bounce around and interact with the water as well. We just sped up the process by shaking the jar. If they are interested, they can set up a second jar that they breathe into the top of, seal and let sit still for a while. It usually takes about 20 minutes for a color change to occur. You can show them a jar you have had sitting for a while so they can see what would happen if they waited.
5. **Review models in science (as needed, if this is the first Exploration Activity learner is doing).** Remind/tell learners that in science, a model is something that is used to help understand, predict, or explain how things work. It is like the thing it represents in some, but not all ways. The two investigations (shaking the jar and not shaking the jar) are using models to represent the ocean. **Ask learners to think about the ways in which these models are accurate for investigating how CO<sub>2</sub> from the atmosphere gets into ocean water, and then ask them to think about the ways they are inaccurate.** Ask a few volunteers to share their ideas. You might ask learners to turn and talk to someone else before sharing out with others at the activity station. Or you might ask learners, *“What do you think about that idea?”*
  - Accurate: The models show what happens when CO<sub>2</sub> from the atmosphere comes in contact with water—that the water becomes more acidic.
  - Inaccurate: The models are much smaller than the actual ocean; the ocean isn't actually shaken in this way; the ocean is not enclosed like this, CO<sub>2</sub> would be able to exit the ocean as well; the ocean is salt water.
6. **Discuss what happens when CO<sub>2</sub> in the atmosphere comes in contact with the ocean.** Ask the learners, **“Based on what you saw in this quick investigation, what can you say about how CO<sub>2</sub> in the atmosphere interacts with ocean water?”** [It seems to take the CO<sub>2</sub> in and make the water more acidic]. Make sure to ask learners to support their ideas with evidence by asking questions like, *“What makes you think that?”* or *“How do you know?”* You can also help learners think together by asking them, *“What do others think about that idea?”*
7. **Introduce the word absorb.** Share that these models demonstrate how the ocean “absorbs” CO<sub>2</sub> from the atmosphere. You could say that a sponge absorbs water or that a couch absorbs odors from cooking fish. The ocean absorbs CO<sub>2</sub> from the atmosphere. The ocean absorbs 40-50% of the CO<sub>2</sub> from the atmosphere.
8. **Respiration also adds CO<sub>2</sub> to ocean water (Optional—if it comes up).** Let learners know that, similar to how respiration from land organisms adds CO<sub>2</sub> to the air, respiration from ocean

organisms also adds CO<sub>2</sub> to ocean water—just like when they blew directly into the water. The water absorbs this CO<sub>2</sub> as well, but the amount of CO<sub>2</sub> absorbed from respiration is much less than the CO<sub>2</sub> that the ocean absorbs from the air. Also, although humans and other animals (and plants) contribute some CO<sub>2</sub> to the atmosphere and directly to the ocean, that amount of CO<sub>2</sub> is pretty much directly balanced by the amount of CO<sub>2</sub> that is taken in by plants or plant-like organisms for photosynthesis.

9. **Share information on pH levels in the ocean (past, present, and future).** Ask learners if they want to know a little bit about how much the pH has changed in the past few hundred years or what pH levels look like in the ocean. If they want more information, share sheet D. When sharing information on sheet D, mention that the orange organisms in the ocean pH diagram actually eat the red organisms. This means that the orange organisms would suffer from loss of prey before they would suffer directly from ocean acidification.
10. **Invite the learner to explore additional questions.** Point out the additional exploration questions and ask the learner if they want to investigate one of these.

***Exploration Activity #2: Why does ocean acidification matter? Which organisms are affected by it?***

1. **Connect to other activities.** If learners have explored one or more of the other exploration questions, invite them to share what they have learned about CO<sub>2</sub> in ocean water.
2. **Introduce the exploration question.** Remind learners that CO<sub>2</sub> occurs naturally in ocean water. Tell them that some ocean organisms, just like land organisms, use CO<sub>2</sub> for photosynthesis AND that organisms that build shells use the carbon from CO<sub>2</sub> for making calcium carbonate shells. Tell them you'll now investigate this Exploration Question: **“What happens to some ocean organisms if there is more CO<sub>2</sub> in ocean water than they are used to?”** (You might want to say “adapted for” instead of “used to” when asking this question. Just be aware that you may need to explain what you mean by “adapted for” as this requires some understanding of bigger life science concepts.)
3. **Introduce two questions to investigate.** Tell learners that to help them think about their answer for the big, broad Exploration Question, they will investigate two smaller questions that focus on forming and maintaining shells. (1) **“Which organisms’ parts might break down in water with more CO<sub>2</sub> than they are used to (adapted for)?”** and (2) **“Can shells form if there is more CO<sub>2</sub> in ocean water than they are used to (adapted for)?”**
4. **Introduce the investigation with a model.**
  - a. Tell learners that they will use calcium carbonate powder to represent shells since this is what shells are made of. Show the learners a few examples of real shells and then point to the calcium carbonate powder.
  - b. Tell them you will use gelatin made of collagen to represent jellyfish since jellyfish are made of the same material.
  - c. Explain that they will use containers of limewater as models of the ocean. Tell them that limewater will act as a model of the ocean because: (1) Ocean water has

many different types of substances dissolved in it naturally, such as nitrogen, calcium, sodium, and carbon dioxide. So ocean water is like soup broth that has many ingredients dissolved in it. (2) Organisms, like corals, snails, and clams, use the calcium and  $\text{CO}_2$  in ocean water to form calcium carbonate that make up their shells. Calcium carbonate makes their shells hard. (3) Limewater is tap water with a lot of calcium dissolved in it (in the form of calcium hydroxide). For our explorations, we are going to use limewater to represent ocean water so that we can make the same calcium carbonate that shell-building organisms make. We will use  $\text{CO}_2$  from our breath to add  $\text{CO}_2$  to the model ocean water since ocean organisms use  $\text{CO}_2$  absorbed by ocean water to make hard parts of their body.

5. **Do “Break Down” investigation with learners.** Share the direction card for the “Break Down” investigation and show learners the tray of labeled materials. If it seems necessary, briefly describe the steps written on the card:
- Spoon a small amount of each of the appropriate materials in each of the labeled spots on the petri dish (seaweed, jellyfish, shells/corals, rocks).
  - Predict what will happen when “High  $\text{CO}_2$  water” is dropped on each of these materials.
  - Using the eyedropper, add a few drops of “High  $\text{CO}_2$  water” to each material on your plate.
  - Note what happens to each material.
  - Discuss these questions: Which materials seem to be most affected by more acidic/high  $\text{CO}_2$  water? Are any of the materials unaffected by the high  $\text{CO}_2$  water? If so, which ones?

Give learners a few minutes to conduct the investigation and discuss the questions. Listen in as they share their responses to the discussion questions. They should notice that the shells/corals are the most affected, while the rocks, seaweed, and jellyfish remain unaffected. Ask, **“What types of organisms might be affected by ocean acidification based on your evidence so far? Which organisms might fare well in a more acidic ocean?”** [shelled organisms might have a tough time maintaining their shells, while jelly fish and seaweeds appear to be unaffected].

6. **Do “Build Up” investigation with learners.** Share the direction card for the “Build Up” investigation and show learners the tray of labeled materials. If it seems necessary, briefly describe the steps written on the card:
- Fill two clear plastic cups with the same amount of limewater—about  $\frac{1}{4}$  cup (you may need to shake up the limewater to remix it before pouring into cups).
  - Label one cup “ocean water of today.”
  - Drop about 20 drops of “High  $\text{CO}_2$  water” into the second cup and then label it “ocean water of year 2100.”
  - Cover each cup with a lid.
  - When  $\text{CO}_2$  mixes with Calcium in water, sometimes calcium carbonate is formed. Predict what will happen if you add  $\text{CO}_2$  to each cup by breathing into them through a straw. This will mimic  $\text{CO}_2$  naturally being absorbed by ocean water. You will be able to tell if calcium carbonate forms in the cups because the cup will become cloudy from the white calcium carbonate.
  - Unwrap the straws; insert one straw through the lids into each of the two cups of limewater. The straws have holes in them to keep you from accidentally sucking the lime



water back in. Do not drink the water.

- Blow into each of the cups for the same amount of time—about 30-45 seconds.
- Compare what you observe in each of the cups.
- Discuss the following question: Which of the cups of water seems to have more calcium carbonate available for organisms to use to build shells? What is your evidence?

Learners should notice that the ocean water of today gets cloudy because a white precipitate forms. Remind participants that this cloudiness is calcium carbonate—the thing ocean organisms use to build their shells. The ocean water of 2100 should not get cloudy. Ask, **“Which of the waters appear to have more calcium carbonate available for building shells? How do you know?”** [The ocean water of today seems to have more calcium carbonate available because it is cloudier than the ocean water of 2100.]

**7. Review models in science (as needed, if this is the first Exploration Activity learner is doing).**

Remind learners that in science, a model is something that is used to help understand, predict, or explain how things work. It is like the thing it represents in some, but not all ways. The two investigations used models to represent the ocean. Ask learners to think about the ways in which these models are accurate for investigating the questions regarding effects of a more acidic ocean on ocean organisms, and then ask them to think about the ways they are inaccurate. Call on a few volunteers to discuss their ideas. Encourage learners to build on each other’s ideas by asking questions like, *“What do others think about that idea?”*

- Accurate: The models use some of the substances dissolved in ocean water, including calcium and CO<sub>2</sub>; the gelatin and the calcium carbonate are pretty much what the actual organisms we’re using them to represent are made of.
- Inaccurate: The models are much smaller than the actual ocean; the CO<sub>2</sub> entering the ocean is not really from blowing into it, but is absorbed from the atmosphere; the high CO<sub>2</sub> water is a lot more acidic than high CO<sub>2</sub> water will actually be, but we have made it more acidic to speed up the process so that it can be seen in a short amount of time.

