Notes on reading 2nd NGSS draft
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What are the NGSS DCIs that address climate change?

***These topics no longer have titles like "HS.ESS - CC" for Climate Change. They are now grouped by DCI (Disciplinary Core Idea) from the NRC Framework. You can still view them by topic (Weather and Climate, Human Sustainability), but they aren't broken down by sub-topic anymore.*

1st draft	2nd draft
MS.ESS-WC: Weather and Climate Systems	MS.ESS2: Earth's Systems
MS.ESS-HI: Human Impacts	MS.ESS3: Earth and Human Activity
HS.ESS-ES: Earth Systems	HS.ESS2: Earth's Systems
HS.ESS-CC: Climate Change	***There is no longer a topic specifically for climate change.***
HS.ESS-HS: Human Sustainability	HS.ESS3: Earth and Human Activity

Model course mapping for NGSS
Here, NGSS maps out 3 options for middle or high schools attempting to design courses around the new standards. They list the options as below, but #2 is definitely the most straightforward.

1. Conceptual understanding model
    a. DCIs build progressively so that each PE builds ones taught before it.
    b. Life science, physical science and earth / space science distributed throughout
    c. Called Course 1, 2 and 3 – each option is limited to 3 courses each because that's typically what high schools require
    d. NGSS acknowledges that teaching this model will be challenging to teachers used to teaching a single topic and

significant PD (professional development) will be needed.

2. Science domains model
    a. Simple: life science, physical science, earth and space science
3. Modified science domains model
    a. Fits all PEs into 3 typical high school science classes: biology, chemistry and physics
    b. Physical science is distributed into both chemistry and physics
    c. Earth and space science is the tough one – has to be spread over the other 3 courses, since it isn't currently taught as its own class in high school.
    d. ESS3.A and ESS3.D (climate change) go into the chemistry course
    e. NGSS also acknowledges here that **PD will need to be needed** to incorporate ESS into traditional courses.

MS.ESS2 – Earth's Systems

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<tr><td>e. Use models of Earth's atmosphere and surface to explain how energy from the sun is absorbed and retained by various greenhouse gases in Earth's atmosphere, thereby regulating Earth's average surface temperature and keeping Earth habitable. [Assessment Boundary: Explanations should include an understanding that energy can take different forms and can be tracked as it moves through Earth's systems. Students do not have to explain the differing wavelengths of radiation received and reemitted from Earth's surface. Amount of energy absorbed by different reservoirs is not assessed at this level.]</td><td><table><tr><td>MS-ESS2-n.</td><td>Use models of Earth's atmosphere and surface to support the explanation of the greenhouse gas effect. [Clarification Statement: Model explanations, physical or conceptual, reveal various ways that heat energy moves through and is stored within Earth's systems.] [Assessment Boundary: The rates of energy absorption by different reservoirs and their effect on the radiation balance of the system are not assessed. A complete understanding of the electromagnetic spectrum is not assessed.]</td></tr></table></td></tr>
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MS.ESS3 – Earth and Human Activity

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<tr><td>e. Use empirical evidence to evaluate technologies that utilize renewable energy resources. [Assessment Boundary: Students will evaluate these technologies based on their cost, benefit, sustainability,</td><td><table><tr><td>MS-ESS3-d.</td><td>Read critically to evaluate competing ideas and present the</td></tr></table></td></tr>
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and environmental impacts.]		findings regarding the use of technologies that rely on renewable and non-renewable energy resources.* [Clarification Statement: Reading sources could be scientific assessments such as the National Research Council's, "America's Energy Future" study and other NRC publications. Energy resources include renewable energy resources (e.g., hydroelectric, geothermal, biomass fuels), inexhaustible energy sources (e.g., sunlight, wind, tides, ocean waves), and non-renewable energy sources (e.g., coal, oil, natural gas, nuclear fission). Constraints on resource use include geographic availability, costs, benefits, safety, performance, sustainability, and environmental impacts.]
c. Design engineering solutions for stabilizing changes to communities by: (1) using water efficiently, (2) minimizing human impacts on environments and local landscapes by reducing pollution, and (3) reducing the release of greenhouse gases.	**MS-ESS3-e.**	Design and communicate solutions that meet criteria and constraints for minimizing human impacts on environments and local landscapes by: (1) managing water resources, (2) reducing pollution, and (3) reducing the release of greenhouse gases.*

