

Appendix B: Lesson Resources

Overview

The materials listed within the lessons include links to suggested articles or websites. Keep in mind that articles and other online resources given as examples often change; links may stop working because they've been moved or deleted. You and your students may wish to explore and seek out additional sources of relevant information. Guide students to be mindful of bias within websites and urge them to use multiple sources, choosing credible sources that are known to check their facts.

The New York Times is cited frequently, as well as United States government websites and other sources. Many articles from commercial publishers are protected by a paywall or are available only to subscribers. After a certain number of articles read per month, non-subscribers aren't allowed to download and read any more. If you and your students are unable to access the suggested articles, here are suggested strategies for finding the information:

- Enter the article title or key words about the topic into a search engine. Articles may be reposted, and alternative reporting on the same topic should be available.
- Check school and local libraries for subscription privileges to periodicals.
- Investigate other media besides periodicals, like blogs, webinars, and video presentations
- Don't forget printed materials – books, magazines, newspapers, etc.

These resources also serve as a bibliography to illustrate where the author obtained information and ideas for the lesson plans, diagrams, and debriefing material.

Find the most recent links for all example data, articles, videos, and audio files [here](#):

http://static.clexchange.org/curriculum/nowwhat/nowwhat_lessonresources_appendixB.pdf

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Chapter One: Sustainability, Systems Thinking, and the Environment

Lesson 1.1 Sustainable Living in Cities

Articles about cities

- [“Designing the City of Tomorrow”](http://www.mcdonough.com/writings/designing-city-tomorrow-2017/)
<http://www.mcdonough.com/writings/designing-city-tomorrow-2017/>
- [“What Happened to the American Boomtown?”](https://www.nytimes.com/2017/12/06/upshot/what-happened-to-the-american-boomtown.html)
Growth patterns in American cities have changed as housing prices climbed.
<https://www.nytimes.com/2017/12/06/upshot/what-happened-to-the-american-boomtown.html>
- [“Sustainable Living”](https://www.bbc.co.uk/bitesize/guides/zqvxdmn/revision/1)
<https://www.bbc.co.uk/bitesize/guides/zqvxdmn/revision/1>
Concise guide to attributes of sustainable communities.

Lesson 1.2 Transportation - Moving Efficiently

No additional examples

Lesson 1.3 Electrical Energy

Graphs of electricity use over time

- [Energy data from The World Bank](http://www.worldbank.org/en/topic/energy)
<http://www.worldbank.org/en/topic/energy>

General information about the difficulty of moving away from fossil fuels

- [“The Long Slow Rise of Solar and Wind”](http://vaclavsmil.com/wp-content/uploads/scientificamerican0114-521.pdf)
Other writing and videos by and about Vaclav Smil provide summaries of his ideas concerning the slow pace of energy transformation.
<http://vaclavsmil.com/wp-content/uploads/scientificamerican0114-521.pdf>

Articles about specific projects for electrical energy

- [“The Power Plants That May Save a Park, and Aid a Country”](https://www.nytimes.com/2017/08/30/business/congo-power-plants-poaching.html)
Hydroelectricity brings economic development to the Democratic Republic of Congo, allowing conservation efforts to move forward.
<https://www.nytimes.com/2017/08/30/business/congo-power-plants-poaching.html>
- [“Hydropower for the habitat of mountain gorillas”](https://www.climatepartner.com/en/carbon-offset-projects/hydropower-virunga-dr-congo)
<https://www.climatepartner.com/en/carbon-offset-projects/hydropower-virunga-dr-congo>
Shows how renewable energy projects help protect the natural environment.
- [“Elon Musk Just Built a Battery the Size of a Football Field in less than 100 Days”](http://theweek.com/speedreads/740735/elon-musk-just-built-battery-size-football-field-less-than-100-days)
Short article contains video
<http://theweek.com/speedreads/740735/elon-musk-just-built-battery-size-football-field-less-than-100-days>
- [“Chile’s Energy Transformation is Powered by Wind, Sun and Volcanoes”](https://www.nytimes.com/2017/08/12/world/americas/chile-green-energy-geothermal.html)
Includes video
<https://www.nytimes.com/2017/08/12/world/americas/chile-green-energy-geothermal.html>
- [“Good news from Chile”](https://energytransition.org/2021/05/good-news-from-chile/)
<https://energytransition.org/2021/05/good-news-from-chile/>
Chile moves toward cleaner energy production.
- [“The \\$3 Billion Plan to Turn Hoover Dam Into a Giant Battery”](https://www.nytimes.com/interactive/2018/07/24/business/energy-environment/hover-dam-renewable-energy.html)
<https://www.nytimes.com/interactive/2018/07/24/business/energy-environment/hover-dam-renewable-energy.html>
- [“Hoover Dam as giant battery? The hurdles are more legal than technical.”](https://deeply.thenewhumanitarian.org/water/articles/2018/09/21/hover-dam-as-giant-battery-the-hurdles-are-more-legal-than-technical)
<https://deeply.thenewhumanitarian.org/water/articles/2018/09/21/hover-dam-as-giant-battery-the-hurdles-are-more-legal-than-technical>
Pumping water upstream may allow Hoover Dam to store energy.
- [“The Biggest, Strangest ‘Batteries’”](https://www.nytimes.com/2017/06/03/business/energy-environment/biggest-batteries.html)
Technologies for storing energy
<https://www.nytimes.com/2017/06/03/business/energy-environment/biggest-batteries.html>
- [“Electricity Storage”](#)

<https://www.epa.gov/energy/electricity-storage>

- “How can we store renewable energy? 4 technologies that can help.”
<https://www.weforum.org/agenda/2021/04/renewable-energy-storage-pumped-batteries-thermal-mechanical/>

