Report: Teacher's guide for a didactic unit in Solar Energy for NM SMART Grid Center Externship award.

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This externship aimed to develop a teacher's guide for a didactic unit in solar energy and related topics in electrical engineering for secondary education students in the State of New Mexico.

Initially, the unit was structured as a self-contained guide of ten lessons. An opening lesson to attract students' interest in the topic of solar energy. Two introductory lessons in electricity to review essential prerequisites to understand solar photovoltaics. A lesson to introduce different energy sources. Four lessons focused on various aspects of the science and technology of solar photovoltaics. A lesson to present alternative solar power sources to photovoltaics and other uses of solar energy. Finally, a lesson to help students recognize educational and work opportunities that photovoltaics in particular and energy-related sectors in New Mexico, in general, can offer.

A more detailed description of the unit's learning objectives, lesson by lesson, is included at the end of this report. The lessons' learning objectives have been defined according to the New Generation Science Learning Objectives. By the end of the externship, the first six lessons were fully completed with their related activities.

Lessons are designed as an investigation process for the student. For this reason, each lesson is structured or divided into five sections: (1)"Link to previous class and set the stage"; (2) "Prepare to investigate"; (3)"Investigate"; (4)"Questions and Discussion"; and (5)"Summary".

Section (1) puts the current lesson in the context of the previous lesson. The idea is that a conducting thread connects all the lessons and helps the instructor set the stage for the present material as part of the

unit. Section (2) provides the instructor different teaching materials to prepare students for the upcoming investigation. Section (3) includes the teacher's guide for the student investigation, which consists of activities to achieve the learning goals defined for the lesson. It contains links to handouts and other materials included in the Appendix of the teacher's guide. Section (4) consists of questions for the students or guidelines for the instructor to promote in classroom discussion. The purpose is twofold: To evaluate the learning objectives' accomplishment and help students identify the lesson's main points. Section (5) consists of a summary and conclusion of the topic addressed in the lesson.

The teaching materials consist of videos, reading materials from multiple sources, and slides explicitly created for this unit. The activities and handouts have been designed specifically for this unit using various sources as references and inspiration. All the references used, from educational materials to journals in education research, are included at the end of the teaching guide for reference.

The didactic unit includes activities using several teaching methodologies, such as group activities or open-ended questions. As far as possible, the design of those activities is grounded on existing education literature.

As part of the didactic unit, a demonstration video was recorded for instructions on one of the experimental activities. It includes the description and instructions for an experiment about basic electric circuits.

Lesson	Objectives.
	Students will be able to…
1	• **interpret** times series plot. • **list** some of the factors that drive use of electricity consumption. • **explain** the reason for the "duck shape" curve. • **summarize** the information contained in a time series plot. • **perform** basic arithmetic operations and command use in *Excel*. • **plot** time series plot on Excel.
2	• **define** electricity**.** • **identify** the parts of an electric circuit (source, load and conductors) • **explain** the conditions required for electricity to flow (need of a voltage difference and a conductive path) • **describe** the physical magnitudes associated with an electric circuit (voltage, current and power), and **relate** them with their units in the SI (Volts, Amperes and Watts).
3	• **perform calculations** using Ohm's Law and to **calculate** power dissipated in a resistor. • **classify** between **parallel** and series **circuits.** • **operate** a voltmeter/amperemeter/multimeter for measuring voltage and current in a circuit • EXTRA: to design basic **parallel** and series **circuits.**
4	• **define** solar energy (transformation of the solar radiation into electricity in general, not necessarily photovoltaic) • **describe** and **give examples** of the factors that influence the generation of solar energy (light hours, seasonal patterns, orientation w/r the Sun, atmospheric conditions). • **justify** the potential of New Mexico in terms of solar availability (location, atmospheric conditions, irradiance map) NOTE: Connection to the VLA. • EXTRA: to **name** units in the SI of solar irradiance.
5	• to **enumerate** potential sources of sources to generate electricity. • **identify** the nature of the energy transformed before and after (chemical, thermal, nuclear,...)

	• **classify** renewable vs non-renewable sources of electricity. • **enumerate** alternative uses of solar energy and **recognize** the different nature of the source and the energy transformation
6	• **distinguish** between DC and AC. • **recognize** the characteristics of an AC signal on a plot (period/frequency, magnitude). • **recall** the justification for the use of AC vs DC. (Appliances requirements, need of transformers, type of generation) • **recall/distinguish** between inverter/rectifier/transformer. (What are they used for?) .
7	• **explain** the need for a match between generation and demand in a power systems. Potential risks derived of a mismatch: outages and appliance damage. • **identify** the basic components of a power grid (power plants, transmission/distribution lines, and loads) and • **relate** the basic components of a power grid with the components (already studied) of an electric circuit (source, conductors and loads). • **justify** the use of energy storage as a solution to a potential mismatch. • EXTRA: to **justify** the need of an operator and utilities to plan a power grid as energy needs evolve, to predict and match demand in real-time.
8	• **interpret** generation and demand plots. • **design** a schedule for storing and shifting demand. • **explain** the potential problems of the so-called “duck curve” effect.
9	• (connection to lesson 4). • **describe in detail** one alternative use of solar energy of their preference. • **explain** how a PV panel works in terms of photovoltaic mechanism. • **predict** the effect in terms of voltage and current of installing panels in series or parallel. • EXTRA: to **describe** how PV panels are manufactured and what are they made of.
10	• **recognize** the educational/work opportunities that energy related sector can offer. In particular in the state of NM.