		[Clarification Statement: The design process could include examining an example of human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating a solution that could reduce that impact. Examples of human “impacts” include but are not limited to: (1) the withdrawal of stream water and groundwater, construction of dams and levees, and removal of wetlands; (2) air and water pollution, light pollution, noise pollution, landfill contamination, and plastics in the ocean; and, (3) carbon dioxide release from combustion and cement production, methane release from agriculture and the warming of permafrost and coastal regions, and nitrous oxide release.]
a. Use system models and representations to explain how human activities significantly impact: (1) the geosphere, (2) the hydrosphere, (3) the atmosphere, (4) the biosphere, and (5) global temperatures. [Clarifying Statement: System models and representations include diagrams, charts, and maps. Examples of human impact are changes in land use and resource development (geosphere); water pollution and urbanization (hydrosphere); air	**MS-ESS3-i.**	Use visual representations of system models to support explanations of how human activities significantly impact: (1) the geosphere, (2) the hydrosphere, (3) the atmosphere, and (4) the biosphere.*

pollution in the form of gases, aerosols, and particulates (atmosphere); changes to natural environments (biosphere); release of greenhouse gases (global temperatures).]		[Clarification Statement: System models and representations can include diagrams, charts, photographs, and maps that demonstrate how these systems have changed over time in response to human activities, examples of which include changes in land use and resource development (geosphere); water pollution and urbanization (hydrosphere); air pollution in the form of gases, aerosols, and particulates (atmosphere); transfer of invasive species to new environments (biosphere).]
d. Ask questions to refine and develop an explanation for the way technological monitoring of Earth's systems can provide the means of informing the public of ways to modify human impacts on Earth's systems.	**MS-ESS3-j.**	Ask questions to refine explanations for how different technologies are used to monitor Earth system changes, providing the basis of assessing human impacts.* [Clarification Statement: Examples of questions are, "How do we know the size of the ozone hole over Antarctica?" or "How do we measure the change over time of global temperatures?" Technological monitoring could include: (1) data from satellites for changes in vegetation, land use,

		surface water content, surface temperature, ice surface area, sea ice, ocean temperature and wave height, atmosphere chemistry and temperature, storm activity, and aerosol content; (2) ice and sediment cores for data on past temperatures and atmospheric composition; (3) data from land and ocean-based weather stations, from ocean buoys, or from river or lake monitoring stations for stream acidity, chemistry, and height; and, (4) data from seismic monitoring for glacier movements and impacts of waste-water injection.]

HS.ESS2 – Earth's Systems

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e. Construct an evidence-based claim about how a change to one part of an Earth system creates feedbacks that causes changes in other systems (e.g., coastal dynamics, watersheds and reservoirs, stream flow and erosion rates, changes in ecosystems).	**HS-ESS2-b.** Construct an evidence-based argument about how a natural or human-caused change to one part of an Earth system can create feedback that causes changes in that system or other systems.* [Clarification Statement: Modern civilization depends on major technological systems and these are critical aspects of decisions about technology usage. Local real world examples could include how removing ground vegetation causes an increase in water runoff and soil erosion; building reservoirs increases groundwater recharge; installing a coastal rock jetty changes currents and resulting beach erosion patterns; removing wetlands causes a decrease in local humidity that further reduces the wetland extent; diminishing glacial ice reduces the amount of sunlight reflected from Earth's surface, which increases surface temperatures and further reduces the amount of ice.]

b. Construct a scientific argument showing that changes to any one of many different Earth and Solar System processes can affect global and regional climates. [Clarification Statement: Examples of these processes include the sun's energy output, Earth's orbit and axis orientation, tectonic events, ocean circulation, volcanic activity, glacial activity, the biosphere, and human activities.] [Assessment Boundary: Use evidence from the geologic record only.] c. Analyze geologic evidence that past climate changes have occurred over a wide range of time scales. **[Clarification Statement: Examples of evidence are ice core data, the fossil record, sea level fluctuations, glacial features.]**	**HS-ESS2-e.** — Construct a scientific explanation based on evidence from the geoscience record that changes to any Earth and Solar System processes can affect global and regional climates over a wide range of time scales.* [Clarification Statement: Examples of evidence include ice core data, tree-ring data, the fossil and sedimentary record, which show the history of surface temperatures, the ice, volume, and sea level fluctuations. Examples of the changes to processes include variations in the sun's energy output, Earth's orbit and axis orientation, tectonic events, ocean circulation, volcanic activity, glacial activity, biosphere interactions, and human activities.] [*Assessment Boundary: Use evidence from the geoscience record only.*]
d. Engage in critical reading of scientific literature about causes of climate change over 10s-100s of years, 10s-100s of thousands of years, or 10s-100s of millions of years. **[Clarification Statement: Examples of causes are changes in solar output, ocean circulation, volcanic activity (10s-100s of years);** changes to Earth's orbit and the orientation of its axis (10s-**100s of thousands of years); or long-term changes in**	**HS-ESS2-f.** — Read scientific literature critically to evaluate and communicate the causes and effects of climate change over 10s-100s of years, 10s-100s of thousands of years, and 10s-100s of millions of years