Lesson 1.4 Recycling

Articles, videos, or research materials about recycling

- [Recycling in auto industry](https://www.nytimes.com/2017/12/21/business/car-companies-recycling.html)
<https://www.nytimes.com/2017/12/21/business/car-companies-recycling.html>
- “From grave to green: The fascinating world behind car recycling”
<https://gasp-pgh.org/2021/04/12/from-grave-to-green-the-fascinating-world-behind-car-recycling/>
- [Recycling basics](https://www.epa.gov/recycle/recycling-basics)
<https://www.epa.gov/recycle/recycling-basics>
- [Problems with plastic recycling \[Opinion video\]](https://www.nytimes.com/2019/12/09/opinion/recycling-myths.html)
<https://www.nytimes.com/2019/12/09/opinion/recycling-myths.html>
- “Plastic Recycling is an Actual Scam” Video from “Climate Town”
<https://www.youtube.com/watch?v=PJnJ8mK3Q3g>
- [Examples of recycling ideas that work](https://www.goodnewsnetwork.org/tag/recycling/)
<https://www.goodnewsnetwork.org/tag/recycling/>

Lesson 1.5 Environmental History

No additional examples

Lesson 1.6 Modeling Population

Lesson plans from *The Shape of Change* - Note: “The Mammoth Game” requires dice

- “The In and Out Game” lesson plan
<http://static.clexchange.org/ftp/documents/x-curricular/CC2010-11Shape1InAndOutSF.pdf>
- “The In and Out Game” simulation
http://www.clexchange.org/curriculum/shapeofchange/soc_1_InOut.asp
- “Making Friends” lesson plan
<http://static.clexchange.org/ftp/documents/x-curricular/CC2010-11Shape2MakingFriendsSF.pdf>
- “Making Friends” simulation
http://www.clexchange.org/curriculum/shapeofchange/soc_2_Friendship.asp
- “The Mammoth Game” lesson plan
<http://static.clexchange.org/ftp/documents/x-curricular/CC2010-11Shape3MammothGameSF.pdf>

Population simulations from Creative Learning Exchange

- “Rabbits, Rabbits, and More Rabbits” activity and simulation
http://www.clexchange.org/curriculum/complexsystems/oscillation/Oscillation_PopulationC.asp
- “Why are there not More Elephants?” activity and simulation
http://static.clexchange.org/ftp/documents/x-curricular/CC2012_Oscillations3BElephantsPopulationDynamics.pdf

Modeling simulation activity

- “Bumbles and Woofs”
http://static.clexchange.org/ftp/documents/x-curricular/CC2018_BumblesWoofs.pdf

Chapter Two: Land

Lesson 2.1 A Parable of Environmental Disaster

Lesson plans

- “Lessons From the Lorax: Using Graphs to Study Change “ and “Studying the Lorax with Feedback Loops”
http://static.clexchange.org/ftp/documents/x-curricular/CC2012_TheLorax.pdf

Lesson 2.2 The Tragedy of the Commons

Explanations and examples of the Tragedy of the Commons archetype

- Primary source - [“The Tragedy of the Commons”](http://static.clexchange.org/ftp/documents/x-curricular/CC1968_TragedyofCommons.pdf) by Garrett Hardin – long, difficult, and technical
- Find summaries, videos, etc. at student level via internet search.

Example of [video summary](#):

<https://ed.ted.com/lessons/what-is-the-tragedy-of-the-commons-nicholas-amendolare#review>

Information about Bears Ears National Monument

- [Fact sheet for Bears Ears](https://www.fs.fed.us/sites/default/files/bear-ears-fact-sheet.pdf)
- Department of the Interior interim [report](https://www.scribd.com/document/351066813/Interim-Report-EO-13792) about reducing the size of Bears Ears Monument
- Summary at the beginning can be enough information for this activity
- News reports about reduction plan for Bears Ears
 - Report 1: <https://www.cbsnews.com/news/trump-bears-ears-national-monument-reduction-plan-utah/>
 - Report 2: <https://news.nationalgeographic.com/2017/12/trump-shrinks-bears-ears-grand-staircase-escalante-national-monuments/>
 - Report 3: <https://www.pbs.org/newshour/politics/biden-to-review-trumps-changes-to-national-monuments>
 - Report 4: <https://apnews.com/article/donald-trump-joe-biden-utah-environment-and-nature-b763897fc47136339bd12360a90079c0>
 - Report 5: <https://www.washingtonpost.com/climate-environment/2021/10/07/bears-ears-biden-monument/>

Suggestion for reading at end of activity

- Donella Meadows [“The Tragedy of the Commons on Georges Bank, and Elsewhere”](http://www.donellameadows.org/archives/the-tragedy-of-the-commons-on-georges-bank-and-elsewhere/)
Spoiler alert – the author describes the “Fishbanks” simulation, so if you plan on playing that in class, only distribute the first part of the article or save to read after playing Fishbanks,” Activity 4.5.

Lesson 2.3 Protecting the Land During the Anthropocene Epoch

Geologic timelines and information about the Anthropocene Epoch

- [“When Did the Anthropocene Begin?”](https://projects.katiepeek.com/Welcome-to-the-Anthropocene) Scientific American September 2016 p.36

Behavior over time graphs showing the human effects on the Earth, marking a new geologic epoch.