**8. Debrief the big idea of the investigations.** Ask, **“Based on the available evidence, what types of organisms do you think will be directly and indirectly affected by ocean acidification?”**

Learners will probably mention that organisms with calcium carbonate shells will suffer. If they do not mention it, you might add that other organisms depend on shelled organisms as a food source, so they may be impacted as well. Share the Ocean Food Web handout to provide more evidence of this.

**9. Share some images of organisms affected by ocean acidification.** If the learners still seem engaged in this exploration question topic, share the pH sheet (D), the organism information sheets and the ocean food web information sheet. Give learners a few minutes to peruse whatever interests them. Ask, **“What’s something you found interesting or surprising on these sheets?”** Accept all responses. If no one points out the information on plankton, you might share that many plankton build parts from calcium carbonate, and plankton are the base of most ocean food webs. *One way to support more peer-to-peer interaction for this portion of the activity is to divide up the information sheets so that each learner is responsible for sharing the information on their sheet with the other learners at the station. This may or may not be possible depending on the audience or number of learners present.*

**13. Point learners toward other Exploration Activities.** Encourage learners to engage in other Exploration Activities based on their current questions or interests.

***Exploration Activity #3: Where is ocean acidification happening?***

Make sure learners have already done at least the “Build Up” portion of Exploration Activity #2 before beginning this section.

**1. Explore world ocean acidification maps.**

- a. Remind learners of the “Build Up” investigation they did in Exploration Activity #2. Ask, **“What was the difference between the amount of calcium carbonate available (the white powder making the water cloudy) in the high CO<sub>2</sub> water of 2100 versus the lower CO<sub>2</sub> water of today?** [The high CO<sub>2</sub> water of 2100 had less CaCO<sub>3</sub> in it than the low CO<sub>2</sub> water. It was less cloudy]. Tell the learners that just as the calcium carbonate level dropped in the high CO<sub>2</sub> water in the Build Up investigation, the amount of available calcium carbonate in ocean water decreases as CO<sub>2</sub> levels rise.
  - b. Show the sheet of world ocean maps (past, present, and future projections). Tell learners that these maps show the amount of calcium carbonate available in the water across the globe. Explain that calcium carbonate availability is one way that scientists measure ocean acidification.
  - c. Help learners locate where they live—Ask, **“What’s happening there? How has ocean pH changed over time? How is it projected to change?”**
  - d. Find other places of interest—Ask, **“What’s happening there? How has ocean pH changed over time? How is it projected to change?”**
  - e. Notice patterns—Ask, **“Is ocean acidification happening more in some places than others? Which places are experiencing the biggest effects? The smallest?”** [Poles are most impacted. Warmer regions are less so, but are still impacted.]
  - f. Make connections—Ask learners to make connections between what they learned in Exploration Activity #2 and what they see in the maps. Tell them that many organisms at the base of food webs have calcium carbonate shells. Ask, **“How do you think food webs in different parts of the ocean might be impacted based on what you are seeing on the maps? What makes you think that?”** Encourage learners to talk to each other and share their ideas. [Polar regions are greatly impacted by ocean acidification, and therefore shelled organisms forming the base of the food web are greatly impacted in those areas. This may have an impact on all parts of the food web. Other parts of the ocean will be similarly affected, but the poles are currently seeing some of the biggest impact.]
- 2. Explore the NOAA Science on a Sphere data sets.** Open the Science on a Sphere data set at: <http://sos.noaa.gov/videos/pH.mov> and <http://sos.noaa.gov/videos/saturation.mov>.
- a. Tell the learners that you will share another way of looking at ocean acidification that is more dynamic than the static images they just observed. The Science on a Sphere data set shows how the surface ocean has changed since the Industrial Revolution from taking up extra atmospheric carbon dioxide. This dataset shows a computer recreation of surface ocean pH from 1890 to the present, and it forecasts

ocean pH between now and 2094. Show the video:

<http://sos.noaa.gov/videos/pH.mov>. Tell learners that dark gray dots show cold-water coral reefs, and lighter gray dots show warm-water coral reefs. The key on the right side shows the colors associated with different pHs. Higher pHs (more basic) are blue, and lower pHs (less basic) are orange. 7.0 is basic. The scale doesn't go below 7.0 because the ocean is not projected to actually become acidic—just less basic. Press play on the animation again. Have learners watch to see what they notice. Ask, **“What did you notice?”** Accept all responses.

- b. If no one mentioned it, show the animation again and point out that ocean acidification was slow at the beginning of the movie, but it speeds up as time goes on. This is because humans are releasing carbon dioxide faster than the atmosphere-ocean system can handle.
- c. Remind the learners that ocean acidification decreases the amount of calcium carbonate available in seawater. The next animation from Science on a Sphere will show similar information to the maps they looked at before. This animation shows the saturation state of calcium carbonate minerals (a proxy for the amount of available calcium carbonate dissolved in sea water). Put on the movie: <http://sos.noaa.gov/videos/saturation.mov>. While the animation is playing, tell learners that areas with higher levels of calcium carbonate available for building shells and exoskeletons are in blue, while those with less are in orange. Areas where calcium carbonate minerals will dissolve (like in the “Break Down” investigation), show up in light gray. Show the animation a second time.
- d. After showing the data visualization, ask, **“What did you find interesting or surprising? Why?”** Provide learners with the opportunity to share their ideas with others by asking, *“What did others think about that?”* or *“Did you notice something different?”* Accept all responses.

#### ***Exploration Activity #4: What can I do about ocean acidification?***

If the learner wants to explore what (s)he can do about sea level rise, tell him/her the best thing to do is focus on actions that can decrease the amount of carbon dioxide entering Earth's atmosphere. Share the relevant EPA solution sheet(s) (home, school, office, on the road—whichever makes sense for the learner). Give the learner the “What can you do?” worksheet, and have them talk to a partner and read over the relevant solution sheets to help complete it. Tell them all of the things listed are actions they can take, but it's hard for any one person to do all of these things. Ask them to select just one or two things they think they really want to try to do and create an action plan for themselves using the worksheet. After completing this activity, ask if the learner wants to explore one of the other questions they might not have explored yet.

## Science Background

A great deal of carbon flows back and forth between the ocean's surface and the atmosphere. Carbon enters the ocean reservoir from the atmosphere by absorption, where it dissolves because of diffusion (moving from places of higher to places of lower concentration). The difference between the concentration of  $\text{CO}_2$  in the ocean and the atmosphere causes  $\text{CO}_2$  to move rapidly between the two in order to equalize concentrations. Once in the ocean, some of the  $\text{CO}_2$  dissolves and forms carbonic acid ( $\text{H}_2\text{CO}_3$ ), which in turn generates bicarbonate ( $\text{HCO}_3^-$ ), carbonate ( $\text{CO}_3^{2-}$ ), and hydrogen ( $\text{H}^+$ ) ions. This means that the concentration of  $\text{CO}_2$  in the ocean has decreased, so more  $\text{CO}_2$  diffuses into the ocean. This process is affected by water temperature—colder water absorbs more  $\text{CO}_2$ , warmer water absorbs less. Therefore, polar regions are seeing bigger and faster changes than other parts of the world. Another influence is surface winds; they agitate ocean surface water and speed up the process of absorption.

As the ocean takes in more and more  $\text{CO}_2$  from the atmosphere, the  $\text{H}^+$  ion concentration increases, thereby making the ocean increasingly acidic (pH is a measure of hydrogen ion concentration). The ocean has already taken in so much  $\text{CO}_2$  over the past 200 or so years that it has become about 30 percent more acidic (a -0.11 drop in average surface ocean pH). When the ocean becomes more acidic (really, less basic, as the ocean will most likely never be acidic), it is called *ocean acidification*.

Between the start of the Industrial Revolution and the publication of this activity, atmospheric  $\text{CO}_2$  had increased by nearly 40 percent. The ocean has absorbed roughly 30 percent of that  $\text{CO}_2$ . Evidence shows that the rate of human-driven ocean acidification is about 100 times faster in the surface ocean than that experienced by marine ecosystems globally for tens of millions of years. One of the biggest problems associated with ocean acidification is that as the ocean gets more acidic, it makes it more difficult for some animals to build their calcium carbonate ( $\text{CaCO}_3$ ) shells.

Many marine organisms, such as corals, oysters, clams, barnacles, sea urchins, and some important plankton species, combine calcium ( $\text{Ca}^{2+}$ ) and carbonate ( $\text{CO}_3^{2-}$ ) ions dissolved in seawater to form calcium carbonate ( $\text{CaCO}_3$ ) shells and skeletons. Calcium is very abundant in Earth's crust and can be found in many places including rocks such as limestone and marble. It dissolves easily in water and is a very important part of ocean water. Calcium is needed for many living organisms to build skeletons, shells, bones, teeth, and lenses for the eye.