atmospheric composition (10s-100s of millions of years).]		[Clarification Statement: Examples of causes are changes in solar output, ocean circulation, and volcanic and human activity (which change atmospheric composition and other systems over 10s-100s of years); changes to Earth's orbit and the orientation of its axis (over 10s-100s of thousands of years); or long-term changes in atmospheric composition (over 10s-100s of millions of years).]
g. Use models to analyze data to make claims about how energy from the sun is redistributed throughout the atmosphere. [Clarification Statement: Unequal heating of the atmosphere results in high and low pressure systems; air moves from areas of high pressure to low pressure; clockwise and counter-clockwise atmospheric circulations develop in response to Earth's rotation (the Coriolis Effect).]	**HS-ESS2-g.**	Develop, revise, and use models of atmospheric circulation to support explanations of how air massess redistribute energy from the sun. [Clarification Statement: The absorption of solar radiation by the ocean and the subsequent heat transfer due to evaporation largely drive atmospheric circulation through the generation of high- and low-pressure systems (e.g., the condensation of water vapor over warm ocean surfaces provides the power for hurricanes and typhoons). Models of atmospheric circulation should include the Coriolis effect and the locations of the continents.]

a. Evaluate and communicate the climate changes that can occur when certain components of the climate system are altered. [Clarification Statement: For example, evaluate variations in incoming solar radiation as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems.]	**HS-ESS2-j.** Use models of the flow of energy between the sun and Earth's atmosphere, ocean, and land to support explanations of how Earth's radiative energy balance is affected by the absorption and retention of heat in Earth's atmosphere. [Clarification Statement: Students examine the radiative properties of different atmospheric gases and surface regions, (e.g., ocean, ice, land), and will evaluate variations in the reflection, absorption, storage, and redistribution of solar radiation among the atmosphere, ocean, and land systems.]
	HS-ESS2-k. Develop, revise, and use quantiative models to support the explanation of the amount of carbon that cycles among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Biogeochemical cycles involve the cycling of carbon and other elements through the ocean,

	atmosphere, soil, and biosphere, providing the foundation for living organisms.]

d. Construct scientific arguments to support the claim that dynamic causes, effects, and feedbacks among Earth's systems result in a continual coevolution of Earth and the life that exists on it. [Assessment Boundary: Students examine examples of feedbacks between Earth's different systems to understand how life has coevolved with Earth's surface (e.g., the atmosphere and biosphere affect the conditions for life, which in turn affects the composition of the atmosphere.]	

HS-ESS2-I.	Apply scientific reasoning, theory, and models to support the claim that dynamic causes, effects, and feedbacks among Earth's systems result in continual coevolution of Earth and the life that exists on it. [Clarification Statement: Students investigate examples of feedbacks among Earth's different systems (e.g., the atmosphere affects the conditions for life, which in turn affects the composition of the atmosphere; or, soil supports life, which in turn increases the rate of development of soil).]

HS.ESS3 – Earth and Human Activity

1st draft	2nd draft	
b. Reflect on and revise design solutions for local resource development that would increase the ratio of benefits to costs and risks to the community and its environment. [Clarification Statement: Examples of local resource development include soil use for agriculture, water use, mining for coal and minerals, pumping for oil and natural gas.]	**HS-ESS3-b.**	Analyze and revise solutions for developing, managing, and utilizing resources that would increase economic, social, environmental, and/or cost: benefit ratios.* [Clarification Statement: Examples include best practices for agricultural soil use, retrieving water from aquifers or desalination, mining for coal and minerals, pumping for oil, hydro-fracturing to retrieve natural gas, recovering off-shore methane gas hydrates, extracting petroleum from tar sands and oil shales, and the conservation, recycling, and reuse of resources. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.]
d. Construct scientific arguments from evidence to support claims that natural hazards and other geologic events have influenced the course of human history. [Clarification Statement: Famines that result from reduced global temperatures can follow	**HS-ESS3-c.**	Ask questions to construct and revise explanations of the impact that natural hazards and other