- [“Anthropocene”](https://www.nationalgeographic.org/encyclopedia/anthropocene/)
- [“Welcome to the Anthropocene”](http://www.anthropocene.info/) website with video

Articles about environmental threats to land ecosystems

Five Examples:

- [“A Vigilant Rwanda is Winning the War on Plastic Bags”](https://www.seattletimes.com/nation-world/a-vigilant-rwanda-is-winning-the-war-on-plastic-bags/)
African nation outlaws plastic bags, imposing strict penalties.
- [“Brazil Wavers on Environment, and Wetlands Start to Wither”](https://www.nytimes.com/2017/12/23/world/americas/brazil-pantanal-wetlands-michel-temer.html)
Development encroaches into forested land.
- [“3 ways Brazil’s environmental decisions affect the world”](https://www.conservation.org/blog/3-ways-brazils-environmental-decisions-impact-the-world)

Brief description of environmental challenges in Brazil

- “[Monsanto’s Weed Killer, Dicamba, Divides Farmers](https://www.nytimes.com/2017/09/21/business/monsanto-dicamba-weed-killer.html)” New York Times 9/22/2017
<https://www.nytimes.com/2017/09/21/business/monsanto-dicamba-weed-killer.html>
Herbicide spreads onto neighboring fields, harming non-resistant crops.
- “[Pesticide police, overwhelmed by Dicamba complaints, ask EPA for help](https://www.npr.org/sections/thesalt/2020/02/06/800397488/pesticide-police-overwhelmed-by-dicamba-complaints-ask-epa-for-help)”
<https://www.npr.org/sections/thesalt/2020/02/06/800397488/pesticide-police-overwhelmed-by-dicamba-complaints-ask-epa-for-help>
Pesticide sprayed on fields may spread to other locations. Includes link to audio
- “[Vikings Razed the Forests. Can Iceland Regrow Them?](https://www.nytimes.com/interactive/2017/10/20/climate/iceland-trees-reforestation.html)”
<https://www.nytimes.com/interactive/2017/10/20/climate/iceland-trees-reforestation.html>
Efforts to restore areas that were deforested over one thousand years ago.
- “[Iceland tries to bring back trees razed by the Vikings](https://phys.org/news/2019-07-iceland-trees-razed-vikings.html)”
<https://phys.org/news/2019-07-iceland-trees-razed-vikings.html>
- “[The Birds and the Bees](https://foe.org/birds-bees-new-research-implicates-pollinator-toxic-pesticides-hummingbird-declines/)”
<https://foe.org/birds-bees-new-research-implicates-pollinator-toxic-pesticides-hummingbird-declines/>
Pesticides imperil hummingbirds and other pollinators.

Lesson 2.4 Cities and Urban Planning

Articles and videos about generic structures of cities compared to other systems

- “[A Physicist Solves the City](https://www.nytimes.com/2010/12/19/magazine/19Urban_West-t.html)” full article
https://www.nytimes.com/2010/12/19/magazine/19Urban_West-t.html
[Summary of “A Physicist Solves the City”](#)
- Video – “[The Surprising Math of Cities and Corporations](https://www.ted.com/talks/geoffrey_west_the_surprising_math_of_cities_and_corporations)”
https://www.ted.com/talks/geoffrey_west_the_surprising_math_of_cities_and_corporations
- Shorter video – “[Geoffrey West Explains Universal Scaling](https://www.youtube.com/watch?v=EXpOOg9fMHY)”
<https://www.youtube.com/watch?v=EXpOOg9fMHY>
- [Speech](http://static.clexchange.org/ftp/documents/roadmaps/RM8/D-4434-1.pdf) by Jay Forrester about generic structures in complex systems
<http://static.clexchange.org/ftp/documents/roadmaps/RM8/D-4434-1.pdf>
pp. 14 - 18

Lesson 2.5 Studying Rapa Nui

Videos

- “[The Fate of Easter Island](http://www.pbs.org/wgbh/nova/earth/fate-of-easter-island.html)”
<http://www.pbs.org/wgbh/nova/earth/fate-of-easter-island.html>

Articles about the history of Rapa Nui

- “[The Lessons of Easter Island](http://blackville.nbed.nb.ca/sites/blackville.nbed.nb.ca/files/noteattach/y2016/Mar/mar.3_the_lessons_of_easter_island_reading.pdf)” by Clive Ponting
http://blackville.nbed.nb.ca/sites/blackville.nbed.nb.ca/files/noteattach/y2016/Mar/mar.3_the_lessons_of_easter_island_reading.pdf
- “[What Really Happened to the People of Easter Island](https://www.sbs.com.au/guide/article/2018/02/06/what-really-happened-people-easter-island)”
<https://www.sbs.com.au/guide/article/2018/02/06/what-really-happened-people-easter-island>
- “[What Happened on Easter Island – A New \(Even Scarier\) Scenario](http://www.npr.org/sections/krulwich/2013/12/09/249728994/what-happened-on-easter-island-a-new-even-scarier-scenario)”
<http://www.npr.org/sections/krulwich/2013/12/09/249728994/what-happened-on-easter-island-a-new-even-scarier-scenario>
- “[The Fate of Easter Island](http://www.pbs.org/wgbh/nova/earth/fate-of-easter-island.html)”
<http://www.pbs.org/wgbh/nova/earth/fate-of-easter-island.html>

Articles about modern times on Rapa Nui

- “[Rapa Nui is Remote. And Then There’s Its Isolated North Coast](https://www.nytimes.com/2016/11/13/travel/rapa-nui-easter-island-north-coast.html)”
<https://www.nytimes.com/2016/11/13/travel/rapa-nui-easter-island-north-coast.html>
- “[Rapa Nui and other fragile lands rally against tourism pollution](https://www.pbs.org/independentlens/blog/rapa-nui-and-other-fragile-lands-rally-against-tourism-pollution/)”
<https://www.pbs.org/independentlens/blog/rapa-nui-and-other-fragile-lands-rally-against-tourism-pollution/>
- “[Easter Island is Eroding](#)”

<https://www.nytimes.com/interactive/2018/03/14/climate/easter-island-erosion.html>

- “Easter Island limiting tourism as erosion puts its famous statues at risk”

<https://www.thetravel.com/easter-island-limiting-tourism/>

Challenges for Rapa Nui and other lands concerning development

Modeling lesson plans

- “Easter Island Population Model” Lesson plan from Diana Fisher
<http://static.clexchange.org/ftp/documents/social-studies/SS1994-09EasterIslandPop.pdf>
- *Model Mysteries* Chapter 5 “The Disappeared” Lesson plan by Anne LaVigne and Lees Stuntz
<http://static.clexchange.org/ftp/documents/modelmysteries/Model%20Mysteries%20Book.pdf>