Since calcium is so abundant, carbonate is the limiting factor needed for shell building. When more  $\text{CO}_2$  dissolves in ocean water, less carbonate is available for shell formation. This is because the hydrogen ions, generated from the dissociation of carbonic acid into bicarbonate and hydrogen ions, bond with the free-floating carbonate ions to make more bicarbonate. The percentage of hydrogen ions increases more than that of bicarbonate, which creates an imbalance in the back and forth reaction  $\text{HCO}_3^- \rightleftharpoons \text{CO}_3^{2-} + \text{H}^+$ . In order to maintain chemical equilibrium, some of the free floating carbonate ions combine with the hydrogen ions and make more bicarbonate. This limits the amount of carbonate ions available for calcium carbonate formation. See [http://www.whoi.edu/home/oceanus\\_images/ries/calcification.html](http://www.whoi.edu/home/oceanus_images/ries/calcification.html) for an animated version of the process.

It is also the case that with extremely high levels of CO<sub>2</sub> absorbed by the ocean, ocean water could become corrosive to some organisms' calcium carbonate shells. However, larger threats to shell formation will and are happening before that. In laboratory studies, most shelled organisms show decreased shell growth as CO<sub>2</sub> levels increase. A thinner shell at the larval other life history stages can impact an organism's chances for survival. Many of the organisms directly impacted by ocean acidification are primary producers or primary consumers. Their fate can have an impact on all levels of marine food webs.

For a quick overview of ocean acidification and other useful resources, see:

<http://www.epa.gov/climatestudents/impacts/signs/acidity.html>

Much of this background section is taken from Ocean Sciences Sequence: The Ocean–Atmosphere Connection and Climate Change. Used by permission from the Regents of the University of California. For more information and additional resources from this instructional material, see: <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview>.

# OCEAN ACIDIFICATION

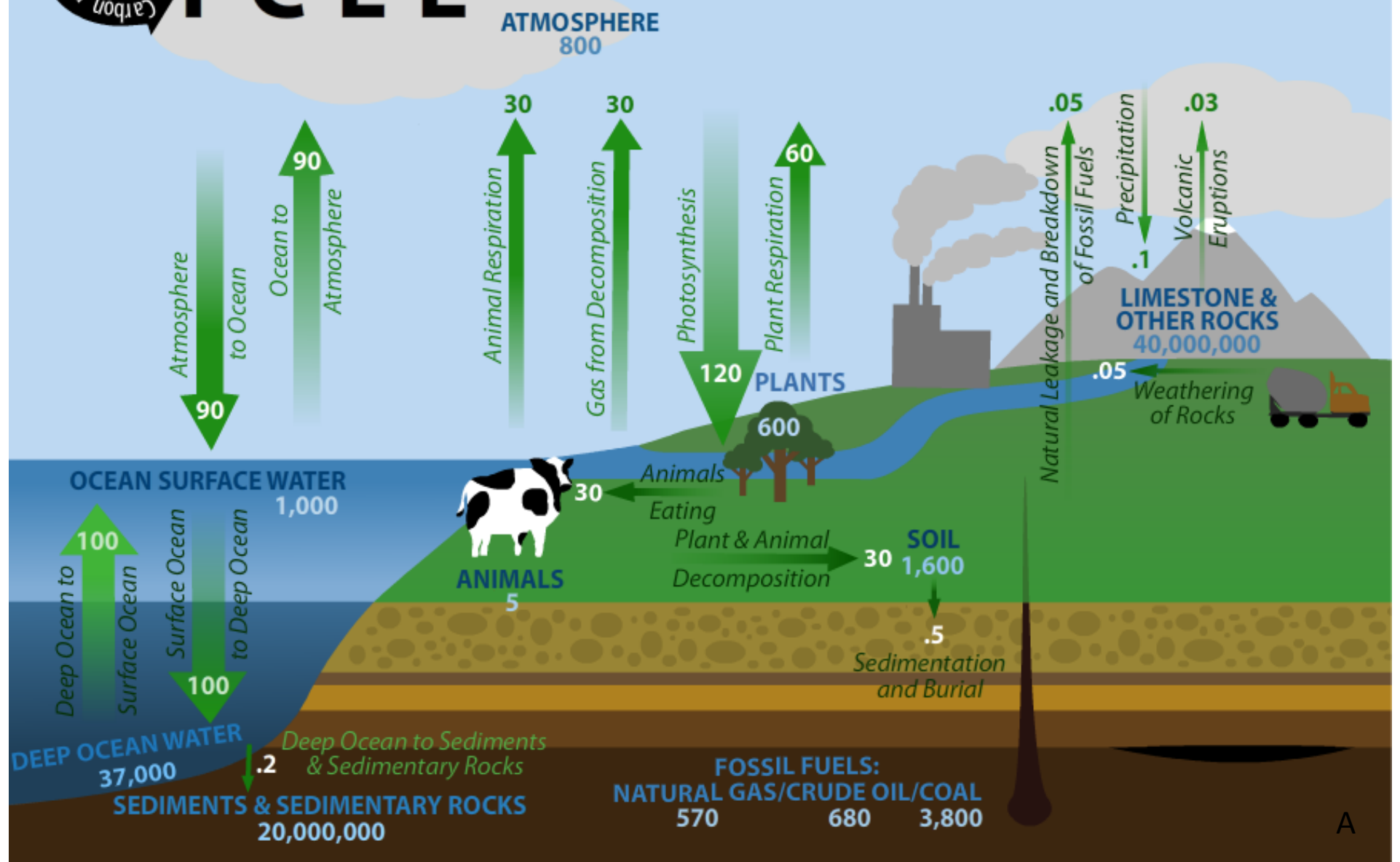
- What is it?
- What causes it?
- Why does it matter? What organisms are affected by it?
- Where is it happening?
- What can you do about it?

What is ocean acidification? And what causes it?

# THE CARBON CYCLE

Carbon measured in gigatons.

Reservoirs | **Natural Flows** | Human Industry Flows  
 Natural Flows into Atmosphere | Flows out of Atmosphere  
 All Flows into Atmosphere | All Flows

