Can green building science support systems thinking for energy education?

Student Data by Teacher

Supplementary File S4

Prior to combining student data, each case study school was analyzed separately. The information in this supplementary file shows the student data analyzed by teacher to highlight some of the similarities and differences evidenced across schools. The organization aligns with the presentation of themes in the main document:

Table of Contents:

- The Energy Grid: Natural Resources & Electrical Production
- The Energy Grid: Electrical Transference
- The Energy-Efficient Classroom: Electrical Use
- The Energy-Efficient Classroom: Light Energy & Building Design
- The Energy-Efficient Classroom: Thermal Energy & Building Design
- Pre and Post Systems Models, by Teacher

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Student Data by Teacher

Supplementary File 4

Methods Overview:

This analysis includes n=162 systems models from n=89 students, with the following numbers in each school:

- School 1 (Faith), n=32
- School 2 (Charlotte), n=8
- School 3 (Sophia), n=49

Qualitative content analysis yielded codebooks for individual elements (Appendix A) and energy flows (Appendix B), where descriptions of each code can be found for each code in the appendices. Those codes are organized by the sections in the table of contents and then separated by teacher (pre- versus post-test) in the pages of this supplementary file. The "percentage of students" is the y-axis of the charts, where each student was included in the count if their test was coded in the category.

In all charts and diagrams, pre-tests are represented in **green** and post-tests in **fuchsia**.

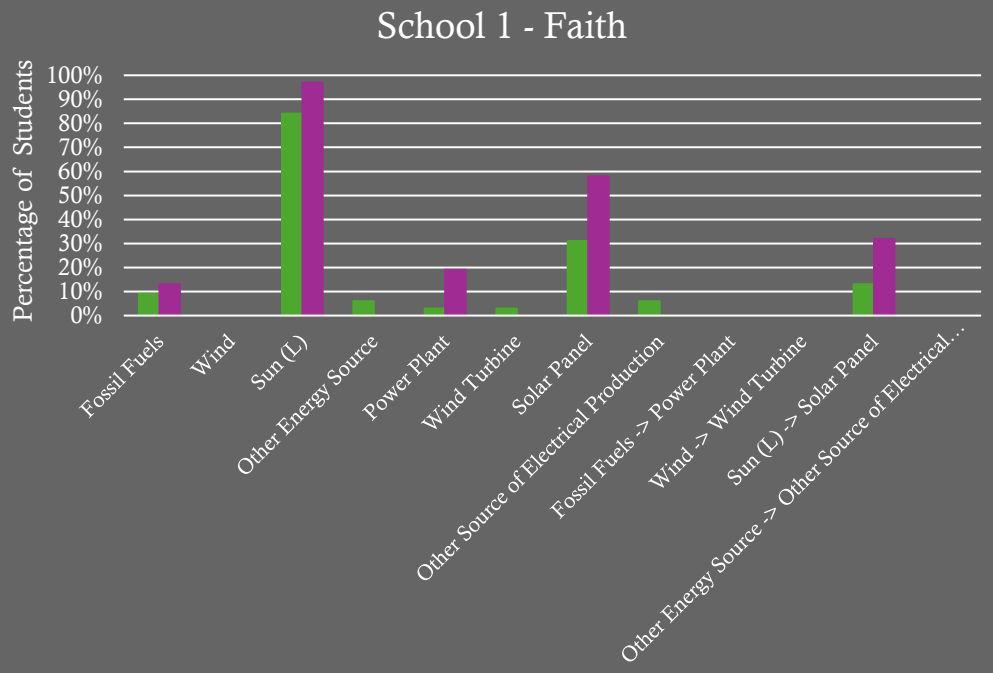
The Energy Grid:
Natural Resources and Electrical Production

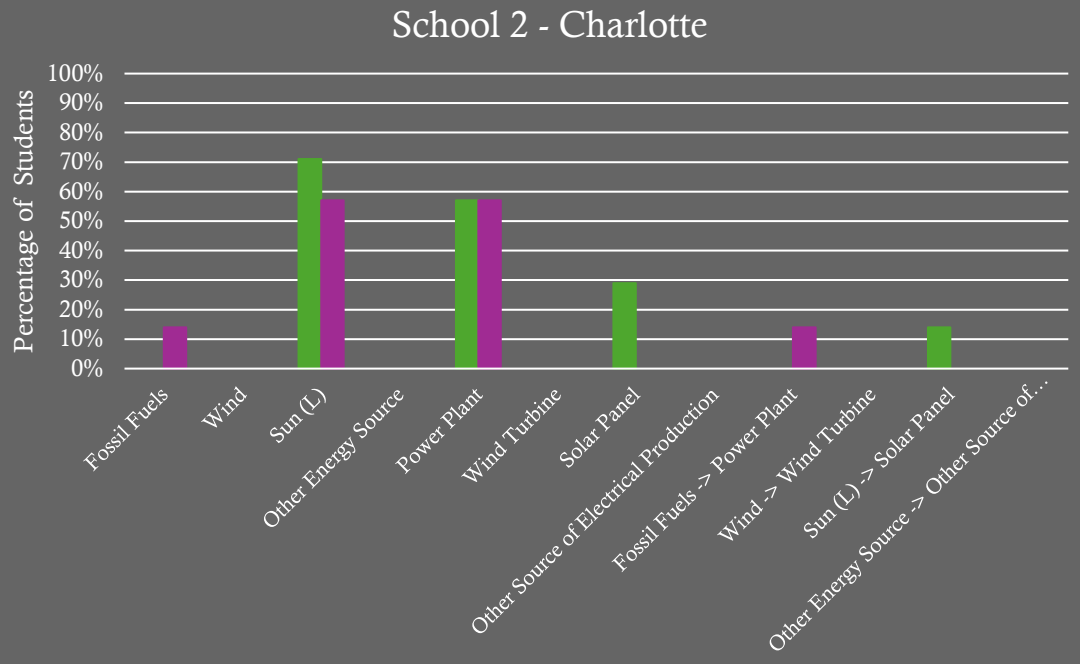
Natural Resources & Electrical Production

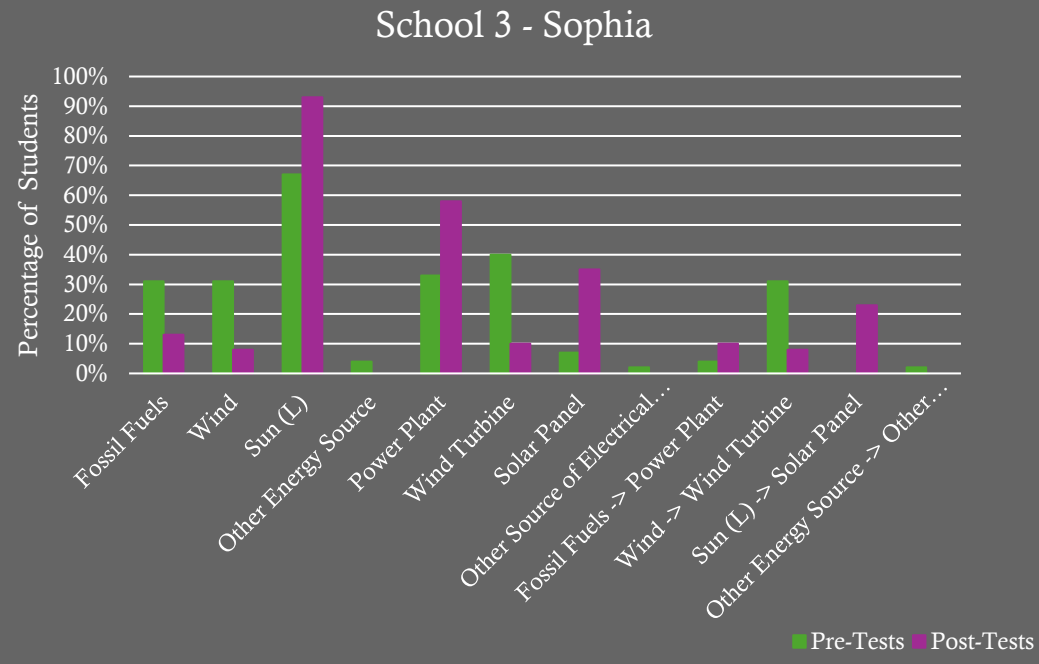
These charts show that Sophia's students had the highest frequency of codes across this category both pre and post. This may be due to being in 9th grade and covering some related content in prior grades.

Students at all schools commonly discussed the sun as a source of light.

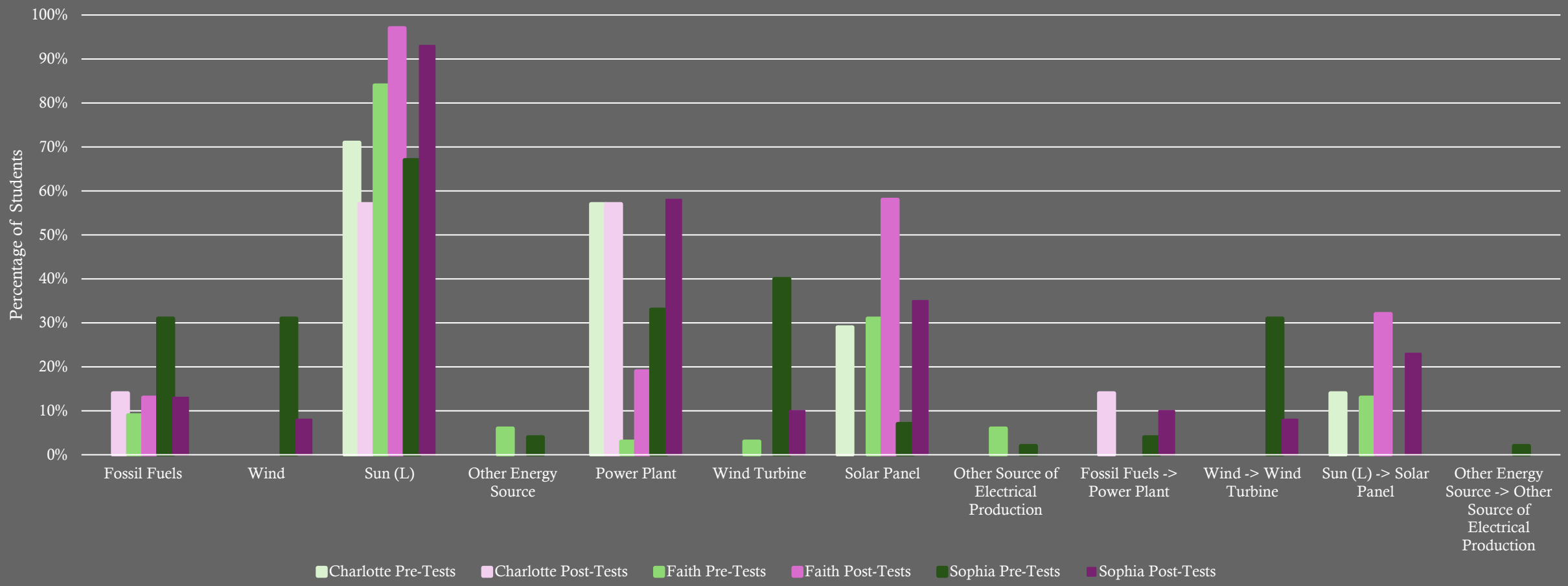
Charlotte and Sophia's students emphasized power plants.