Chapter Three: Air

Lesson 3.1 Protecting the Atmosphere

Background information

- Video - “How Does Air Pollution Affect Health?”
<https://blogs.scientificamerican.com/plugged-in/video-how-does-air-pollution-affect-health/>
- Map of pollution sources - “The Top-22 Air Polluters Revealed”
<https://www.scientificamerican.com/article/the-top-22-air-polluters-revealed/>

Articles about air pollution

- “Smothered by Smog, Polish Cities Rank Among Europe’s Dirtiest”
<https://www.nytimes.com/2018/04/22/world/europe/poland-pollution.html>
Burning coal causes air pollution in Poland. The government has implemented programs to modernize heating systems.
- “Poland launches “clean air” program”
<https://www.trade.gov/market-intelligence/poland-launches-clean-air-program>
- “Ship Exhaust Makes Oceanic Thunderstorms More Intense”
<https://news.agu.org/press-release/ship-exhaust-makes-oceanic-thunderstorms-more-intense/>
- “New Delhi, Its Air Toxic, Declares a Health Emergency and Closes Schools”
<https://www.nytimes.com/2019/11/01/world/asia/delhi-pollution-health-emergency.html>
Dangerous air pollution creates a serious health crisis in India’s capital city.
- “Delhi, the world’s most air polluted capital, fights back”
<https://www.brookings.edu/blog/future-development/2020/11/25/delhi-the-worlds-most-air-polluted-capital-fights-back/>
- “Popular National Parks Experience as Much Ozone Pollution as Major Cities”
<https://www.pbs.org/newshour/nation/popular-national-parks-experience-as-much-ozone-pollution-as-major-cities>
or <https://www.scientificamerican.com/article/visiting-a-national-park-this-summer-hold-your-breath/>
- Connection to plastic pollution (not diagrammed in lesson plan)
“Where’s Airborne Plastic? Everywhere, Scientists Find.”
<https://www.nytimes.com/2020/06/11/climate/airborne-plastic-pollution.html>
Scientists have discovered airborne microplastics exist even in remote parts of the world.
- Opinion “You’re Probably Inhaling Microplastics Right Now”
<https://www.nytimes.com/2020/06/25/opinion/plastic-air-pollution.html>
Environmental scientist warns that we must reduce the amount of plastic, which has become ubiquitous in modern civilization.
- “Thousands of Tons of Microplastics are Falling from the Sky”
<https://www.scientificamerican.com/article/thousands-of-tons-of-microplastics-are-falling-from-the-sky/>

3.2 Climate Change

Background information about climate change

- Frontline video “Climate of Doubt”
<https://www.pbs.org/wgbh/frontline/film/climate-of-doubt/>

Documentary explores how organizations spread doubt about climate change.

- Video: “How Global Warming Stacks Up”
https://climate.nasa.gov/climate_resources/144/video-how-global-warming-stacks-up/
- Home page of climate and energy resources
<https://cleanet.org/index.html>
- Video “Climate Change Basics”
<https://www.youtube.com/watch?v=ScX29WBJI3w#at=81>
- Set of introductory lessons
<http://www.explainingclimatechange.ca>

Audio and links to additional articles

- “Time Is Running Out To Control Climate Change, U.N. Report Says”
<http://www.wbur.org/onpoint/2018/10/09/climate-change-un>
- “Here’s How Far the World Is From Meeting Its Climate Goals”
<https://www.nytimes.com/interactive/2017/11/06/climate/world-emissions-goals-far-off-course.html>

Graphs and analysis of CO2 emissions around the world from 1990 projected to 2030.

- “Climate Change is Complex. We’ve Got Answers to Your Questions.”
<https://www.nytimes.com/interactive/2017/climate/what-is-climate-change.html>

Overview of climate change facts presented in a question-and-answer format.

Articles about wildfires

- “Fire on the Mountain: 2 Forests Offer Clues to Yellowstone’s Fate in a Warming World”
<https://www.nytimes.com/2017/09/13/climate/yellowstone-western-fires-in-two-forests.html>
Comparing two areas of forest that burned in Yellowstone National Park in 2000
- “Resilience of Yellowstone’s forests tested by unprecedented fire”
<https://news.wisc.edu/resilience-of-yellowstones-forests-tested-by-unprecedented-fire/>
Scientists study changing conditions involving forest fires.
- Book review podcast “The Fire Next Time”
<https://www.nytimes.com/2017/12/29/books/review/the-fire-next-time.html>
Text of book reviews discussed in podcast.
- “Are American West’s Wildfires Inevitable?”
<https://www.nytimes.com/2017/12/12/books/review/megafire-michael-kodas-american-wildfires.html>
Review of two books about the increasing size and threats of wildfires.
- “Why the American west’s ‘wildfire season’ is a thing of the past - visualized”
<https://www.theguardian.com/world/2021/oct/10/wildfire-climate-emergency-us-west>
Climate change is suspected as a cause of increasing fire occurrence.
- “An Uncertain Future”
<https://www.npca.org/articles/1622-an-uncertain-future>
How climate change is affecting Mesa Verde National Park.
- “Australia’s Wildfires Have Now Been Linked to Climate Change”
<https://www.sciencenews.org/article/australia-wildfires-climate-change>

Lesson 3.3 - Bathtub Thinking

Materials to introduce stocks and flows

- Lessons 1 and 2 from *The Shape of Change* are helpful for beginners and for review.
http://www.clexchange.org/cleproducts/shapeofchange_lessons.asp
- These [worksheets](#) from starting lessons in system dynamics (p. 11, p.16) help students distinguish between stocks and flows
<http://static.clexchange.org/ftp/documents/system-dynamics/SD1996-03GetStarted5Lessons.pdf>
- Large problem set of [stock/flow exercises](#) with answer sheet attached. Look through the set and choose any pages for students that you think are useful:
<http://static.clexchange.org/ftp/documents/x-curricular/CC2013>