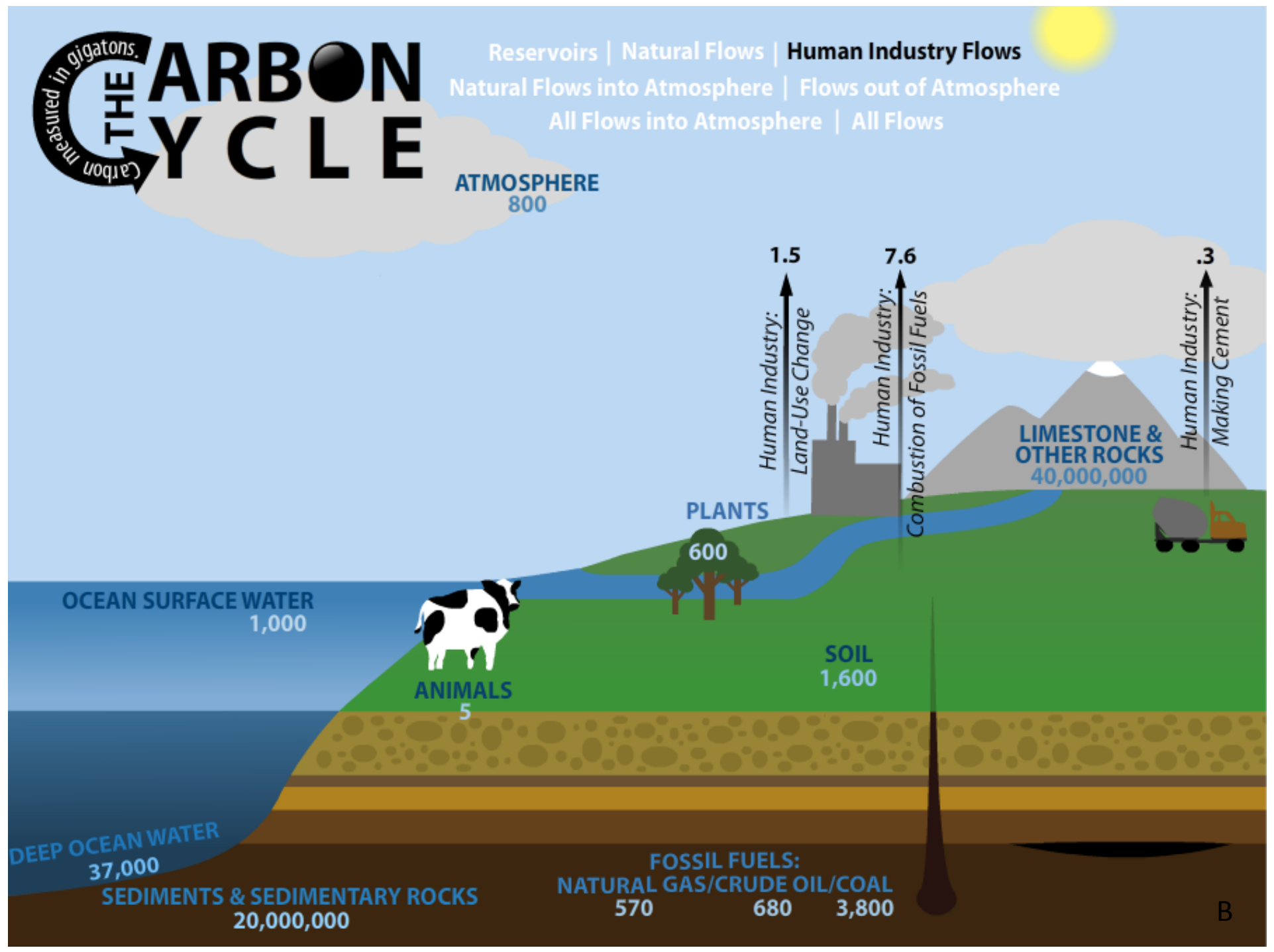




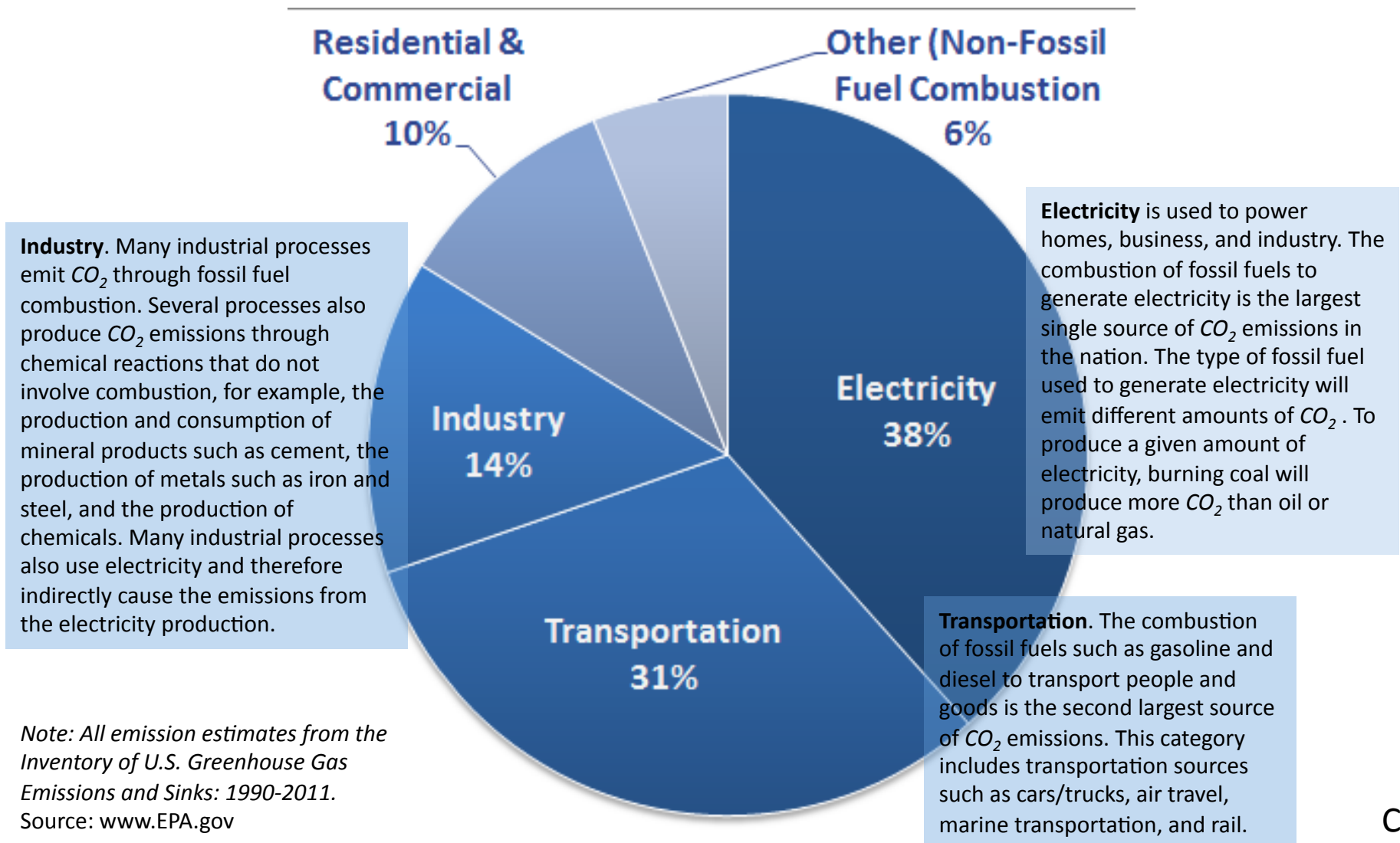
# THE CARBON CYCLE

Carbon measured in gigatons.

Reservoirs | Natural Flows | Human Industry Flows  
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 All Flows into Atmosphere | All Flows

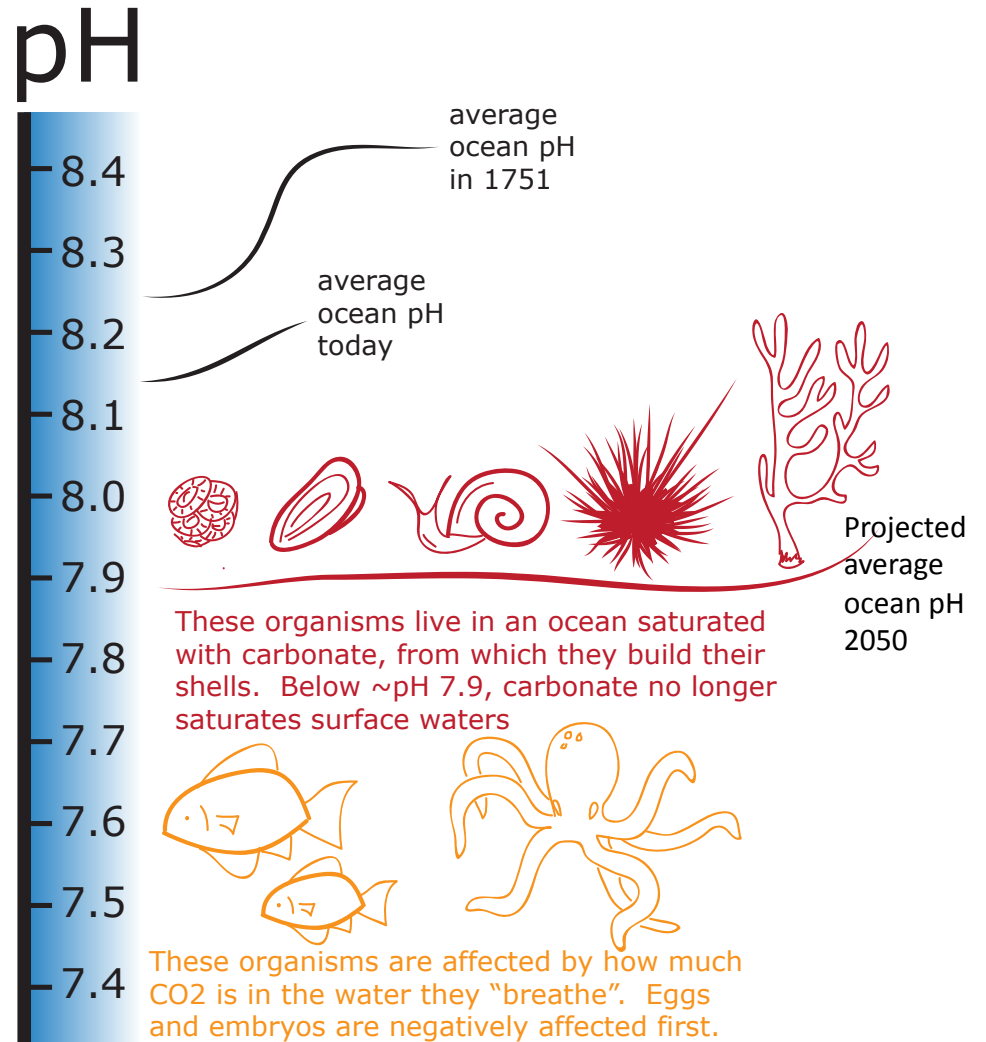


The main human activity that emits  $CO_2$  is the **combustion of fossil fuels** (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit  $CO_2$ . The main sources of  $CO_2$  emissions in the United States are described below.



The **pH scale** is what mathematicians call a logarithmic scale. A change of one unit (say from pH 7 to pH 8, or from pH 7 to pH 6) represents a change in ten times the amount. A solution with a pH of 6 has ten times the acidity of neutral water (pH 7). A solution with a pH of 8 has one tenth the acidity of neutral water. The chart below shows how much the acidity increases for different decreases in pH. Note that as pH goes down, acidity goes up.

How Much the Acidity Increases for Different Changes in pH	
pH Decrease	Amount of Increase in Acidity
0.1 pH decrease	25% more acidity
0.2 pH decrease	60% more acidity
0.3 pH decrease	2 times more acidity
0.7 pH decrease	5 times more acidity
1.0 pH decrease	10 times more acidity
2.0 pH decrease	100 times more acidity
3.0 pH decrease	1,000 times more acidity



Credit: pH scale graphic created by Dr. Mary Whelan

Why does ocean acidification matter?  
Which organisms are affected by it?