Natural Resources & Electrical Production



Collapsing all pre and post schools into one bar chart emphasizes the prevalence of codes for sunlight and solar panels, where solar energy is the energy source with the most growth.

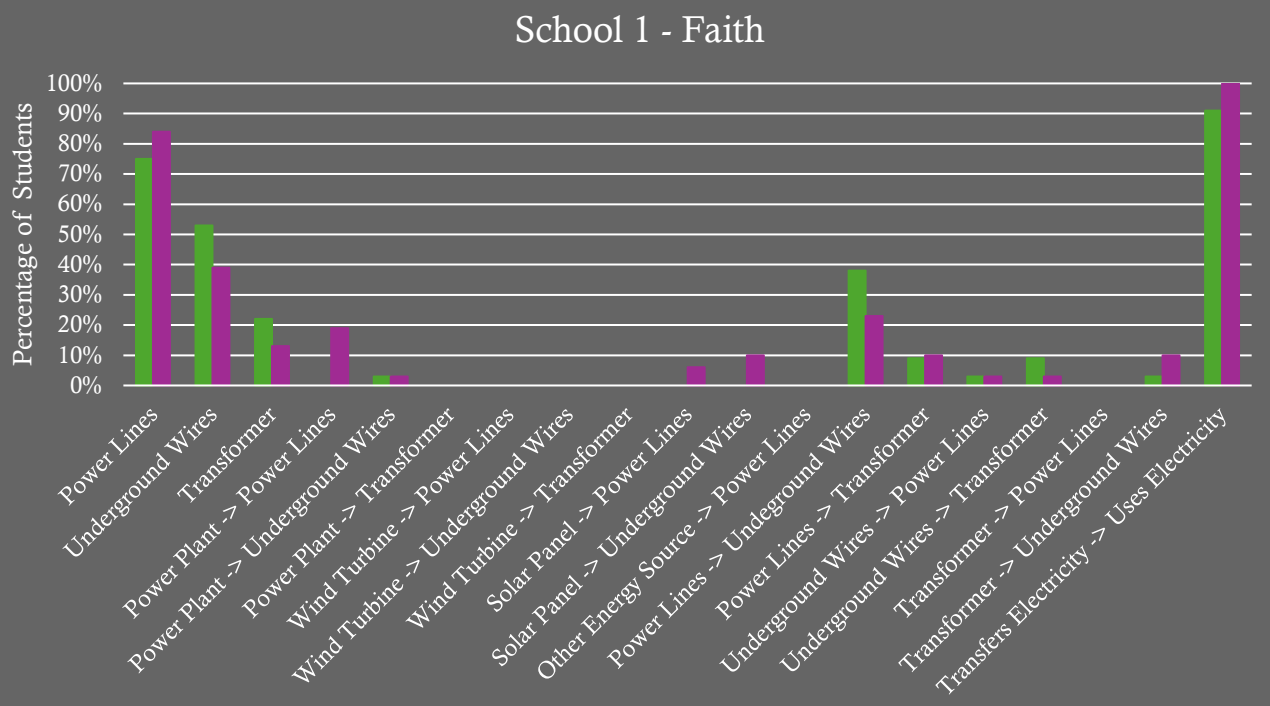
The Energy Grid:
Transfers Electricity

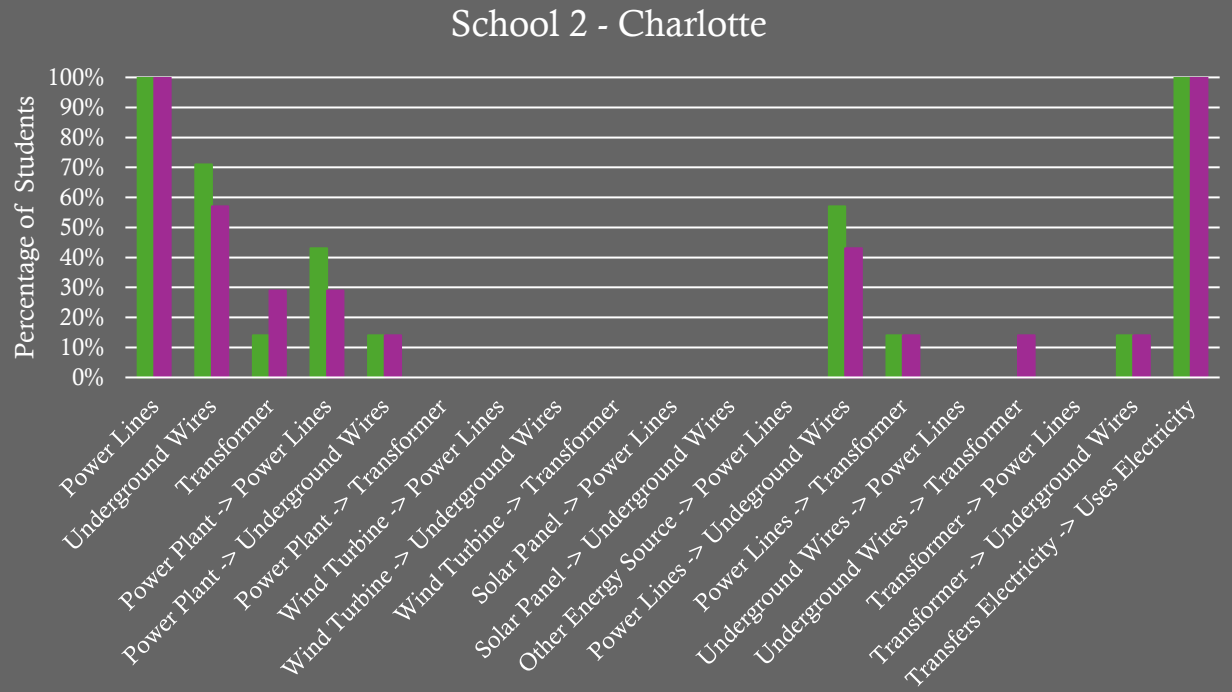
Transfers Electricity

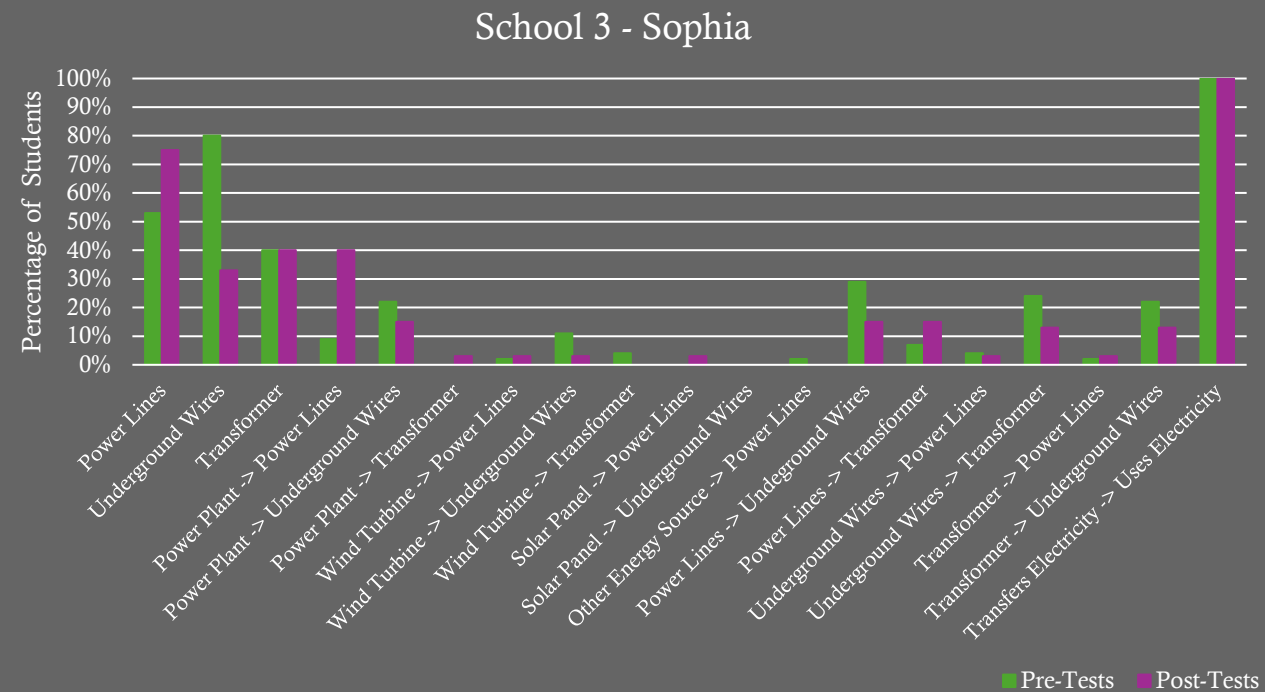
Students across schools generally depicted electricity transmission elements and connected power lines to the building.

It was less common to see student models depict transmission lines with alternative energy sources.