large historic volcanic eruptions. Large earthquakes and tsunamis can destroy cities, and there is a strong correlation between historic climate changes and the number of wars.]		geoscience events have had on the course of human history at regional and global scales. [Clarification Statement: Natural hazard events (e.g., earthquakes, volcanoes, floods) and changes in regional or global climates can affect populations, drive mass migrations, and influence the rise and fall of civilizations.]
e. Construct scientific claims about the impacts of human activities on the frequency and intensity of some natural hazards. [Clarification Statement: Natural hazards to include floods, droughts, forest fires, landslides, etc.]	**HS-ESS3-d.**	Construct and evaluate scientific claims based on valid and reliable evidence that human activities can contribute to the frequency and intensity of some natural hazards.* [Clarification Statement: Human activities (e.g., building dams and levees, urbanizing ground cover, removing wetlands, managing fires, removing vegetation) can increase the frequency and/or severity of certain natural hazards (floods, droughts, forest fires, landslides, coastal erosion).]
f. Identify mathematical relationships using data on the rates of production and consumption of natural resources in order to assess the global sustainability of human society. [Assessment	**HS.ESS3-e.**	Identify mathematical relationships between natural resource production and consumption rates

Boundary: Students construct equations for linear relationships, but not expected to construct equations for non-linear relationships.]	in order to assess the global sustainability of humans and the biodiversity that supports them.* [Clarification Statement: Use equations for linear relationships.] [*Assessment Boundary: The construction of equations is not expected for non-linear relationships, which can be studied graphically (e.g., with "Hubbert" curves) or computationally.*]
g. Construct arguments about how engineering solutions have been and could be designed and implemented to mitigate local or global environmental impacts. [Clarification Statement: Environmental impacts to include acid rain, water pollution, the ozone hole, etc.]	**HS-ESS3-f.** Analyze data regarding the effects of human activities on natural systems to make valid scientific claims for how engineering solutions are designed and implemented to help limit environmental impacts.* [Clarification Statement: Examples of environmental impacts that have been mitigated include water and air pollution, landfill leakage, acid rain, the growth of the Antarctic ozone hole, and agricultural soil erosion. Claims can be qualitative or quantitative, in cases where quantitative data are available. New technologies enhance the ability to construct

		scientific claims based on evidence.]
e. Use global climate models in combination with other geologic data to predict and explain how human activities and natural phenomena affect climate, providing the scientific basis for planning for humanity’s future needs. **[Clarification Statement: For example, use global climate models together with topographic maps to investigate effects of sea level change or combine global climate models with precipitation maps to investigate locations where new water supplies will be needed.]**	**HS-ESS3-g.**	Use geoscience data and the results from global climate models to make evidence-based forecasts of climate change. [Clarification Statement: Geoscience data can include charts, tables, or maps of topography, biomass, precipitation, temperature, or weather-related events.]
f. Apply scientific knowledge to investigate how humans may predict and modify their impacts on future global climate systems (e.g., investigating the feasibility of geoengineering design solutions to global temperature changes).	**HS-ESS3-h.**	Apply scientific reasoning, theory, and models to construct explanations for how humans may predict and modify their impacts on future global climate systems.* [Clarification Statement: Examples can range from large-scale geoengineering design solutions to alter global temperatures (e.g., seeding the atmosphere with aerosols or seeding the ocean with iron to enhance microbe growth) to more local efforts (e.g., reducing resource consumption and energy use, recycling and reusing, and using renewable energy sources)

		done by both societies and individuals. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.]
h. Use results from computational General Circulation Models (GCMs) to investigate how the hydrosphere, atmosphere, geosphere, and biosphere are being modified in response to human activities.	**HS-ESS3-i.**	Use models of Earth system interactions to support explanations of the relationships among the hydrosphere, atmosphere, cyrosphere, geosphere, and biospehere systems and how they are being modified in response to human activities.* [Clarification Statement: Examples include: changes to groundwater levels and recharge rates; ocean acidity and coral health; atmospheric composition and rain acidity and lake life health; deforestation and erosion rates and local biosphere health; agricultural fertilization; stream composition and “dead” zones in offshore regions.]