***Break down: Which organisms' parts might break down in water with more CO<sub>2</sub> than they are used to (adapted for)?***

- Spoon a small amount of each of the appropriate materials in each of the labeled spots on the petri dish (seaweed, jellyfish, shells/corals, rocks).
- Predict what will happen when “High CO<sub>2</sub> water” is dropped on each of these materials.
- Using the eyedropper, add a few drops of “High CO<sub>2</sub> water” to each material on your plate.
- Note what happens to each material.
- Discuss these questions: Which materials seem to be most affected by more acidic/high CO<sub>2</sub> water? Are any of the materials unaffected by the high CO<sub>2</sub> water? If so, which ones?

## ***Build Up: Can shells form if there is more CO<sub>2</sub> in ocean water than they are used to (adapted for)?***

- Fill two clear plastic cups with the same amount of limewater—about ¼ cup.
- Label one cup “ocean water of today.”
- Drop about 20 drops of “High CO<sub>2</sub> water” into the second cup and label it “ocean water of year 2100.”
- Cover each cup with a lid.
- When CO<sub>2</sub> mixes with Calcium in water, sometimes calcium carbonate is formed. Predict what will happen when you add CO<sub>2</sub> to each cup by breathing into them through a straw. This will mimic CO<sub>2</sub> naturally being absorbed by ocean water. You will be able to tell if calcium carbonate forms in the cups because the cup will become cloudy from the white calcium carbonate.
- Unwrap the straws; insert one straw through the lids into each of the two cups of limewater. The straws have holes in them to keep you from accidentally sucking the lime water back in. Do not drink the water.
- Blow into each of the cups for the same amount of time—about 30-45 seconds.
- Compare what you observe in each of the cups.
- Discuss the following question: Which of the cups of water seems to have more calcium carbonate available for organisms to use to build shells? What is your evidence?

# Pteropods

The pteropod, or “sea butterfly”, is a tiny sea creature about the size of a small pea. Pteropods are eaten by organisms ranging in size from tiny krill to whales and are a major food source for North Pacific juvenile salmon. The photos below show what happens to a pteropod’s shell when placed in sea water with pH and carbonate (what pteropods make their shells from) levels projected for the year 2100. The shell slowly dissolves after 45 days.

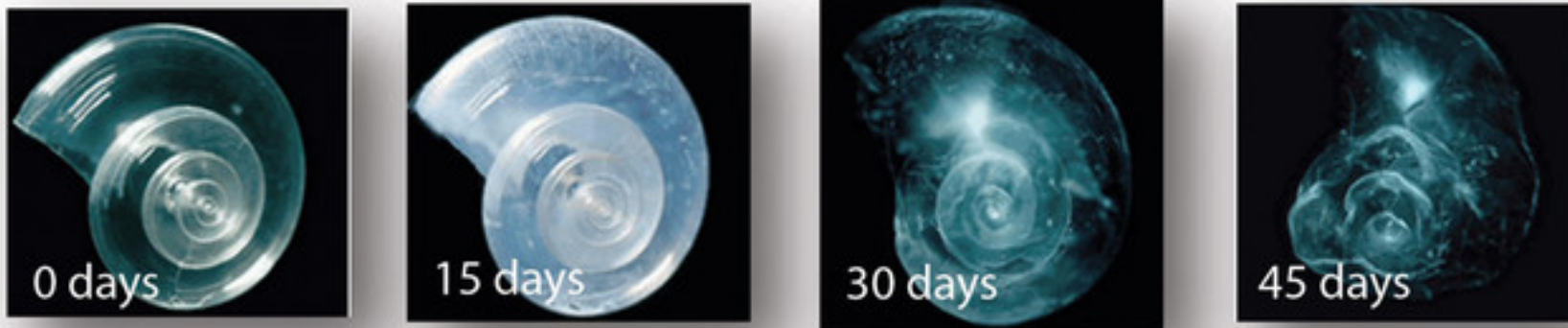


Photo credit: David Liittschwager/National Geographic Stock. Used with permission. All rights reserved. National Geographic Images.

If pteropods disappear, animals that rely on them—everything from small schooling fishes to commercially important species like Pacific salmon—will be affected in ways no one can predict.

(<http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F>)

Present day  
Less acidic



Ocean of 2100  
More acidic

***Ocean acidification will impact different organisms differently. In laboratory experiments, most shelled organisms' shells grow weaker and/or dissolve. But some shelled organisms grow stronger, thicker shells.***

Credit: [www.WHOI.edu](http://www.WHOI.edu)



***In more acidic water:***

Conch shells dissolve; they grow weaker shells

Sea urchin spines fall off and their tests (hard parts) start off weaker

Crustaceans, including some crabs, lobsters and shrimp grew stronger, thicker shells



# Shellfish

- In recent years, the majority of oyster larvae have been dying off in both aquaculture facilities and natural ecosystems on the West Coast of the United States.
- Oysters, like other shellfish, make their shells from carbonate available in ocean water. These larval oyster deaths appear to be linked with naturally occurring upwelling events that bring low pH waters with limited carbonate to nearshore environments.
- Lower pH values occur naturally on the West Coast during upwelling events, but recent observations indicate that CO<sub>2</sub> from human industry is contributing to seasonal drops in available carbonate in the ocean.
- Low pH may be a factor in the current oyster reproductive failure; however, more research is needed to disentangle potential acidification effects from other risk factors (occasional excess freshwater, pathogen increases, or low oxygen in the water).
- Oysters are a \$100 million a year industry

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<http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F>



From top to bottom: freshly harvested oysters from Yaquina Bay, Oregon (Credit: NOAA); plate of shucked oysters (Credit: Claude Covo-Farchi)

# Corals

Corals build rocky skeletons from calcium and carbonate, chemicals found naturally in the ocean. But when oceans become more acidic, acid soaks up the loose carbonate. With less of that critical building block, it's much harder for corals to form a reef. (<http://www.montereybayaquarium.org/climate/science.aspx>)

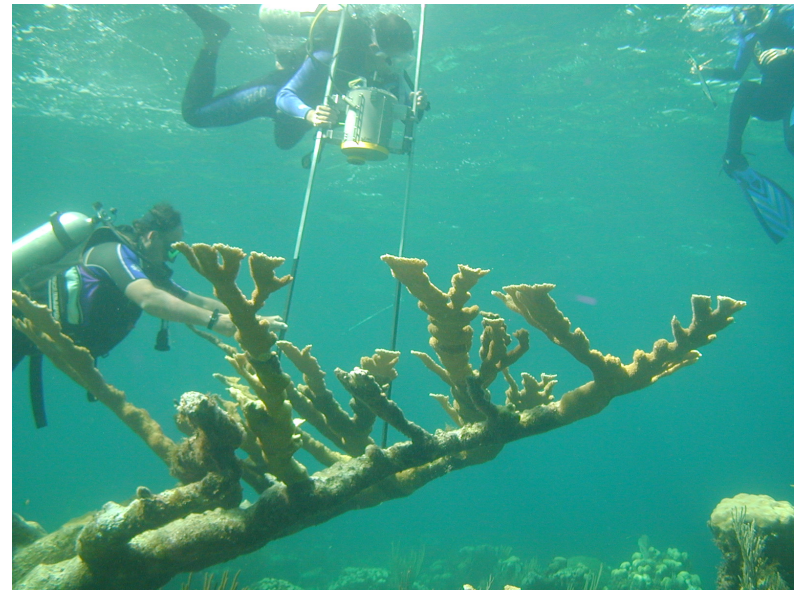


Photo credit: NASA

# Plankton that build shells

Plankton are animals and plant-like organisms that drift with currents. Most plankton are very small and form the base of ocean food webs. Many plankton build shells from calcium **carbonate**. Ocean acidification may have drastic impacts on shell-building plankton, which could impact all ocean food webs.