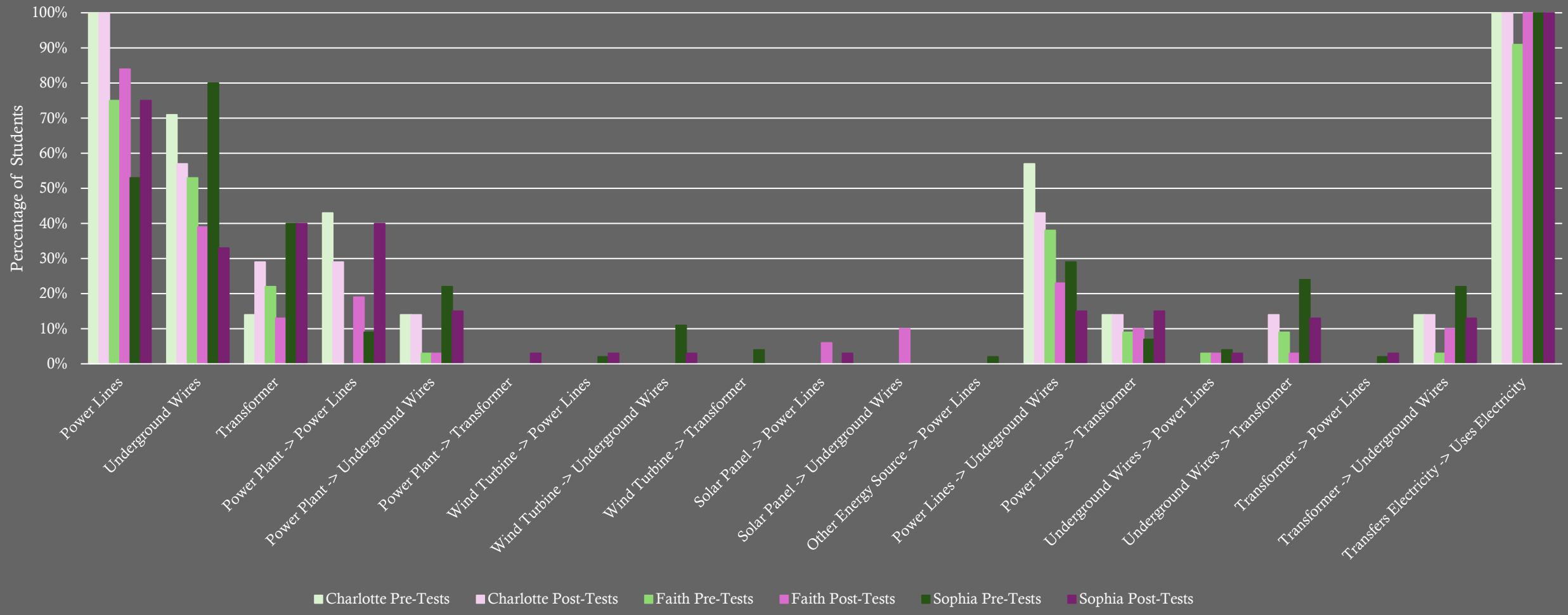
Students drew a mixture of power lines and underground lines, potentially influenced by the EYE unit visuals showing power lines







Transfers Electricity

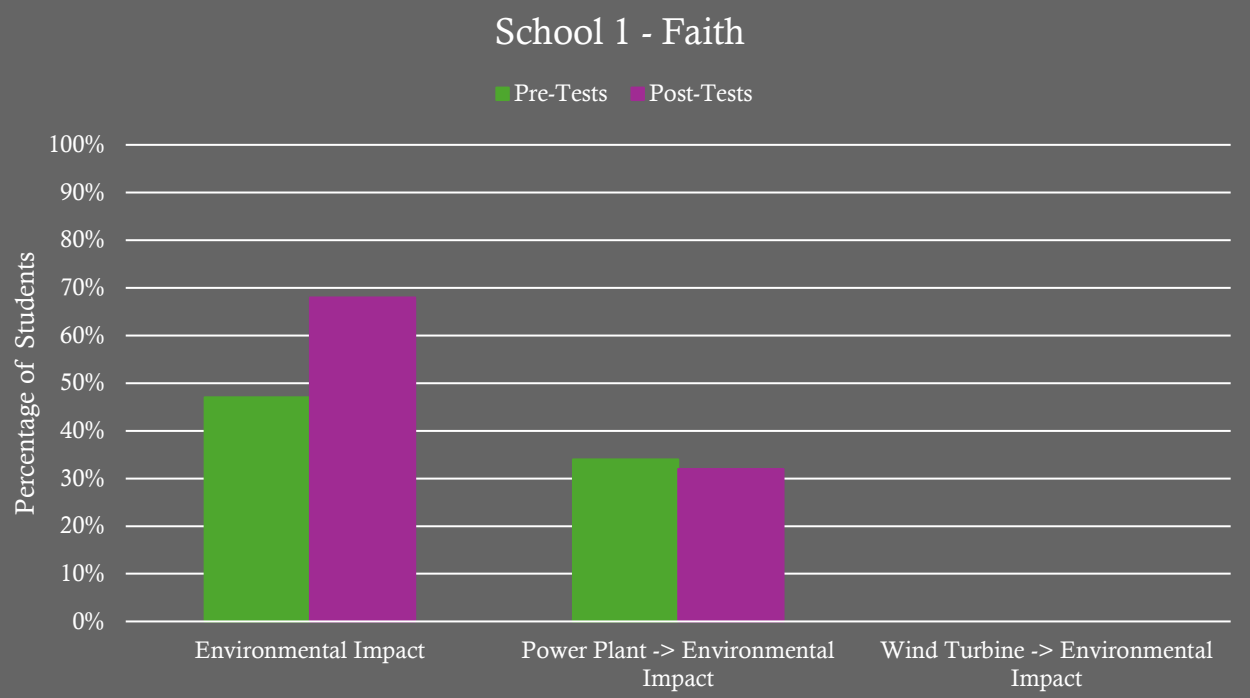


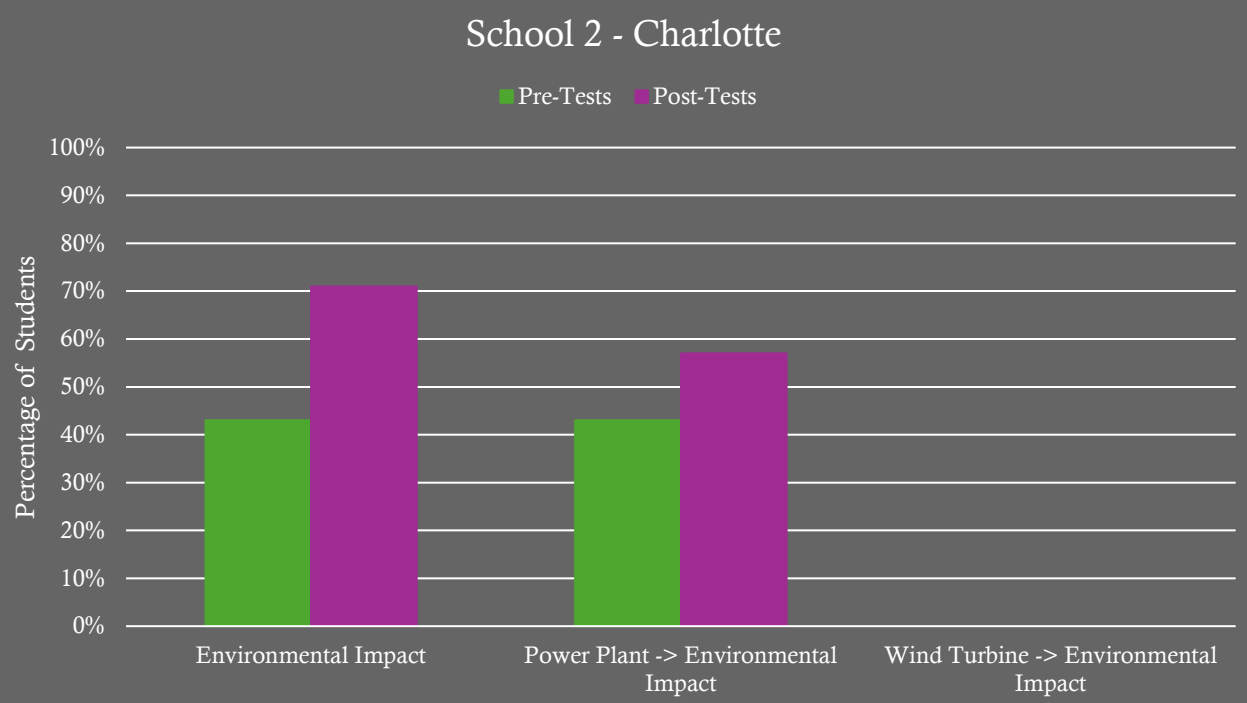
Students are comparable across schools on the 'Transfers Electricity' codes. Charlotte's students put more emphasis on power lines, which may have been influenced by the teacher given that 100% of students evidenced this element. Sophia's students show strong understanding in the pre-tests on this concept.