[EverydayStocksandFlowsProblemSets.pdf](#)

The Department Store Task

- [Academic paper](#). Third page contains the problem. Do not reveal the answer, which is in the text on that page. Only reproduce the graph and questions for distribution to students:
<http://jsterman.scripts.mit.edu/docs/Cronin-2009-WhyDontWellEducated.pdf>
- Department Store Problem is on p.48 of this paper:
[“Why don’t well-educated adults understand accumulation? A challenge to researchers, educators, and citizens.”](#)
<http://web.mit.edu/jsterman/www/CroninGonzalezStermann061210.pdf>
- [Blog post](#) including problem, hints, and answers. Be sure not to reveal solution until students have given their answers:
<http://www.generationaldynamics.com/pg/ww2010.i.macro061025.sterman.htm>

Diagramming atmospheric CO₂ as a stock/flow diagram

- [Bathtub dynamics – Atmospheric stock/flow diagram of CO₂](#)
<https://climateinteractive.files.wordpress.com/2009/11/ngbathtub.jpg>

3.4 The Carbon Cycle

Carbon cycle and greenhouse gas information

- [Atmospheric carbon dioxide](#)
<https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide>
- [Composition of greenhouse gas emissions](#)
<https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>
- Carbon cycle diagrams – multiple options available via web search
[“Basics of Carbon Cycle and the Greenhouse Effect”](#)
https://www.esrl.noaa.gov/gmd/education/carbon_toolkit/basics.html
- Copy of [Keeling Curve](#)
<https://scripps.ucsd.edu/programs/keelingcurve/>
<http://www.esrl.noaa.gov/gmd/ccgg/trends/graph.html>
- [Diagrams including pre-Industrial Revolution](#)
<http://www.ems.psu.edu/~radovic/COxTask3A.html>
- Explanations of Keeling Curve available via web search
[Example: https://www.britannica.com/science/Keeling-Curve](#)

Instructions for building diagrams and models

- From Cornell University:
http://www.geo.cornell.edu/eas/education/course/descr/EAS302/302_06Lab11.pdf
- [Carbon Cycle Model](#): <http://mvhs.shodor.org/mvhsproj/carbon/carbon.html>
- [Video of a bathtub simulation](#)
<https://www.youtube.com/watch?v=7Nt0v4YAAVg&t=57s>
- [En-ROADS climate simulator](#)
<https://www.climateinteractive.org/tools/en-roads/>

3.5 - The Greenhouse Effect

Media about the greenhouse effect

- [Article about greenhouse effect](#)
<https://climatekids.nasa.gov/greenhouse-effect/>
- Video [“The Greenhouse Effect”](#) from US Environmental Protection Agency
<https://www.youtube.com/watch?v=VYMjSule0Bw>
- [Audio](#) about methane as a greenhouse gas
<http://www.npr.org/templates/story/story.php?storyId=14288215>
Scientist measures methane escaping from lakes in the far northern regions.

3.6 Global Warming

Historical behavior over time graphs displaying temperature and CO₂ levels

- <http://climate.nasa.gov/>
- https://earthobservatory.nasa.gov/Features/GISTemperature/giss_temperature2.php

Introductory videos about global warming

- Video (Optional) “An Inconvenient Truth” 2006 (Full length about 1.5 hours)
Sequel released 2017
- [Five minute summary of global warming by Al Gore](https://www.youtube.com/watch?v=jOKqYtRDGak)
<https://www.youtube.com/watch?v=jOKqYtRDGak>
- “Scientist Measures an Overlooked Greenhouse Gas” NPR article and video
Also linked in Lesson 3.5 The Greenhouse Effect
<https://www.npr.org/templates/story/story.php?storyId=14288215>

Articles about effects of global warming

- “The Top Ten Global Warming ‘Skeptic’ Arguments Answered”
<https://www.theguardian.com/environment/climate-consensus-97-per-cent/2014/may/06/top-ten-global-warming-skeptic-arguments-debunked>
- “It’s Not Your Imagination. Summers Are Getting Hotter”
<https://www.nytimes.com/interactive/2017/07/28/climate/more-frequent-extreme-summer-heat.html>
- “2018 is Shaping Up to be the Fourth-Hottest Year. Yet We’re Still Not Prepared for Global Warming.”
<https://www.nytimes.com/2018/08/09/climate/summer-heat-global-warming.html>
- “2020 Tied for Warmest Year on Record, NASA Analysis Shows”
<https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows>
- “A Historic Heat Wave Roasts Siberia”
<https://www.nytimes.com/2020/06/25/world/europe/siberia-heat-wave-climate-change.html>
- “Siberian heatwave of 2020 almost impossible without climate change”
<https://www.worldweatherattribution.org/siberian-heatwave-of-2020-almost-impossible-without-climate-change/>
- “How We Know It Was Climate Change”
<https://www.nytimes.com/2017/12/29/opinion/sunday/climate-change-global-warming.html>
Scientist connects destructive weather events to climate change. Includes behavior over time graphs.
- “Arctic Sea Ice Missed a Record Low This Winter. Barely.”
<https://www.nytimes.com/interactive/2018/03/23/climate/arctic-ice-maximum.html>
- “Current State of Sea Ice Cover”
<https://earth.gsfc.nasa.gov/cryo/data/current-state-sea-ice-cover>
Descriptions, graphs, and maps of Arctic sea ice
- “As Earth Warms the Diseases That May Lie Within Permafrost Become a Bigger Worry”
<https://www.scientificamerican.com/article/as-earth-warms-the-diseases-that-may-lie-within-permafrost-become-a-bigger-worry/>
- “Portugal Forest Fires Worsen, Fed by Poor Choices and Inaction”
<https://www.nytimes.com/2017/08/12/world/europe/portugal-forest-fires-pedrogao-grande.html>
- “How to live with mega-fires? Portugal’s feral forests may hold the secret”
<https://www.nationalgeographic.com/science/article/how-to-live-with-mega-fires-portugal-forests-may-hold-secret>
Long, informative article about how changing climate and human activity contributes to fire intensity.
- “How Global Warming Fueled Extreme Weather Events”
<https://www.nytimes.com/2017/12/14/climate/climate-extreme-weather-attribution.html>
2016 was the hottest year recorded to date. Scientists linked these five extreme weather events