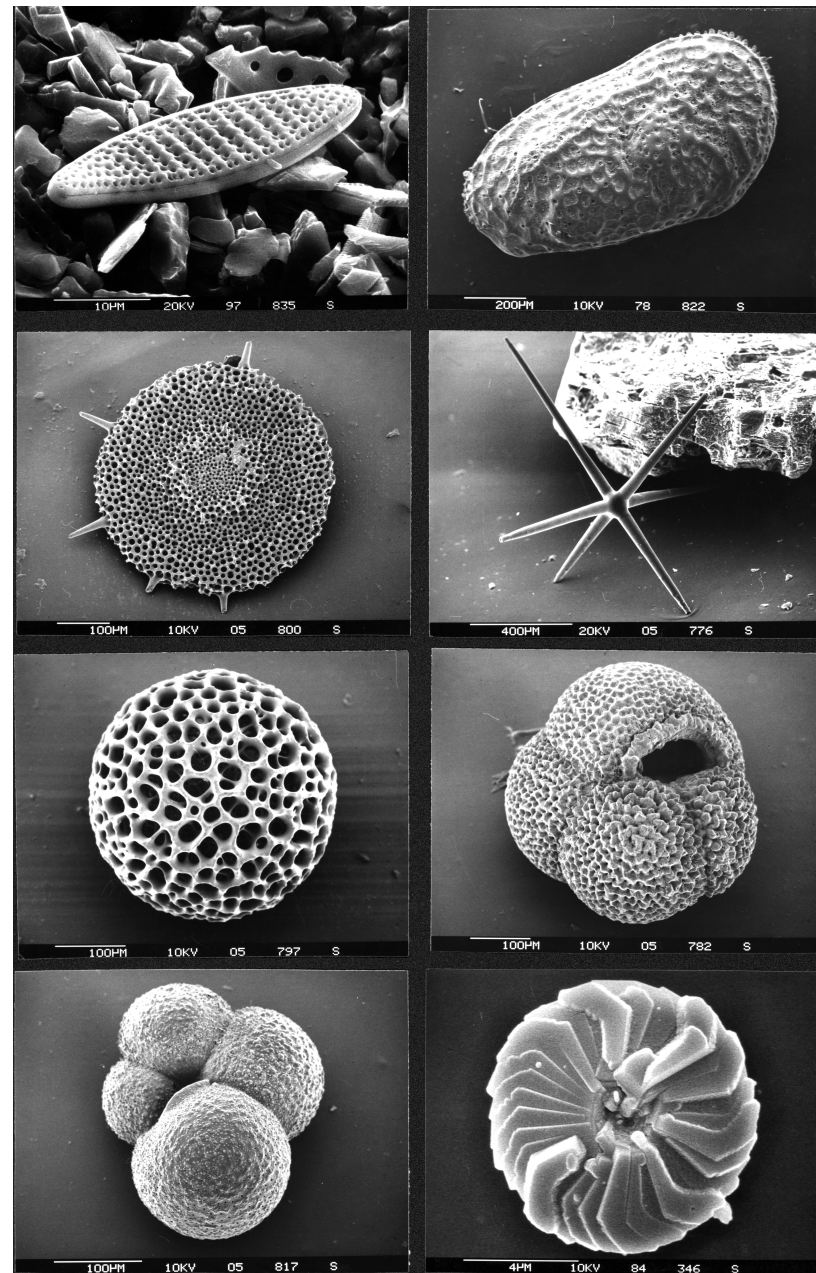


Image credit: Hannes Grobe/AWI

# Jellyfish

Jellyfish thrive in acidifying ocean conditions. Scientists are also starting to learn that they quickly bring carbon from the surface to the deep ocean.

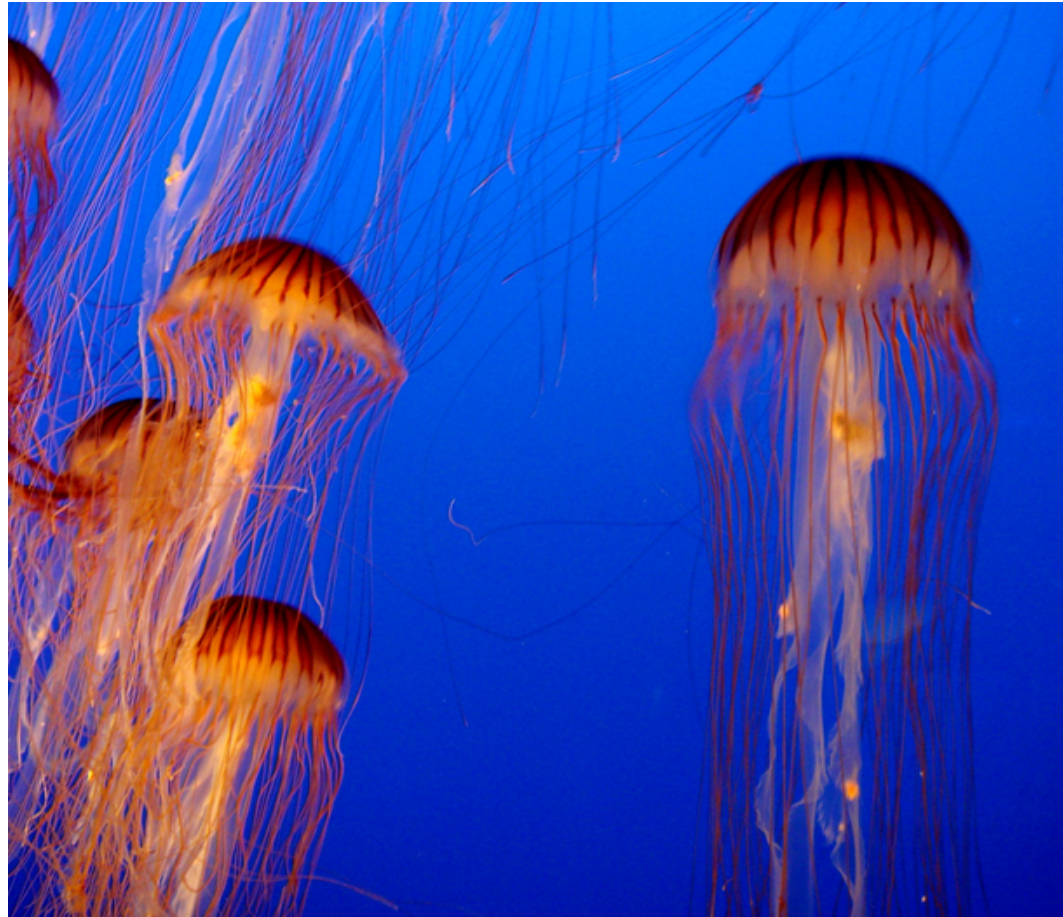
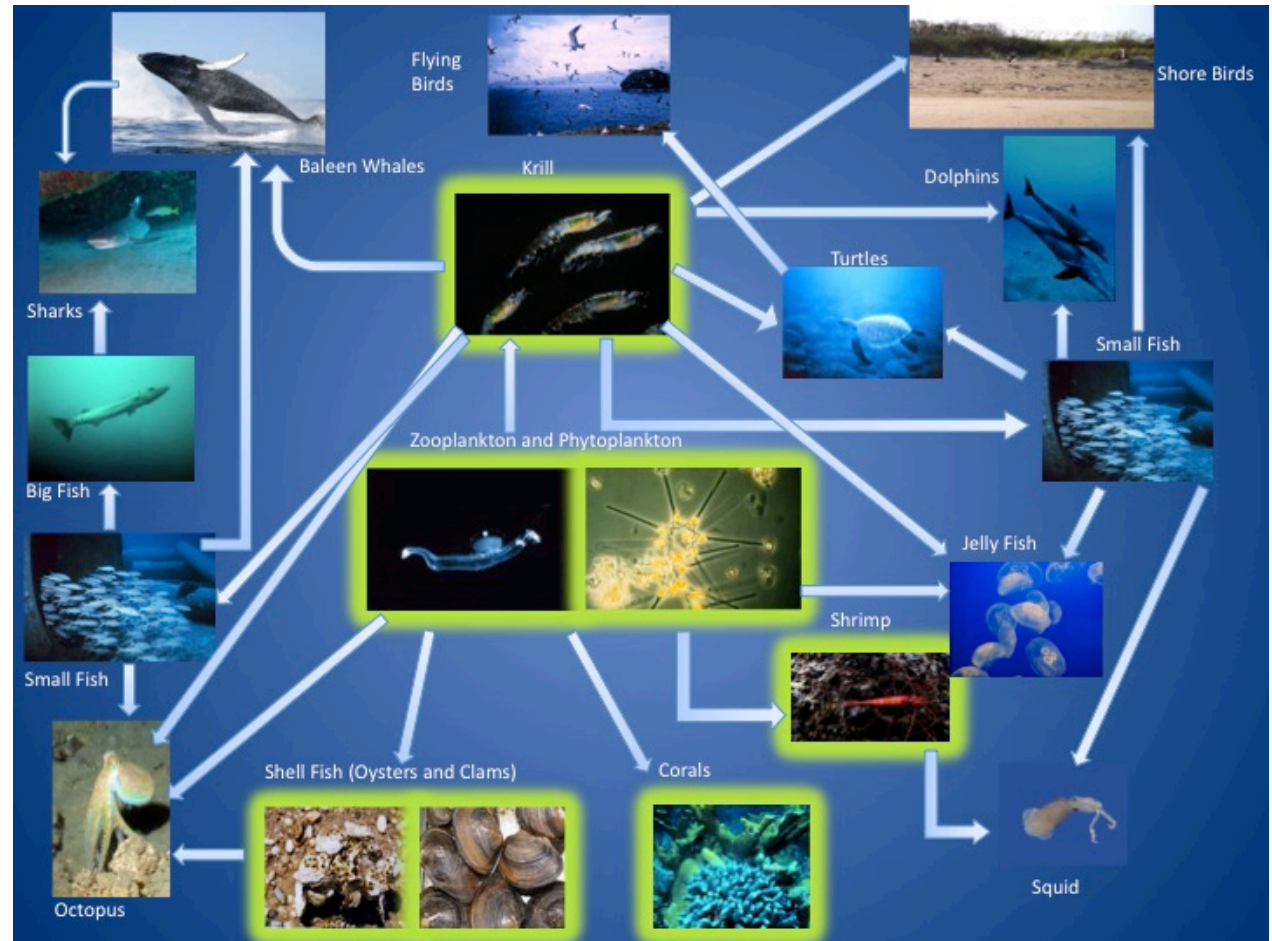