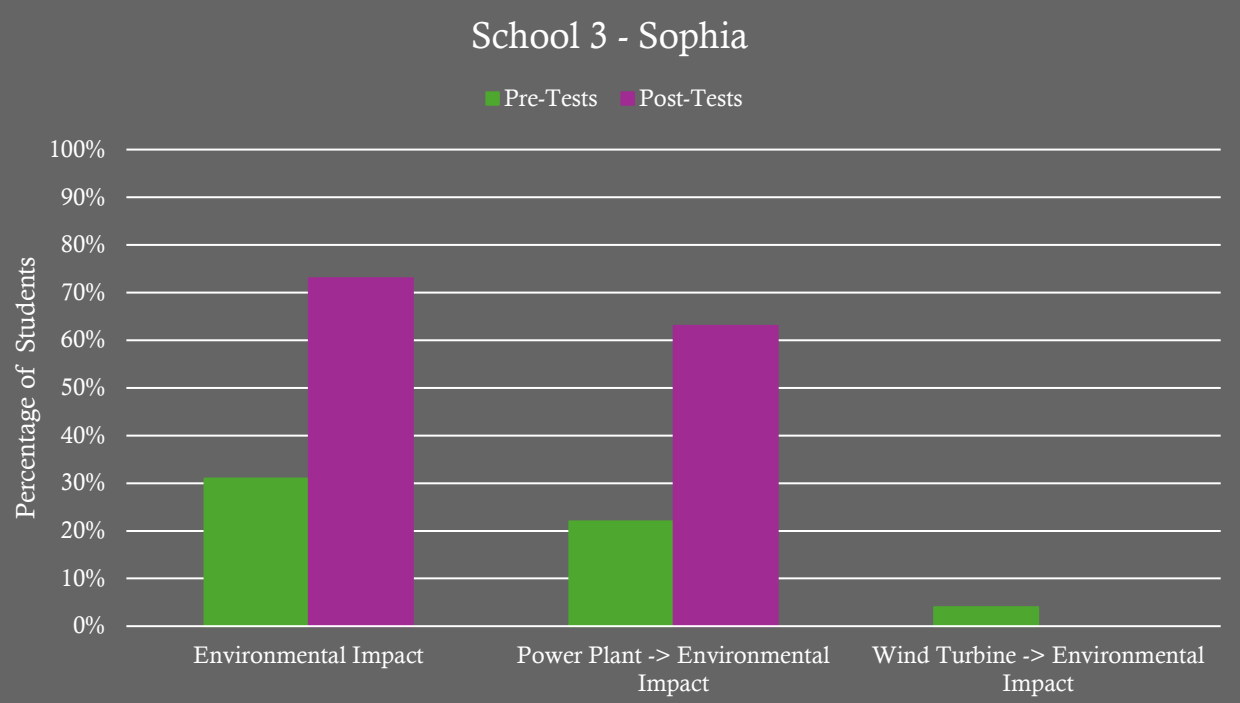
The Energy Grid:
Environmental Impact

Environmental Impact

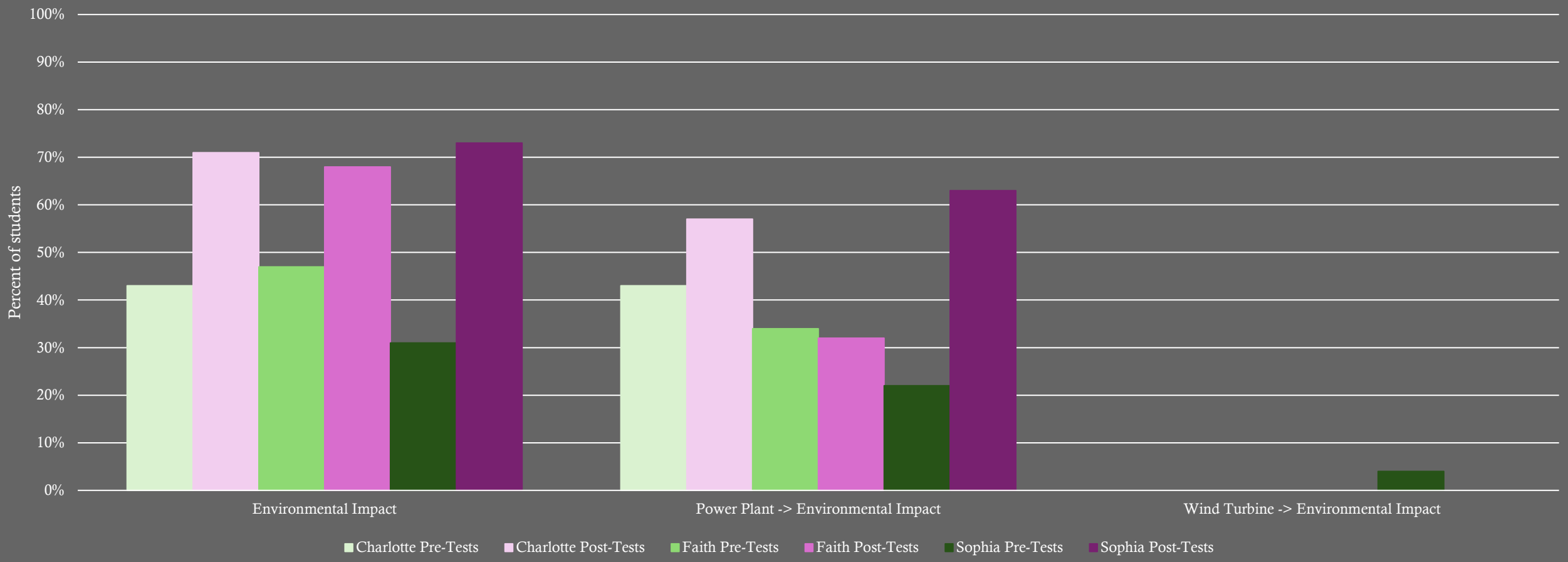
All groups gained understanding of environmental impact in relation to energy systems.







Environmental Impact



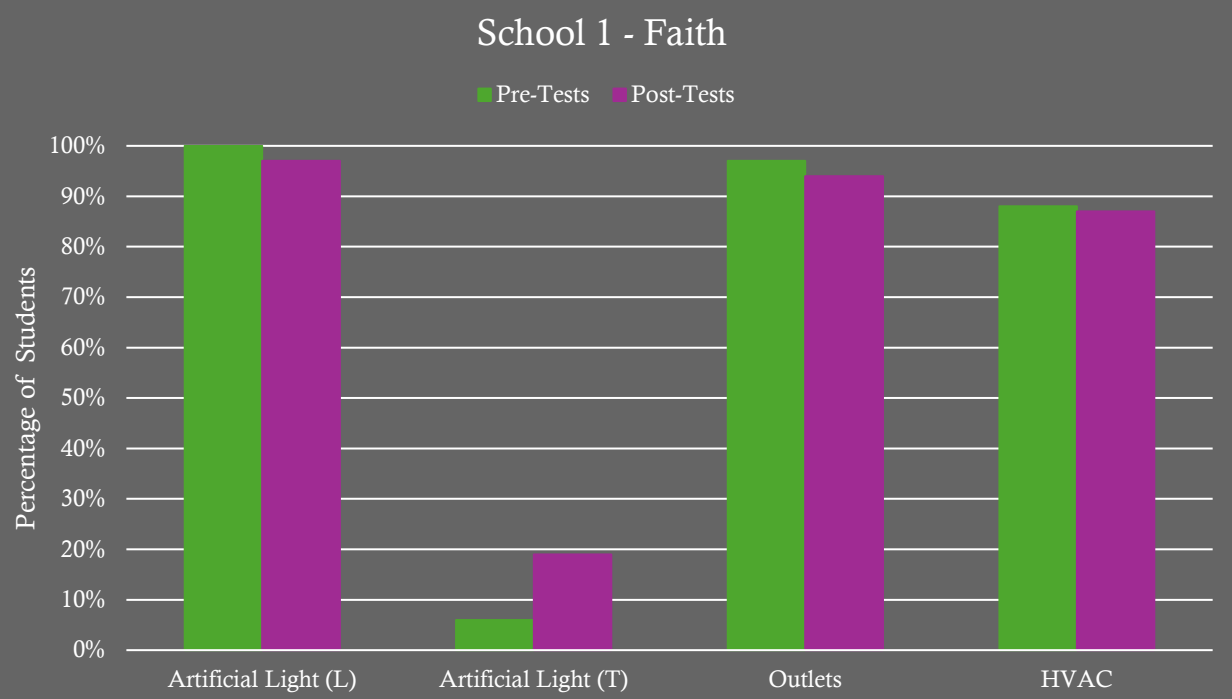
The Energy Efficient Classroom:
Uses Electricity