(among others) to global warming:

- ◇ record temperatures around the world
- ◇ coral bleaching
- ◇ drought in Africa
- ◇ wildfires in North America
- ◇ warm 'blob' in the Pacific Ocean
- ["Wild Weather"](#)
<https://www.nationalgeographic.com/climate-change/how-to-live-with-it/weather.html>
How extreme weather events are affecting humans.
- ["In a Warming California, a Future of More Fire"](#)
<https://www.nytimes.com/2017/12/07/climate/california-fires-warming.html>
- ["What climate change means for California"](#)
<https://www.epa.gov/sites/default/files/2016-09/documents/climate-change-ca.pdf>
- ["Climate Change is Fueling Wildfires Nationwide, New Report Warns"](#)
<https://www.nytimes.com/interactive/2018/11/27/climate/wildfire-global-warming.html>
- ["In Peru's Deserts, Melting Glaciers Are a Godsend \(Until They're Gone\)"](#)
<https://www.nytimes.com/2017/11/26/world/americas/peru-climate-change.html>
Melting glaciers have been providing water for farming in arid regions. But the glaciers may soon be gone.
- ["Vanishing Glaciers: The Future of Water in Peru's High Andes"](#)
<https://news.climate.columbia.edu/2018/06/12/vanishing-glaciers-future-water-perus-high-andes/>
Retreating glaciers reduce water supplies for people living in the Andes.
- ["What Climate Scientists Want you to See in the Floodwaters"](#)
<https://www.nytimes.com/2017/09/02/opinion/climate-hurricanes-flooding-harvey.html>
Scientists explain the increasing number and size of floods and describe how people must adjust to them.
- ["Extreme flooding to increase as temperatures rise, study finds"](#)
<https://www.washingtonpost.com/weather/2021/09/13/extreme-flooding-increase-climate-change/>

3.7 Examining Climate Models

Climate background info

- [Gapminder home page](#)
<http://www.gapminder.org/>
- EPA webpages
 - ◇ <https://www.epa.gov/climate-indicators>
 - ◇ <https://science2017.globalchange.gov/chapter/executive-summary/>
 - ◇ <http://scenarios.globalchange.gov/>

Climate Interactive simulation website

Be sure to register and familiarize yourself with the program ahead of time.

- [Climate Interactive home page](#)
<https://www.climateinteractive.org/>
- [Climate Interactive Climate Summit](#)
<https://www.climateinteractive.org/world-climate-simulation/>

Chapter Four: Water

4.1 Protecting Water

Articles or research material about water

Drying waterways

- ["In a Warming West, the Rio Grande is Drying Up"](#)
<https://www.nytimes.com/interactive/2018/05/24/climate/dry-rio-grande.html>

Drought reduces water available to people who depend upon the Rio Grande River.

- [“Diverted, drained, and dwindling: What’s the fate of New Mexico’s Rio Grande?”](https://www.hcn.org/articles/climate-change-diverted-drained-and-dwindling-whats-the-fate-of-new-mexicos-rio-grande)
<https://www.hcn.org/articles/climate-change-diverted-drained-and-dwindling-whats-the-fate-of-new-mexicos-rio-grande>

Drought and demand for water cause the river to dry up.

Products that pollute

- [“Is Your Sunscreen Poisoning the Ocean?”](https://www.nytimes.com/2017/08/19/opinion/sunday/sunscreen-poisoning-ocean-reef.html)
<https://www.nytimes.com/2017/08/19/opinion/sunday/sunscreen-poisoning-ocean-reef.html>
Chemicals toxic to coral threaten reefs’ survival.
- [“Sunscreen pollution accelerating demise of coral reefs, experts say”](https://abcnews.go.com/International/sunscreen-pollution-accelerating-demise-coral-reefs-experts/story?id=68807099)
<https://abcnews.go.com/International/sunscreen-pollution-accelerating-demise-coral-reefs-experts/story?id=68807099>
Includes video after advertisement.
- [“Fertilizers, a Boon to Agriculture, Pose Growing Threat to US Waterways”](https://www.nytimes.com/2017/07/27/climate/nitrogen-fertilizers-climate-change-pollution-waterways-global-warming.html)
<https://www.nytimes.com/2017/07/27/climate/nitrogen-fertilizers-climate-change-pollution-waterways-global-warming.html>
Nitrogen runoff from agricultural fertilizers harms aquatic ecosystems.
- [“Nitrogen and water”](https://www.usgs.gov/special-topics/water-science-school/science/nitrogen-and-water)
<https://www.usgs.gov/special-topics/water-science-school/science/nitrogen-and-water>
- [“Phosphorus and water”](https://www.usgs.gov/special-topics/water-science-school/science/phosphorus-and-water)
<https://www.usgs.gov/special-topics/water-science-school/science/phosphorus-and-water>
Summaries of the effects of nutrients entering waterways
- [“Planning for a Rainy Day”](https://www.nature.org/en-us/magazine/magazine-articles/planning-for-a-rainy-day/)
<https://www.nature.org/en-us/magazine/magazine-articles/planning-for-a-rainy-day/>
How Washington, DC, works to reduce rainwater runoff from paved surfaces.