Photo credit: NOAA

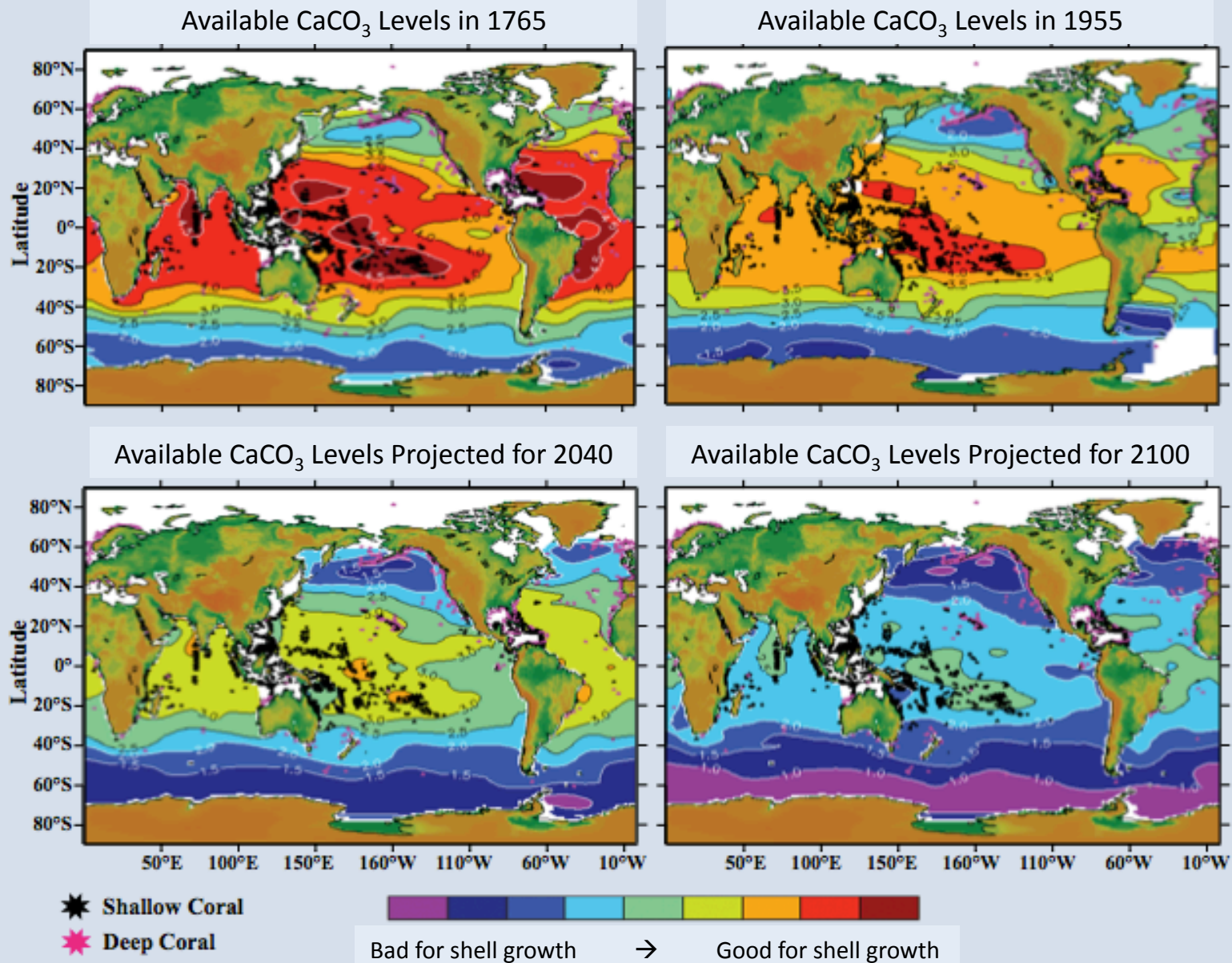
# Ocean food web

Many organisms at the base of ocean food webs are being negatively impacted by ocean acidification. This will have a big impact on all of the other organisms that rely on the impacted organisms for food.



Organisms highlighted in green will be/are being directly affected by ocean acidification. (Photo credits: NOAA)

Where is ocean acidification  
happening?



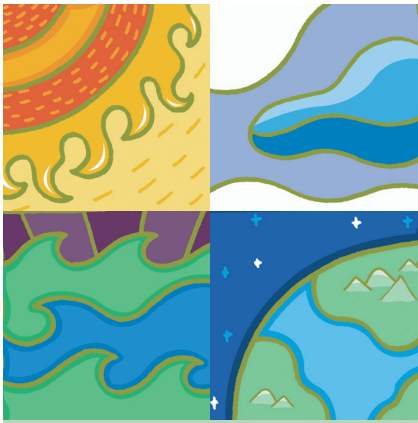
Modified from: Feely, R.A., J. Orr, V.J. Fabry, J.A. Kleypas, C.L. Sabine, and C. Langdon (2009): Present and future changes in seawater chemistry due to ocean acidification. In Carbon Sequestration and Its Role in the Global Carbon Cycle, Brian J. McPherson and Eric T. Sundquist (eds.), AGU Monograph, pp 175-188, Washington D.C. *Estimated aragonite saturation states of the surface ocean for the years 1765, 1995, 2040, and 2100 based on the modeling results of Orr et al. (2005) and a business-as-usual  $\text{CO}_2$  emissions scenario. Distributions of deep-sea corals are from Guinette et al. (2006).*

What can I do about ocean  
acidification?



# What can you do?

<b>Something I can do</b>	<b>What steps do I have to take to make this happen?</b>	<b>When will I start?</b>



# Climate Change & You

## WHAT YOU CAN DO on the road

*The burning of fuels releases carbon dioxide into the atmosphere and contributes to climate change. By taking actions to reduce the amount of fuel you use, you can reduce your greenhouse gas emissions, reduce the nation's dependence on oil, and save money.*

### Resources

Federal Fuel Economy Guide:  
[www.fueleconomy.gov/](http://www.fueleconomy.gov/)

Federal Bicycle and Pedestrian Program: [www.fhwa.dot.gov/environment/bikeped/](http://www.fhwa.dot.gov/environment/bikeped/)

Public Transportation Web site:  
[www.publictransportation.org/](http://www.publictransportation.org/)

EPA's Green Vehicle Guide:  
[www.epa.gov/greenvehicles/](http://www.epa.gov/greenvehicles/)

DOE's Alternative Fueling Station Locator:  
<http://www.afdc.energy.gov/afdc/locator/stations/>

EPA's Climate Change: What You Can Do on the Road Web site:  
[www.epa.gov/climatechange/wycd/road.html](http://www.epa.gov/climatechange/wycd/road.html)



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### 1. Buy smart

Before buying a new or used vehicle (or even renting), check out EPA's Green Vehicle Guide and the jointly run EPA/DOE Fuel Economy Guide. These resources provide information about the emissions and fuel economy performance of different vehicles. The Green Vehicle Guide provides detailed information on emissions (including air pollution and greenhouse gas scores for each model), and the Fuel Economy Guide focuses on fuel efficiency (including side-by-side fuel economy comparisons and a customized fuel cost calculator).

### 2. Drive smart

To improve fuel economy and reduce greenhouse gas emissions, go easy on the brakes and gas pedal, avoid hard accelerations, reduce time spent idling, and unload unnecessary items in your trunk to reduce weight. If you have a removable roof rack and you are not using it, take it off to improve your fuel economy by as much as 5 percent. Use overdrive and cruise control on your car if you have those features.

### 3. Tune your ride

A well-maintained car is more fuel-efficient, produces lower greenhouse gas emissions, is more reliable, and is safer! Keep your car well-tuned, follow the manufacturer's maintenance schedule, and use the recommended grade of motor oil. Also check and replace your vehicle's air filter regularly.

### 4. Check your tires

Check your tire pressure regularly. Under-inflation increases tire wear, reduces your fuel economy by up to 3 percent, and leads to increased emissions of greenhouse gases and air pollutants. If you don't know the correct tire pressure for your vehicle, you can find it listed on the door to the glove compartment or on the driver's side door pillar.

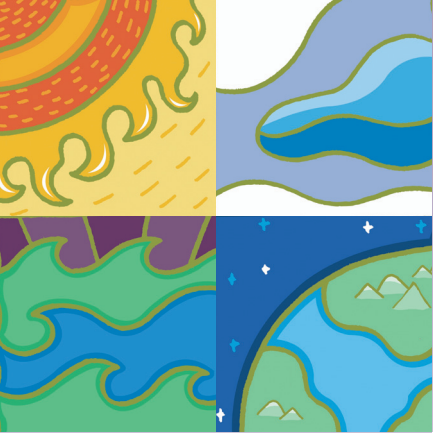
### 5. Give your car a break

Use public transportation, carpool, or walk or bike whenever possible to avoid using your car. Leaving your car at home just two days a week will reduce greenhouse gas emissions by an average of 1,600 pounds per year. Whenever possible, combine activities and errands into one trip. For daily commuting, consider options such as telecommuting (working from home via phone or over the Internet) that can reduce the stress of commuting, reduce greenhouse gas emissions, and save you money.

### 6. Use renewable fuels

Both E85 and biodiesel are renewable fuels that can reduce greenhouse gas emissions from your vehicle. E85 is a fuel blend containing 85 percent renewable ethanol, and can be used in certain vehicles called flex fuel vehicles (FFVs). Biodiesel is a renewable fuel made from agricultural resources such as vegetable oils. DOE's Alternative Fueling Station Locator can help you locate both E85 and biodiesel fuel stations in your area.