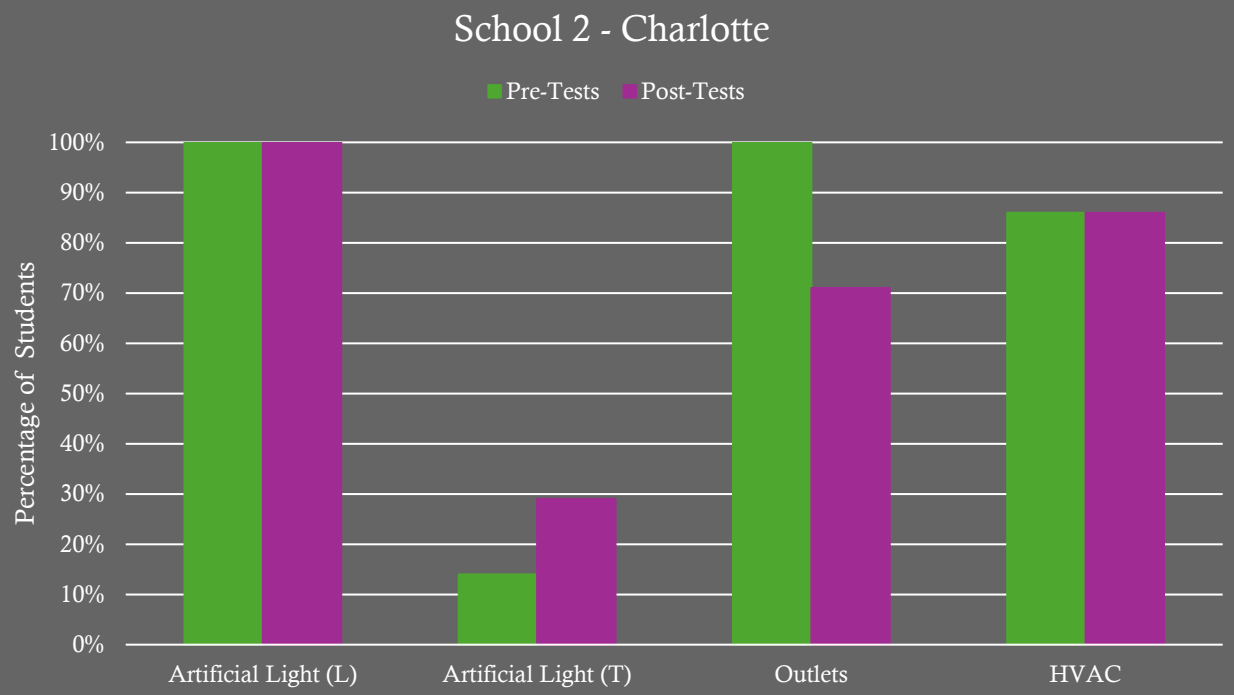
Uses Electricity

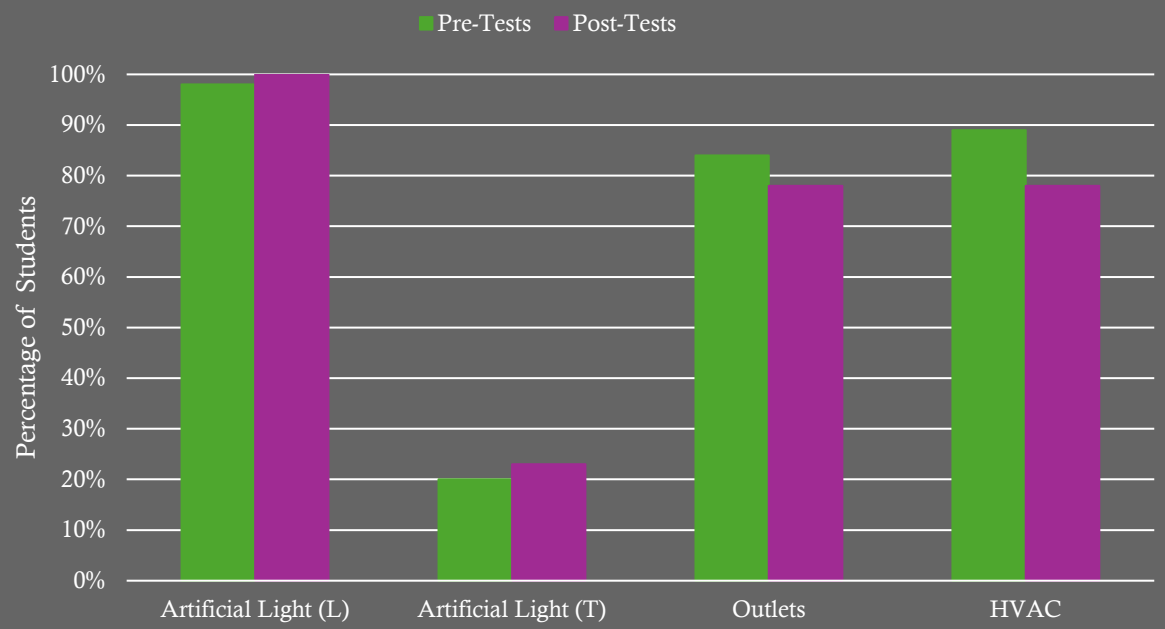
These are the groups of codes of elements in the classroom that use electricity.

All groups started with very strong understandings of artificial light, outlets, and the HVAC systems.

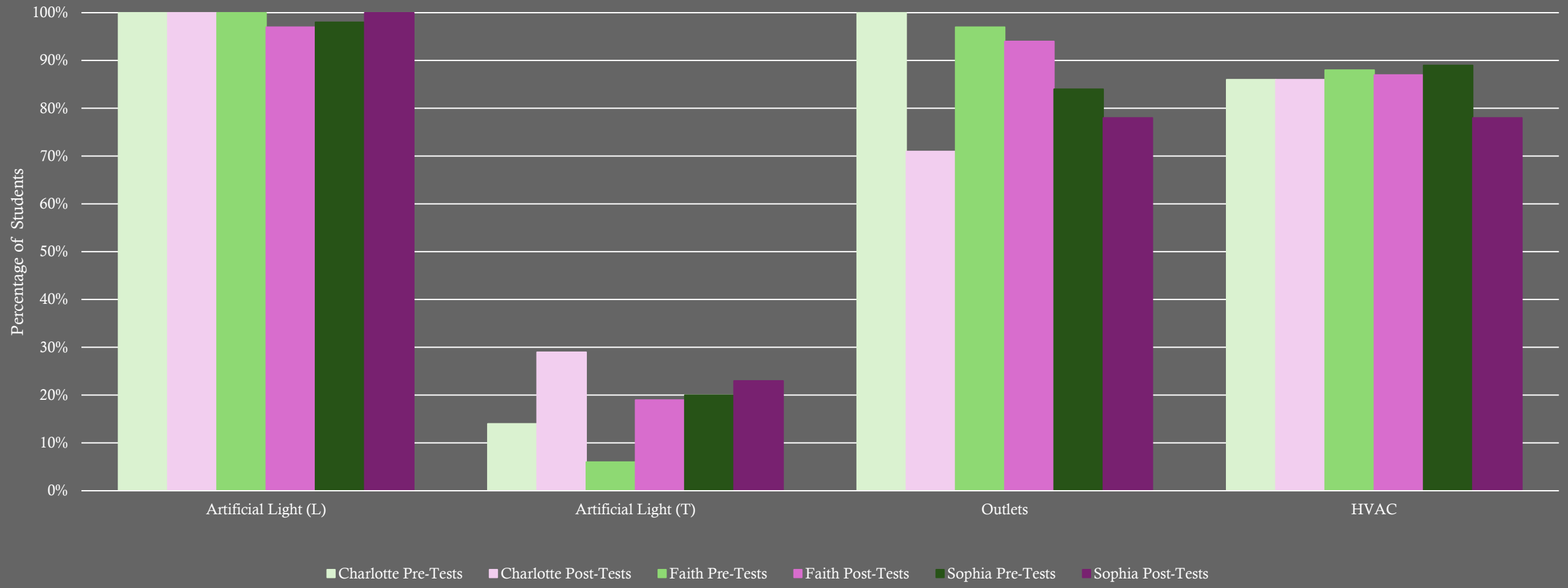
All groups gained understanding about artificial lights as a source of thermal energy.







Uses Electricity



Students across schools had similar frequencies and strong initial understandings.

The Energy Efficient Classroom: Light Energy & Building Design

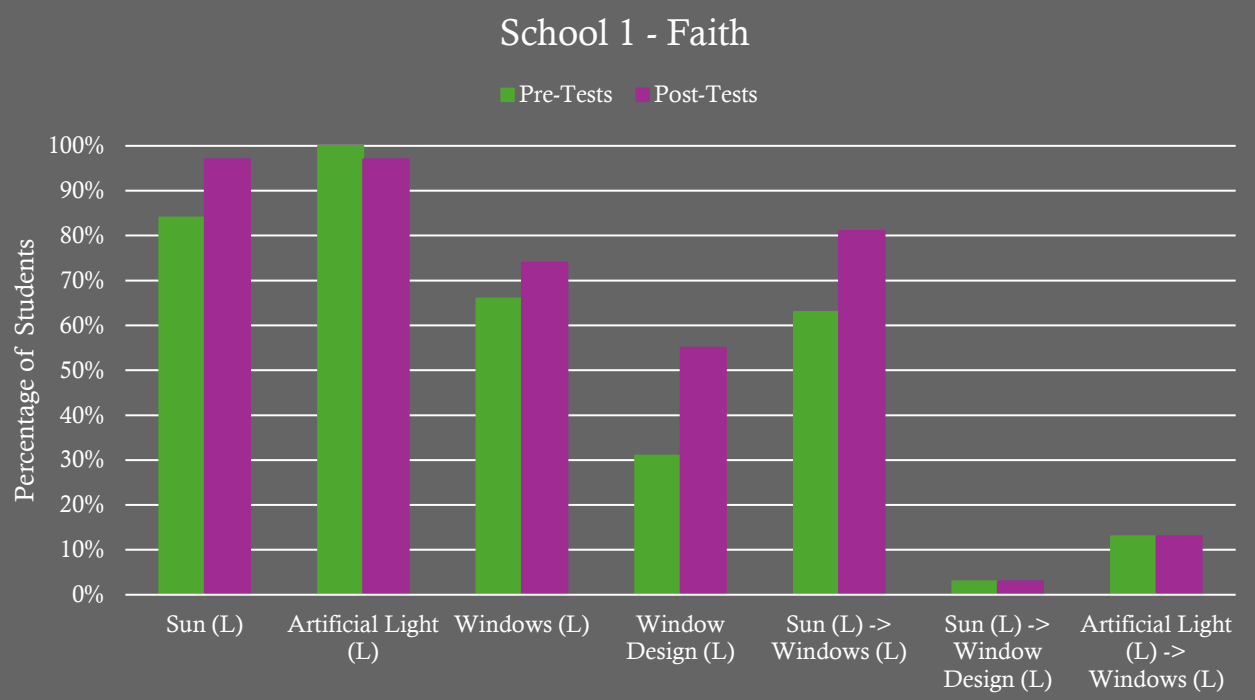
Light Energy & Building Design

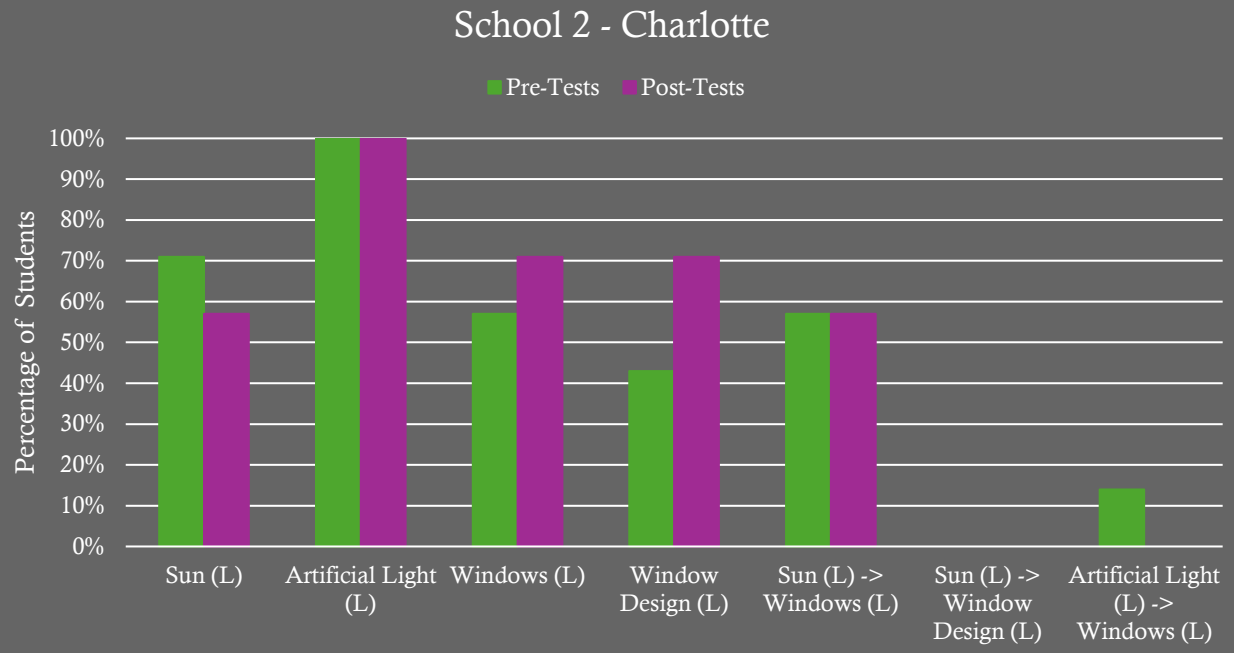
All groups started with very strong understandings of artificial light.

