HS-ETS1-1

Students who demonstrate understanding can:

HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.	- *Connections to Engineering, Technology, and Applications of Science* **Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

	Observable features of the student performance by the end of the course:		
1	Identifying the problem to be solved		
	a	Students analyze a major global problem. In their analysis, students:	
		i.	Describe the challenge with a rationale for why it is a major global challenge;
		ii.	Describe, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
		iii.	Document background research on the problem from two or more sources, including research journals.
2	Defining the process or system boundaries, and the components of the process or system		
	a	In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.	
	b	In their analysis, students describe societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).	
3	Defining the criteria and constraints		
	a	Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.	

HS-ETS1-2

Students who demonstrate understanding can:

HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.	

	Observable features of the student performance by the end of the course:	
1	Using scientific knowledge to generate the design solution	
	a	Students restate the original complex problem into a finite set of two or more sub-problems (in writing or as a diagram or flow chart).
	b	For at least one of the sub-problems, students propose two or more solutions that are based on student-generated data and/or scientific information from other sources.
	c	Students describe how solutions to the sub-problems are interconnected to solve all or part of the larger problem.
2	Describing criteria and constraints, including quantification when appropriate	
	a	Students describe criteria and constraints for the selected sub-problem.
	b	Students describe the rationale for the sequence of how sub-problems are to be solved, and which criteria should be given highest priority if tradeoffs must be made.

HS-ETS1-3

Students who demonstrate understanding can:

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions	**ETS1.B: Developing Possible Solutions**	- -
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.	• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	*Connections to Engineering, Technology, and Applications of Science*
• Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.		**Influence of Science, Engineering, and Technology on Society and the Natural World**
		• New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

	Observable features of the student performance by the end of the course:	
1	Evaluating potential solutions	
	a	In their evaluation of a complex real-world problem, students:
		i. Generate a list of three or more realistic criteria and two or more constraints, including such relevant factors as cost, safety, reliability, and aesthetics that specifies an acceptable solution to a complex real-world problem;
		ii. Assign priorities for each criterion and constraint that allows for a logical and systematic evaluation of alternative solution proposals;
		iii. Analyze (quantitatively where appropriate) and describe the strengths and weaknesses of the solution with respect to each criterion and constraint, as well as social and cultural acceptability and environmental impacts;
		iv. Describe possible barriers to implementing each solution, such as cultural, economic, or other sources of resistance to potential solutions; and
		v. Provide an evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution, and barriers to be overcome.
2	Refining and/or optimizing the design solution	
	a	In their evaluation, students describe which parts of the complex real-world problem may remain even if the proposed solution is implemented.

HS-ETS1-4

Students who demonstrate understanding can:

HS-ETS1-4. **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**ETS1.B: Developing Possible Solutions** • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.

		Observable features of the student performance by the end of the course:
1		Representation
	a	Students identify the following components from a given computer simulation:
		i. The complex real-world problem with numerous criteria and constraints;
		ii. The system that is being modeled by the computational simulation, including the boundaries of the systems;
		iii. What variables can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions; and
		iv. The scientific principle(s) and/or relationship(s) being used by the model.
2		Computational Modeling
	a	Students use the given computer simulation to model the proposed solutions by:
		i. Selecting logical and realistic inputs; and
		ii. Using the model to simulate the effects of different solutions, tradeoffs, or other decisions.
3		Analysis
	a	Students compare the simulated results to the expected results.
	b	Students interpret the results of the simulation and predict the effects of the proposed solutions within and between systems relevant to the problem based on the interpretation.
	c	Students identify the possible negative consequences of solutions that outweigh their benefits.
	d	Students identify the simulation's limitations.