# Climate Change & You

## WHAT YOU CAN DO *at home*

*Making a few small changes in your home and yard can lead to big reductions of greenhouse gas emissions and save money.*

### Resources

ENERGY STAR  
Change A Light program:  
[www.energystar.gov/  
changealight](http://www.energystar.gov/changealight)

EPA's Green Power Web site:  
[www.epa.gov/greenpower](http://www.epa.gov/greenpower)

EPA's Reduce, Reuse, and Recycle  
Web site: [www.epa.gov/msw/  
reduce.htm](http://www.epa.gov/msw/reduce.htm)

EPA's WaterSense Web site:  
[http://www.epa.gov/  
watersense/](http://www.epa.gov/watersense/)

EPA's GreenScapes program:  
[www.epa.gov/epaoswer/  
non-hw/green/index.htm](http://www.epa.gov/epaoswer/non-hw/green/index.htm)

EPA's Climate Change: What You  
Can Do at Home Web site:  
[www.epa.gov/climatechange/  
wycd/home.html](http://www.epa.gov/climatechange/wycd/home.html)

EPA's Household Emissions  
Calculator: [www.epa.  
gov/climatechange/wycd/  
calculator/ind\\_calculator.html](http://www.epa.gov/climatechange/wycd/calculator/ind_calculator.html)



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### 1. Change five lights

Replace your five most frequently used light fixtures or the bulbs in them with ENERGY STAR qualified options and you will help the environment while saving about \$60 a year on energy bills. ENERGY STAR qualified lighting provides bright, warm light but uses at least 2/3 less energy than standard lighting, generates 70 percent less heat, and lasts up to 10 times longer.

### 2. Look for ENERGY STAR qualified products

When buying new products, such as appliances for your home, get the features and performance you want AND help reduce greenhouse gas emissions and air pollution. Look for ENERGY STAR qualified products in more than 50 product categories, including lighting, home electronics, heating and cooling equipment, and appliances.

### 3. Heat and cool smartly

Simple steps like cleaning air filters regularly, installing adequate insulation, and having your heating and cooling equipment tuned annually by a licensed contractor can save energy and increase comfort at home, and at the same time reduce greenhouse gas emissions.

### 4. Use green power

Green power is electricity that is generated from renewable energy sources such as wind and the sun that don't contribute to climate change. Consider buying green power or modifying your house to generate your own renewable energy. EPA's Green Power Web site provides information on both options.

### 5. Reduce, reuse, and recycle

Reduce the amount of waste you generate and water you consume whenever possible. Pursue simple water saving actions such as not letting the water run while shaving or brushing teeth. If there is a recycling program in your community, recycle your newspapers, beverage containers, paper, and other goods. Reducing, reusing, and recycling in your home helps conserve energy and reduces pollution and greenhouse gases from resource extraction, manufacturing, and disposal.

### 6. Be green in your yard

Composting your food and yard waste reduces the amount of garbage that you send to landfills and reduces greenhouse gas emissions. EPA's GreenScapes program provides tips on how to improve your lawn or garden while also benefiting the environment.

### 7. Calculate your household's carbon footprint

Use EPA's Personal Greenhouse Gas Emissions Calculator to estimate your household greenhouse gas emissions resulting from energy use, transportation, and waste disposal. This tool helps you understand where your greenhouse gas emissions come from and identify ways to reduce your greenhouse gas emissions.





# Climate Change & You

## WHAT YOU CAN DO *at school*

*Students, educators, and school administrators can all play a key role in reducing greenhouse gas emissions.*

### Resources

EPA's Climate CHECK Tool:  
[www.epa.gov/climatechange/wycd/downloads/ClimateCHECK\\_1.0.zip](http://www.epa.gov/climatechange/wycd/downloads/ClimateCHECK_1.0.zip)

EPA's Global Warming Wheel Card Kit: [www.epa.gov/climatechange/downloads/ActivityKit.pdf](http://www.epa.gov/climatechange/downloads/ActivityKit.pdf)

ENERGY STAR for K-12 School Districts: [www.energystar.gov/index.cfm?c=k12\\_schools.bus\\_schoolsk12](http://www.energystar.gov/index.cfm?c=k12_schools.bus_schoolsk12)

EPA's Reduce, Reuse, and Recycle Web site: [www.epa.gov/msw/reduce.htm](http://www.epa.gov/msw/reduce.htm)

EPA's Climate Change: What You Can Do at School Web site: [www.epa.gov/climatechange/wycd/school.html](http://www.epa.gov/climatechange/wycd/school.html)

EPA's Climate Change Kid's Web site: [www.epa.gov/climatechange/kids/](http://www.epa.gov/climatechange/kids/)



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### 1. Power down your classroom

Remember to turn off computers, lights, and other devices that use energy when no one is in the classroom. Turning off just one 60-watt incandescent bulb that would otherwise burn eight hours a day can save about 1,000 pounds of carbon dioxide over the lifetime of the bulb.

### 2. Learn about climate change science, impacts, and solutions

Explore the many resources available to learn about climate change. Investigate what other schools and organizations are doing to educate their audiences on climate change. EPA's Climate Change Web site provides educational resources on the What You Can Do at School page.

### 3. Calculate your school's carbon footprint

Use EPA's Climate Change Emission Calculator Kit (Climate CHECK) (for high schools) or EPA's Global Warming Wheel Card Kit (for middle schools) to investigate the link between everyday actions at your school, greenhouse gas emissions, and climate change. These interactive tools help students learn about climate change and how to address it.

### 4. Ask your school administrators if your school has earned the ENERGY STAR

The least efficient schools use three times more energy than the best energy performers. By partnering with ENERGY STAR for K-12 program, school districts can serve as environmental leaders in their community, become energy efficient, reduce greenhouse gas emissions, and save 30 percent or more on energy bills.

### 5. Reduce, reuse, and recycle

Recycle school or classroom paper, newspapers, beverage containers, electronic equipment, and batteries. Reducing, reusing, and recycling at school and in the classroom helps conserve energy, minimize pollution, and reduce greenhouse gases. You can reduce, reuse, and recycle at school or in the classroom by using two-sided printing and copying, buying supplies made with recycled content, and recycling used electronics and printer cartridges.





# Climate Change & You

## WHAT YOU CAN DO *at the office*

*Business and home offices use a significant amount of electricity for heating and cooling, lighting, and operating equipment.*

*Here are a number of easy ways to reduce greenhouse gas emissions and help make the air cleaner.*

### Resources

ENERGY STAR:  
[www.energystar.gov](http://www.energystar.gov)

Federal Fuel Economy Guide:  
[www.fueleconomy.gov](http://www.fueleconomy.gov)

EPA's Green Vehicle Guide:  
[www.epa.gov/greenvehicles](http://www.epa.gov/greenvehicles)

EPA's Reduce, Reuse, and Recycle  
Web site: [www.epa.gov/msw/reduce.htm](http://www.epa.gov/msw/reduce.htm)

EPA's Electronics Recycling Web  
site: [www.epa.gov/eCycling](http://www.epa.gov/eCycling)

ENERGY STAR Buildings Web  
site: [www.energystar.gov/buildings](http://www.energystar.gov/buildings)

EPA's Climate Change: What You  
Can Do at the Office Web site:  
[www.epa.gov/climatechange/wycd/office.html](http://www.epa.gov/climatechange/wycd/office.html)



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### 1. Manage office equipment energy use better

Office equipment and electronics use energy even when idle or on stand-by. To save energy and reduce greenhouse gas emissions at work, always activate the power management features on your computer and monitor, unplug laptop power cords when not in use, and turn off equipment and lights at the end of the day. Consider using a power strip that can be turned off when you're done using your computers, printers, wireless routers, and other electronics.

### 2. Look for ENERGY STAR qualified products for the office

When buying new products for your office at work or at home, get the features and performance you want and help reduce emissions of greenhouse gases and air pollutants. Look for ENERGY STAR qualified office equipment, such as computers, copiers, and printers, in addition to more than 50 product categories, including lighting, heating and cooling equipment, and commercial appliances.

### 3. Ask your office building manager if your office building has earned the ENERGY STAR

ENERGY STAR-labeled buildings provide safe, healthy, and productive environments that use about 35 percent less energy than average buildings. Their efficient use of energy also reduces the total operational cost of the building.

### 4. Use less energy for your commute

Switch to public transportation, carpooling, biking, telecommuting, and other innovative ways to save energy and reduce greenhouse gas emissions on your way to and from work. Encourage your employer to offer commuter benefits that address limited or expensive parking, reduce traffic congestion, improve employee recruiting and retention, and minimize the environmental impacts associated with drive-alone commuting. If you do drive, find out the fuel efficiency of your vehicle using EPA's and DOE's Fuel Economy Web site, and make more environmentally informed choices when purchasing your next vehicle by using EPA's Green Vehicle Guide.

### 5. Reduce, reuse, and recycle

Recycle office paper, newspapers, beverage containers, electronic equipment, and batteries. Reducing, reusing, and recycling in your office helps conserve energy, and reduces pollution and greenhouse gas emissions.

You can reduce, reuse, and recycle at the office by using two-sided printing and copying, buying supplies made with recycled content, and recycling used printer cartridges. For your old electronics, investigate leasing programs to ensure reuse and recycling or donate used equipment to schools or other organizations.