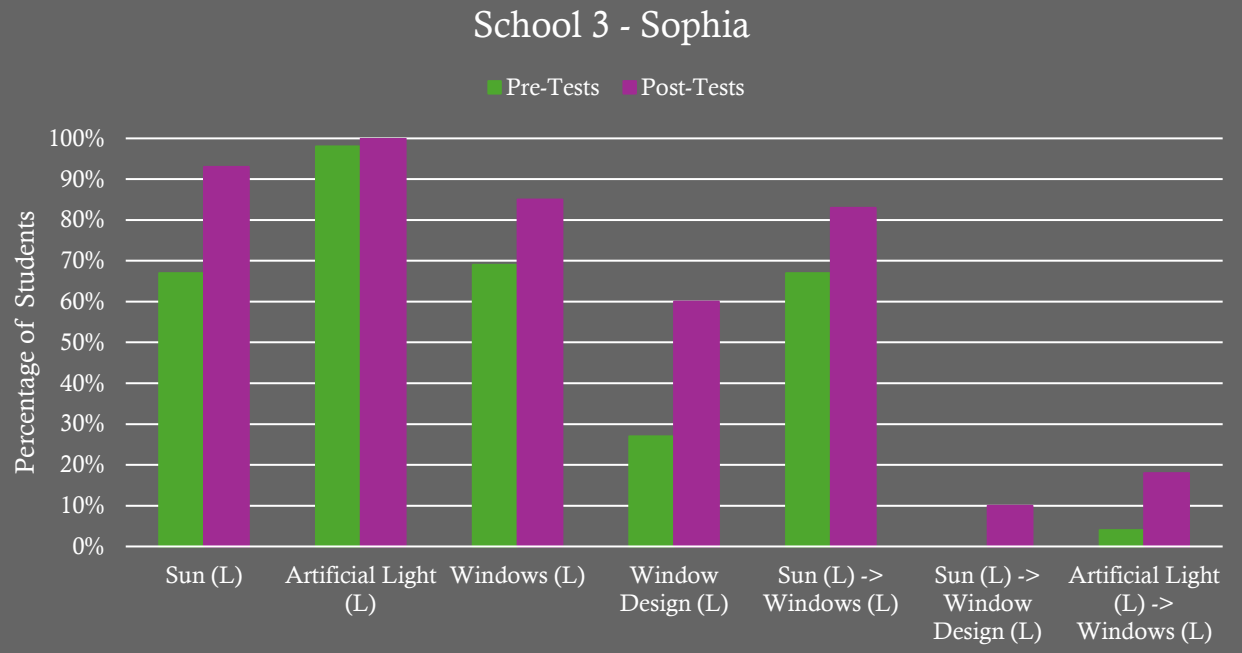
All groups had significant gains in understanding about windows as a light source and window design features that block light.

Faith's and Sophia's students had significant gains in understanding about sun light and light energy traveling from the sun to windows while Charlotte's students showed less understanding about sun light in post-tests.

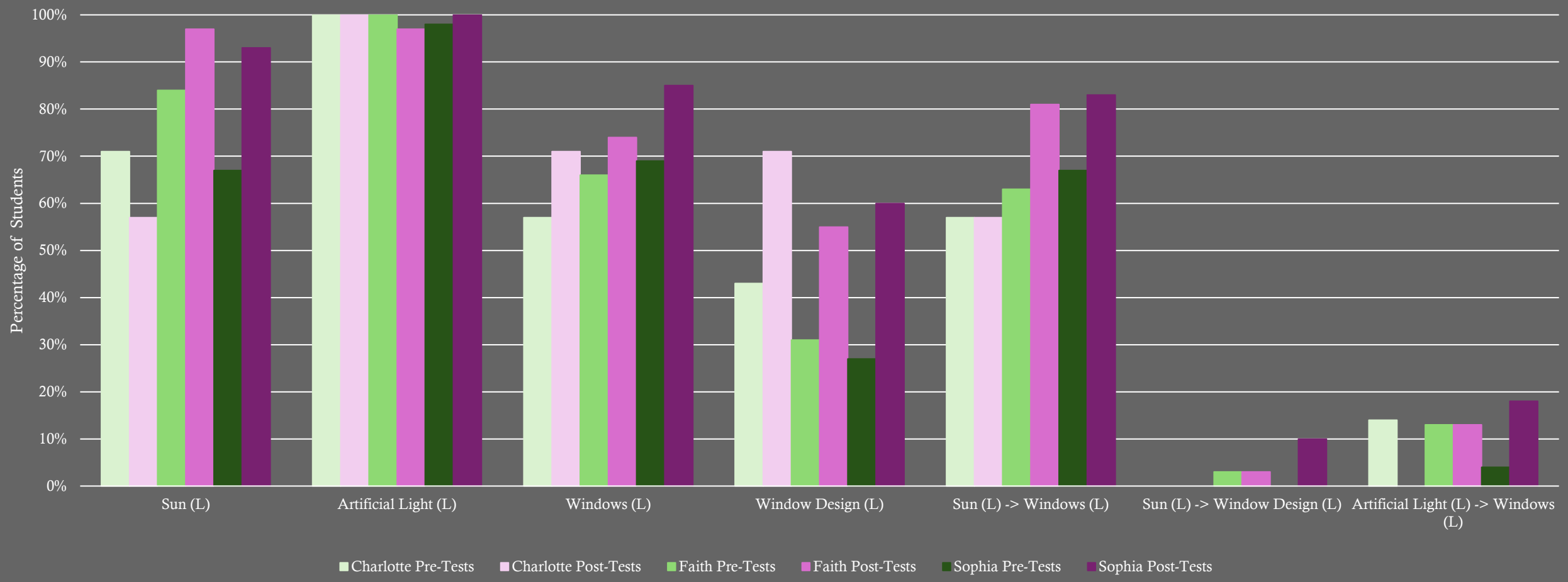
Sophia's students showed the greatest gains in understanding that sun light is blocked by window design features that block light and that light energy put off by artificial light also travels through windows.







Light Energy & Building Design



Clear gains in all schools regarding window design related to light energy.

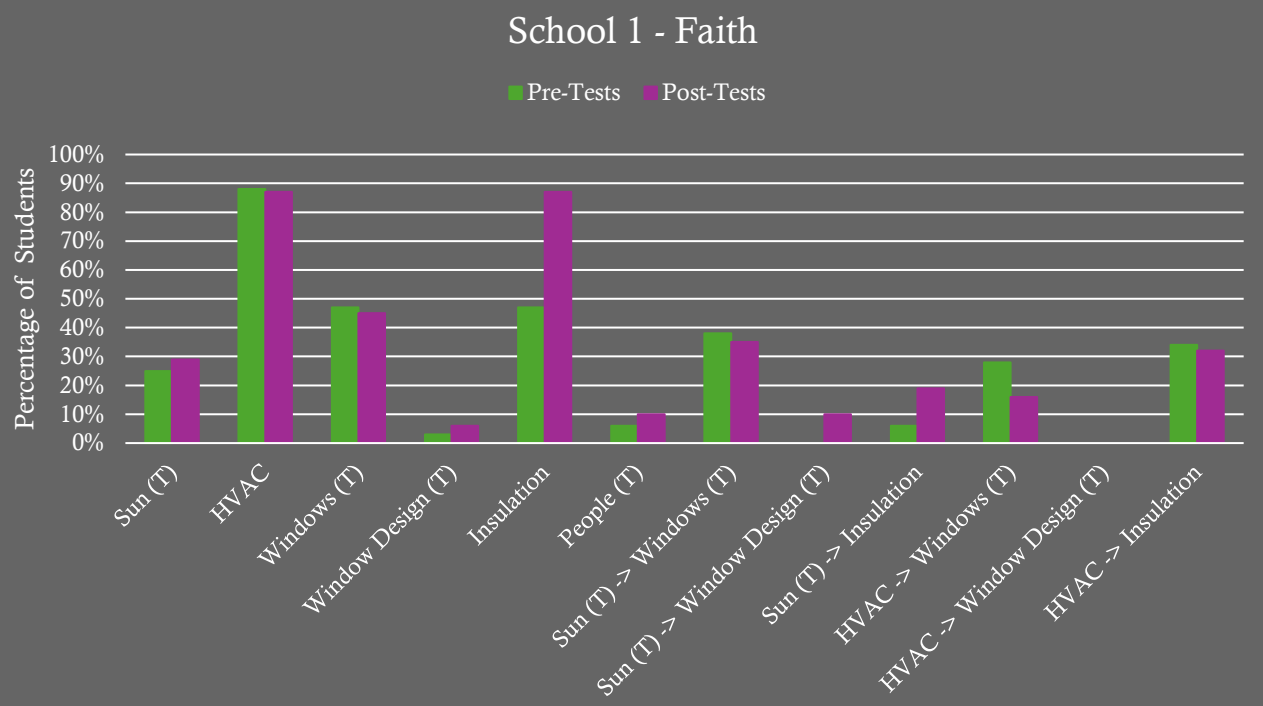
The Energy Efficient Classroom:
Thermal Energy & Building Design