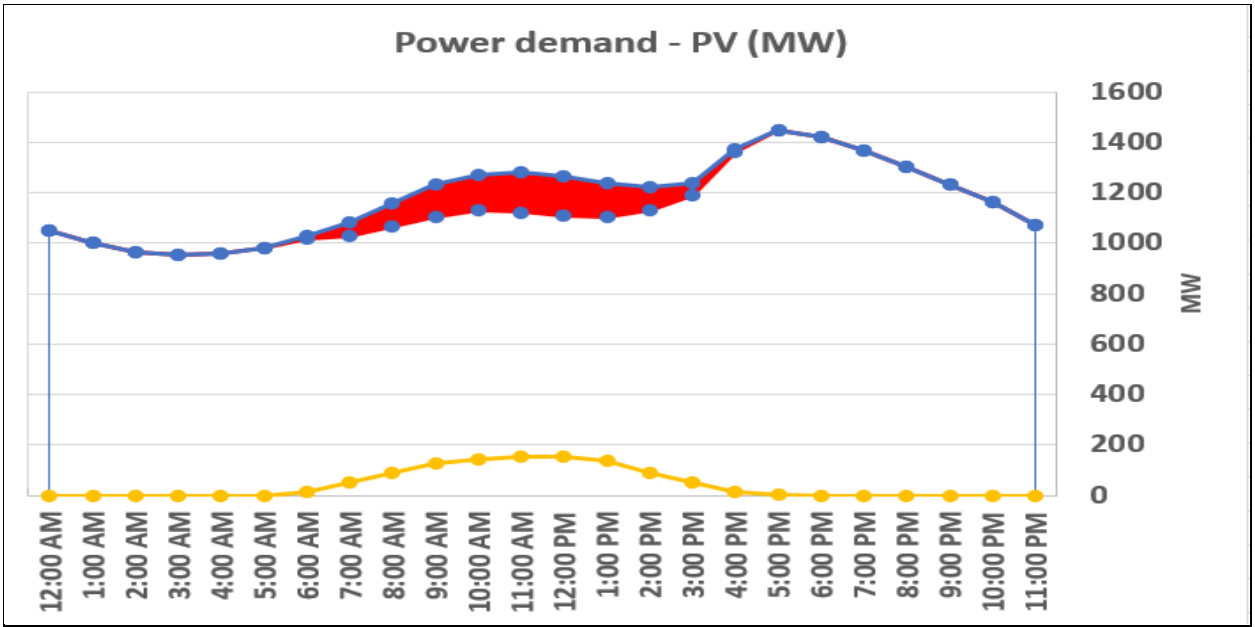

Figure 1: Example of simulation for investigation activity about the "Duck-curve".

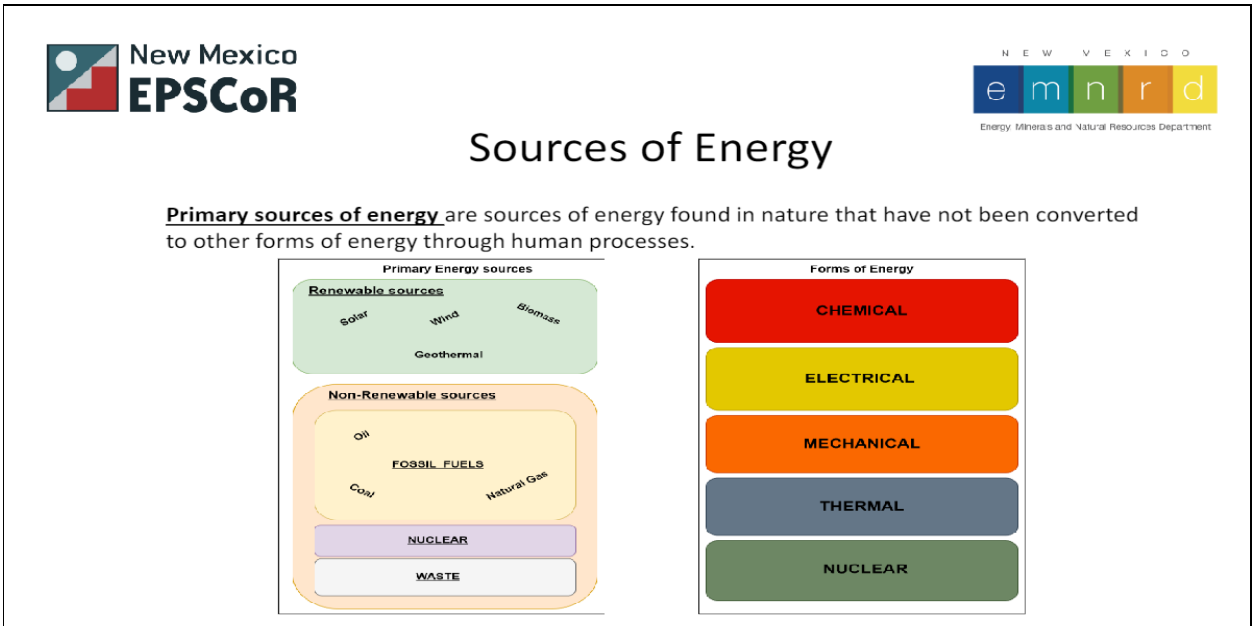

Figure 2: Slide for Lesson 4 (Primary energy sources)

Figure 3: Picture of the experimental setup for circuit design with maker tape in Lesson 2.