Plastics

- [“The ‘Great Pacific Garbage Patch’ is Ballooning, 87,000 Tons of Plastic and Counting”](https://www.nytimes.com/2018/03/22/climate/great-pacific-garbage-patch.html)
<https://www.nytimes.com/2018/03/22/climate/great-pacific-garbage-patch.html>
- [“The Immense Eternal Footprint Humanity Leaves on Earth: Plastics”](https://www.nytimes.com/2017/07/19/climate/plastic-pollution-study-science-advances.html)
<https://www.nytimes.com/2017/07/19/climate/plastic-pollution-study-science-advances.html>
Scientists calculate the amount of plastic humans have produced, most of it not in use but still around.
- [“Small Plastic, Big Problem”](https://www.npca.org/articles/1862-small-plastic-big-problem)
<https://www.npca.org/articles/1862-small-plastic-big-problem>
The prevalence of microplastics is a problem in all ecosystems.
- [“Garbage Patches”](https://marinedebris.noaa.gov/info/patch.html)
<https://marinedebris.noaa.gov/info/patch.html>
- [“The world’s plastic pollution crisis explained”](https://www.nationalgeographic.com/environment/article/plastic-pollution)
<https://www.nationalgeographic.com/environment/article/plastic-pollution>

4.2 Mosquito Nets and Overfishing

Article and video about malaria and mosquito nets

- [“Meant to Keep Malaria Out, Mosquito Nets are used to Haul Fish In.”](http://www.nytimes.com/2015/01/25/world/africa/mosquito-nets-for-malaria-spawn-new-epidemic-overfishing.html)
<http://www.nytimes.com/2015/01/25/world/africa/mosquito-nets-for-malaria-spawn-new-epidemic-overfishing.html>
Mosquito nets can protect people from contracting malaria, but using them for fishing has serious unintended consequences.
- [“Mosquito nets: Are they catching more fishes than insects?”](https://www.sciencedaily.com/releases/2019/11/191111100910.htm)
<https://www.sciencedaily.com/releases/2019/11/191111100910.htm>

George Richardson’s systems **diagrams**

- <http://static.clexchange.org/ftp/newsletter/CLEx24.4.pdf>

4.3 Sea Level Change

Research material about sea level

- [Behavior over time graphs](https://climate.nasa.gov/vital-signs/sea-level/)
<https://climate.nasa.gov/vital-signs/sea-level/>

Background information

- ["Is Sea Level Rising?"](https://oceanservice.noaa.gov/facts/sealevel.html)
<https://oceanservice.noaa.gov/facts/sealevel.html>
- ["Sea Level Rise, Explained"](https://www.nationalgeographic.com/environment/global-warming/sea-level-rise/)
<https://www.nationalgeographic.com/environment/global-warming/sea-level-rise/>

Articles about sea level rise

- ["Greenland's Melting Ice Nears a 'Tipping Point,' Scientists Say"](https://www.nytimes.com/2019/01/21/climate/greenland-ice.html)
<https://www.nytimes.com/2019/01/21/climate/greenland-ice.html>
Accelerating melting of Greenland ice can be speeding up sea level rise.
- ["Greenland Ice Sheet Reached Tipping Point 20 Years Ago, New Study Finds"](https://news.climate.columbia.edu/2020/09/02/greenland-tipping-point-20-years-ago/)
<https://news.climate.columbia.edu/2020/09/02/greenland-tipping-point-20-years-ago/>
- ["Jakarta is sinking so fast, it could end up underwater"](https://www.nytimes.com/interactive/2017/12/21/world/asia/jakarta-sinking-climate.html)
<https://www.nytimes.com/interactive/2017/12/21/world/asia/jakarta-sinking-climate.html>
Indonesian city of Jakarta is sinking, adding to troubles brought by climate-caused sea level rise.
- ["Jakarta, the fastest-sinking city in the world"](https://www.bbc.com/news/world-asia-44636934)
<https://www.bbc.com/news/world-asia-44636934>
- ["A Crisis Right Now: San Francisco and Manila Face Rising Seas"](https://www.nytimes.com/interactive/2020/02/13/climate/manila-san-francisco-sea-level-rise.html)
<https://www.nytimes.com/interactive/2020/02/13/climate/manila-san-francisco-sea-level-rise.html>
Two modern cities face crises caused by sea level rise.
- [In Manila and San Francisco, rising seas are a crisis now"](https://news.abs-cbn.com/news/02/14/20/in-manila-and-san-francisco-rising-seas-are-a-crisis-right-now)
<https://news.abs-cbn.com/news/02/14/20/in-manila-and-san-francisco-rising-seas-are-a-crisis-right-now>
- ["Explainer: Nine 'tipping points' that could be triggered by climate change"](https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change)
<https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change>

Multimedia and links to videos

- ["Earth's Albedo and Global Warming"](https://mass.pbslearningmedia.org/resource/ipy07.sci.ess.watcyc.albedo/earths-albedo-and-global-warming/)
<https://mass.pbslearningmedia.org/resource/ipy07.sci.ess.watcyc.albedo/earths-albedo-and-global-warming/>

4.4 Altering the Ocean Temperature and Chemistry

Part One: Cooling water experiment

- Lesson 4 from [The Shape of Change](http://static.clexchange.org/ftp/documents/x-curricular/CC2010-11Shape4ItsCoolSF.pdf), "It's Cool."
<http://static.clexchange.org/ftp/documents/x-curricular/CC2010-11Shape4ItsCoolSF.pdf>
- For building a computer model, download the following link and open the pdf file
<http://static.clexchange.org/ftp/documents/science/SC1999-09ItsCool.zip>

Part Two: Information about length of day and temperature

- <https://www.timeanddate.com/sun/>
- <https://www.almanac.com/astronomy/sun-rise-and-set>
- <http://www.usclimatedata.com/>
- <http://www.weatherbase.com/>
- <https://www.seatemperature.org/>

Part Three: Suggested articles and resources about ocean heat and chemistry

Water's ability to store heat

- ["Heat Capacity and Water"](https://www.usgs.gov/special-topic/water-science-school/science/heat-capacity-and-water?qt-)
<https://www.usgs.gov/special-topic/water-science-school/science/heat-capacity-and-water?qt->