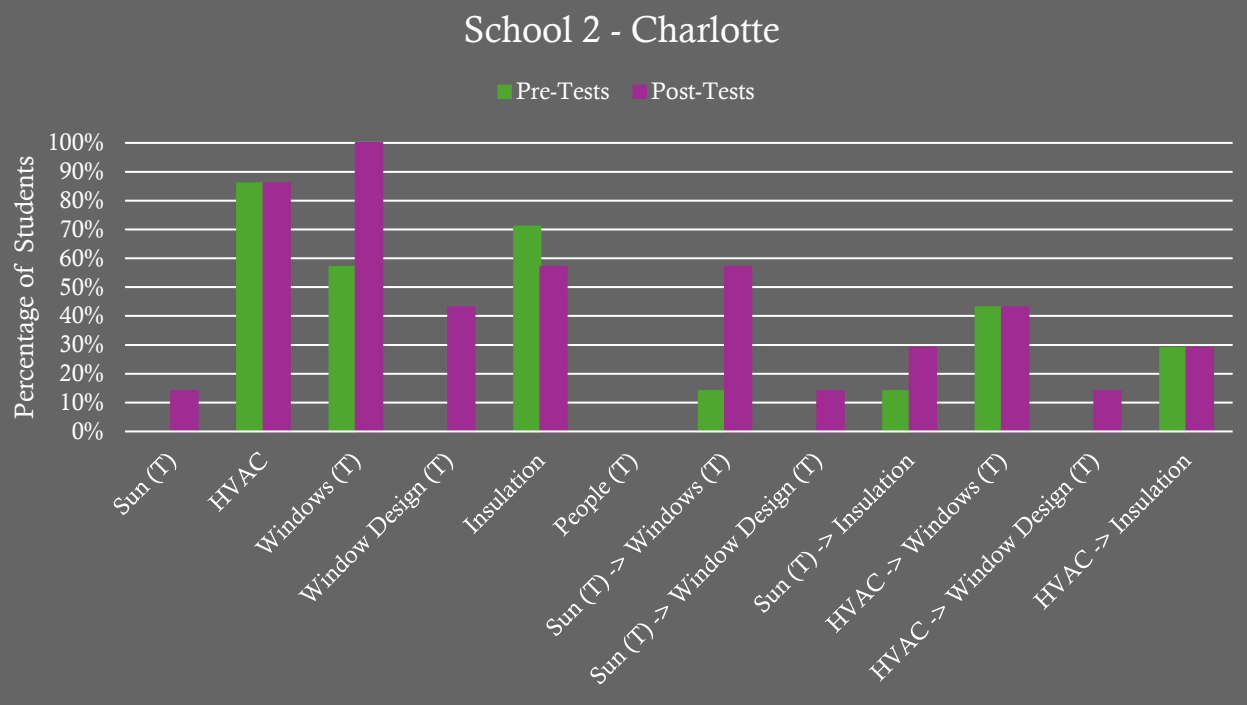
Thermal Energy & Building Design

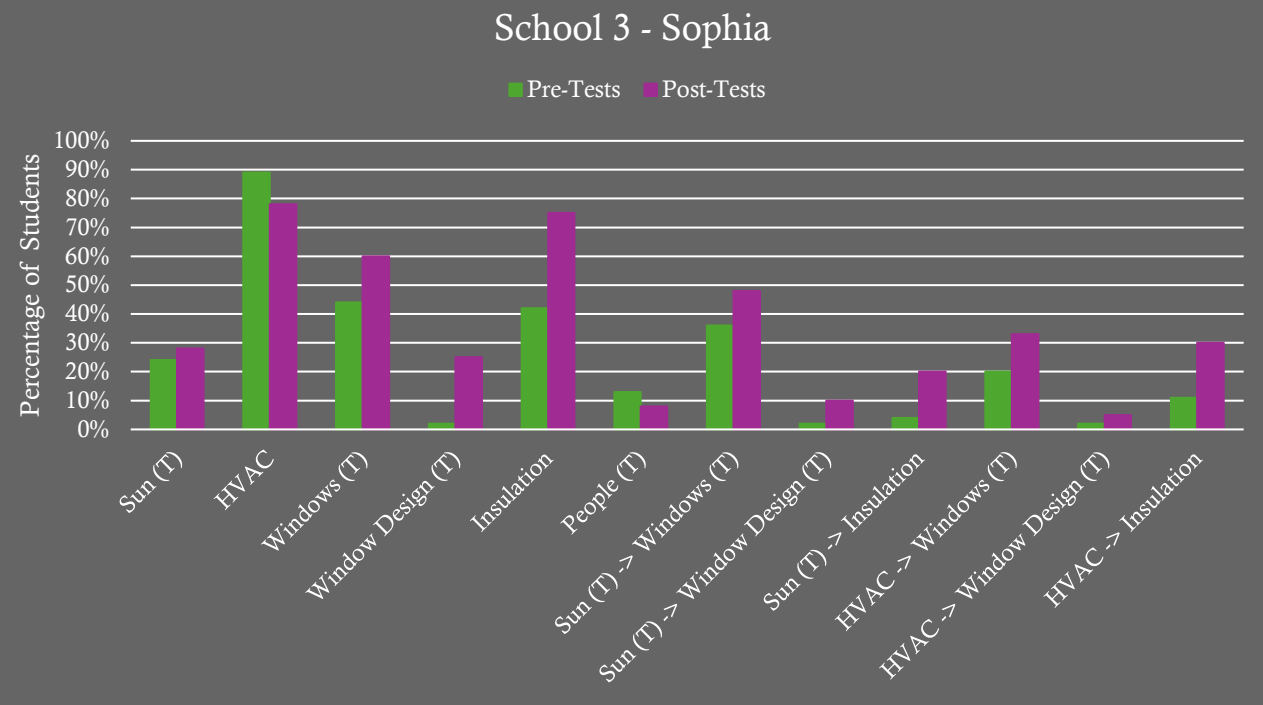
All groups gained an understanding about insulation blocking thermal energy from the sun.

Sophia and Charlotte's students show the strongest gains on window design for thermal, while Faith's class started strong on this element.

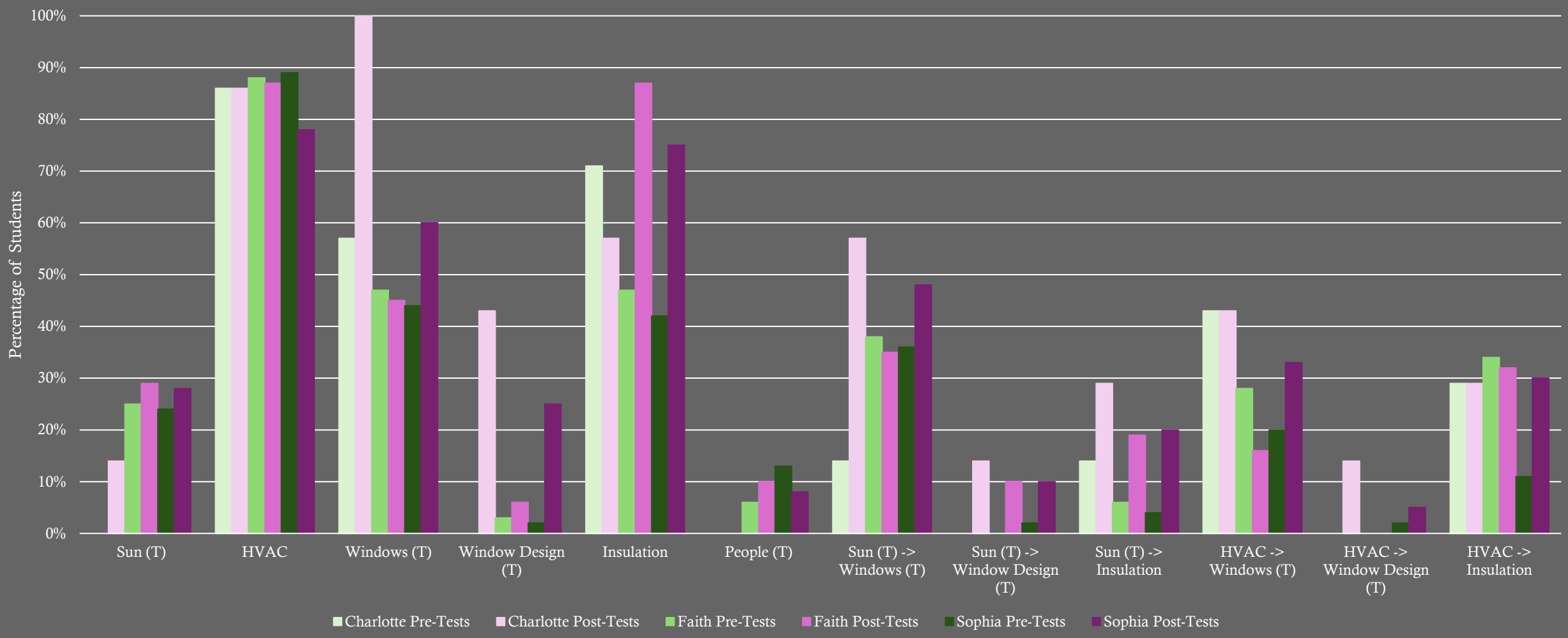
Sophia's students gained an understanding of how thermal energy from the HVAC system will travel out through windows but can be kept in the classroom by insulation.