[science_center_objects=0#qt-science_center_objects](#)

Overall threats to oceans

- [“The World’s Oceans are in Danger, Major Climate Change Report Warns”](#)
<https://www.nytimes.com/2019/09/25/climate/climate-change-oceans-united-nations.html>
A United Nations report from September 2019 states that climate change is causing damaging storms, harm to ecosystems and fish stocks, and serious risk to coastal populations.
- [“Climate Change Poses a Threat to Our Oceans”](#)
<https://www.un.org/en/chronicle/article/climate-change-poses-threat-our-oceans>

Ocean warming and climate

- [NOAA resource](#)
<http://oceanexplorer.noaa.gov/facts/climate.html>
- [“Ocean Warming is Accelerating Faster Than Thought, New Research Finds”](#)
<https://www.nytimes.com/2019/01/10/climate/ocean-warming-climate-change.html>
Research cites the increasing rate of ocean warming and warns of catastrophic consequences.
- [“Ocean Warming”](#)
<https://www.whoi.edu/know-your-ocean/ocean-topics/climate-ocean/ocean-warming/>

Ocean’s role in the carbon cycle

- <https://www.noaa.gov/education/resource-collections/climate/carbon-cycle>

Ocean acidification

- [Ocean Acidification information](#) from Smithsonian Institution (includes videos)
<https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification>
- NOAA resources
 - ◇ <https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F>
 - ◇ <http://www.pmel.noaa.gov/co2/story/Ocean+Acidification>
 - ◇ <https://www.noaa.gov/education/resource-collections/ocean-coasts-education-resources/ocean-acidification>
- [Woods Hole Oceanographic Institution](#)
<http://www.whoi.edu/main/topic/ocean-acidification>
- [“Untangling the Many Ways Acidification Harms Marine Life”](#)
<http://theyearsproject.com/learn/news/untangling-the-many-ways-ocean-acidification-harms-marine-life/>

Coral reef conditions

- [“Global Warming’s Toll on Coral Reefs: As If They’re ‘Ravaged by War’ ”](#)
<https://www.nytimes.com/2018/01/04/climate/coral-reefs-bleaching.html>
- [“How does climate change affect coral reefs?”](#)
<https://oceanservice.noaa.gov/facts/coralreef-climate.html>
- [“Building a Better Coral Reef”](#)
<https://www.nytimes.com/2017/09/20/climate/coral-great-barrier-reef.html>
Scientists seek ways to strengthen and restore coral reefs.
- [“The Science of Super Corals” \(video\)](#)
<https://oceantoday.noaa.gov/fullmoon-scienceofsupercorals/welcome.html>
Scientists assist corals to adapt to higher ocean temperatures.

How whales sequester carbon

- [“How Whales Help Cool the Earth”](#)
<https://www.bbc.com/future/article/20210119-why-saving-whales-can-help-fight-climate-change>

4.5 Running a Fishing Company

Online Fishbanks simulation with related resources

- Creative Learning Exchange downloadable set of materials, links, and instructions (Highly recommended) written by Anne LaVigne, an outstanding educator and curriculum developer. The simulation may be accessed directly from MIT, but Ms. LaVigne’s work will add value and guidance.
- [Fishbanks packet](#) from Creative Learning Exchange

- <http://www.clexchange.org/curriculum/simulations/>
Scroll down to “Fishbanks.”
- [Simulation](https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx) (link also available in Creative Learning Exchange packet)
<https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/fish-banks.aspx>
- [Article by Donella Meadows “The Tragedy of the Commons on Georges Bank, and Elsewhere”](http://www.donellameadows.org/archives/the-tragedy-of-the-commons-on-georges-bank-and-elsewhere/)
<http://www.donellameadows.org/archives/the-tragedy-of-the-commons-on-georges-bank-and-elsewhere/>

Reference Article on drawing stock/flow diagrams

- [“Building the Fish Banks Model and Renewable Resource Depletion”](http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/readings/fish.pdf)
<http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/readings/fish.pdf>

Chapter Five: Pulling it All Together

5.1 Connecting Systems

Reference Articles

- [“What a Week’s Disasters Tell Us About Climate and the Pandemic”](https://www.nytimes.com/2020/05/23/climate/climate-change-coronavirus.html)
<https://www.nytimes.com/2020/05/23/climate/climate-change-coronavirus.html>
A journalist explains how global climate and health crises coming together make difficult lives even harder.
- [“Corona Virus and Climate Change”](https://www.hsph.harvard.edu/c-change/subtopics/coronavirus-and-climate-change/)
<https://www.hsph.harvard.edu/c-change/subtopics/coronavirus-and-climate-change/>
Scientist answers questions about the connections between climate and public health.
- [“Social Dimensions of Climate Change”](https://www.worldbank.org/en/topic/social-dimensions-of-climate-change#1)
<https://www.worldbank.org/en/topic/social-dimensions-of-climate-change#1>
- [“Learn About Environmental Justice”](https://www.epa.gov/environmentaljustice/learn-about-environmental-justice)
<https://www.epa.gov/environmentaljustice/learn-about-environmental-justice>
- [“Why ‘I Can’t Breathe’ is Resonating with Environmental Justice Activists”](https://www.nbcnews.com/science/environment/why-i-can-t-breathe-resonating-environmental-justice-activists-n1228561)
<https://www.nbcnews.com/science/environment/why-i-can-t-breathe-resonating-environmental-justice-activists-n1228561>
Racial prejudice extends throughout society, including issues of environmental justice.
- [“Mold, Possums and Pools of Sewage: No One Should Have to Live Like This”](https://www.nytimes.com/2020/11/14/opinion/sunday/coronavirus-poverty-us.html)
<https://www.nytimes.com/2020/11/14/opinion/sunday/coronavirus-poverty-us.html>
Poverty, inequality, illness, and environmental injustice in Alabama. (Note:graphic and disturbing)

Lesson 5.2 Choosing a Topic

No additional resources