Thermal Energy & Building Design



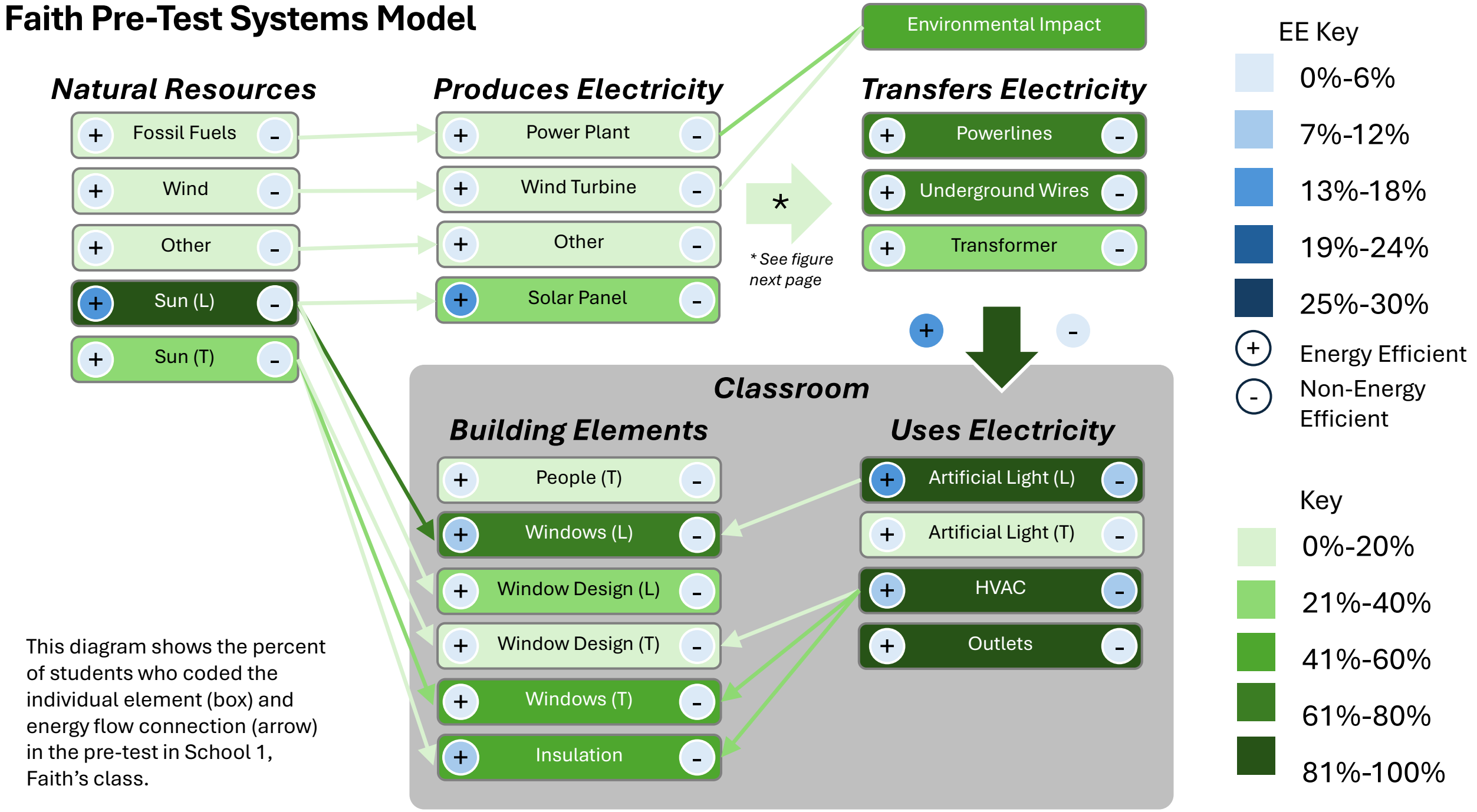
A high number of students in all schools depicted HVAC systems. The role of windows and insulation is elevated across the classroom in the post-test codes.

Systems Models by Teacher, Pre and Post

The following slides show the systems model diagram for each individual teacher, highlighting where their students collectively shifted emphasis from pre to post in their systems thinking

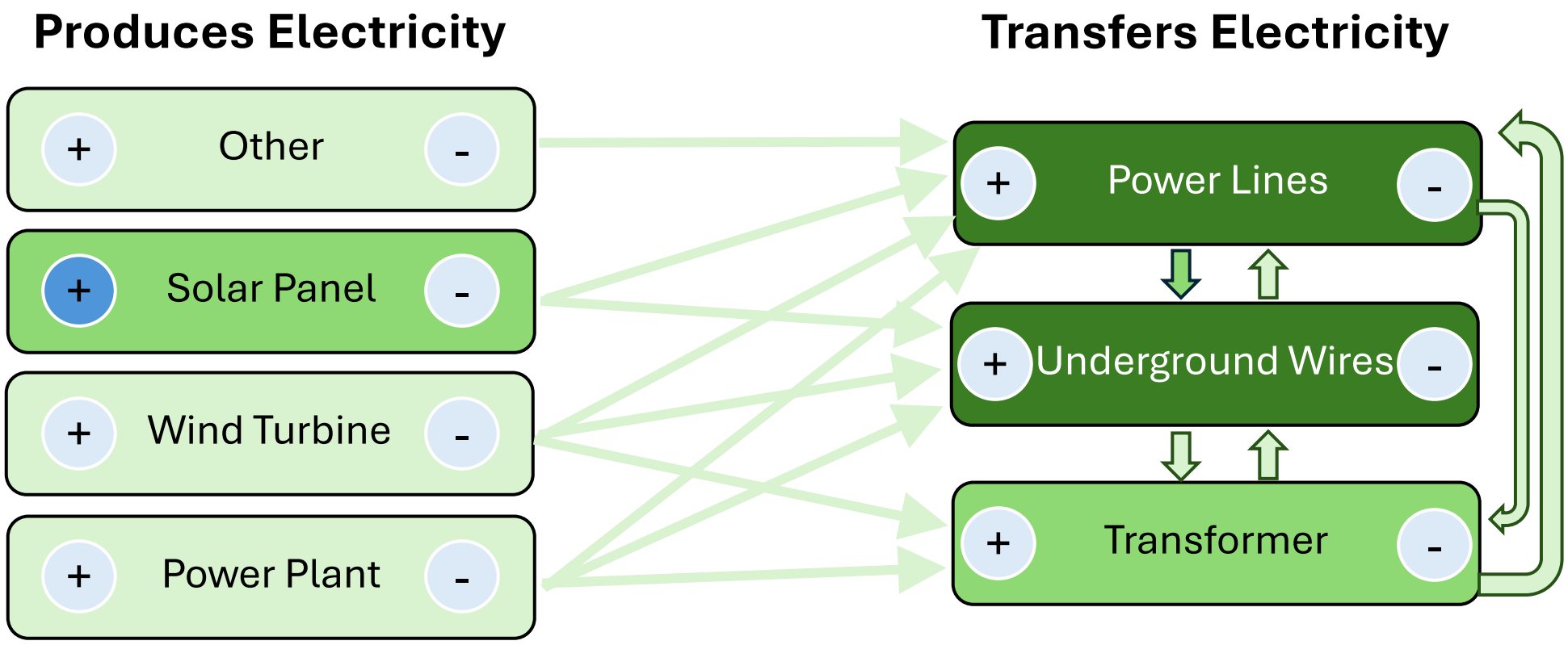
School 1
Faith

Faith Pre-Test Systems Model



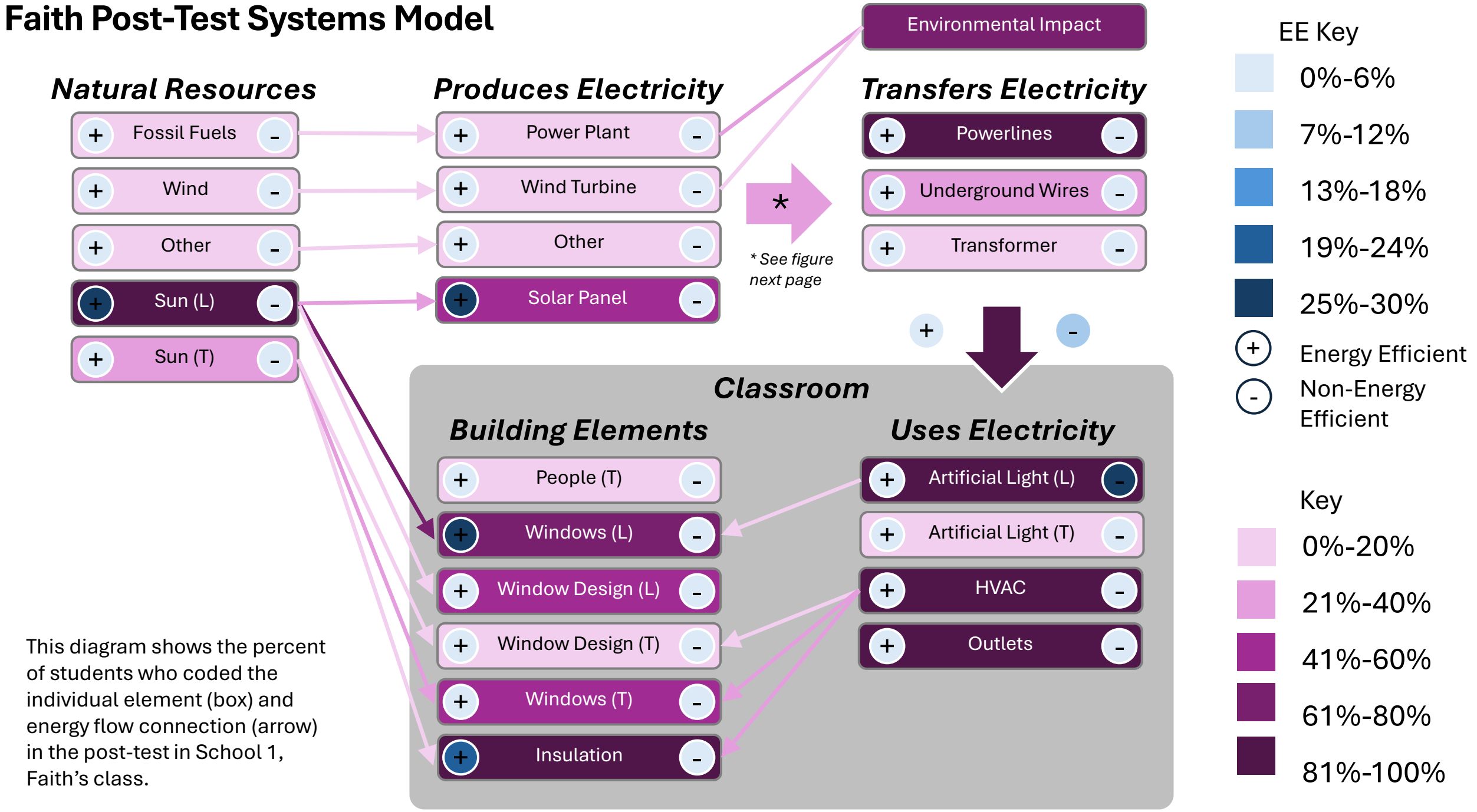
This diagram shows the percent of students who coded the individual element (box) and energy flow connection (arrow) in the pre-test in School 1, Faith's class.

*Faith Pre-Test Connections between Produces Electricity and Transfers Electricity



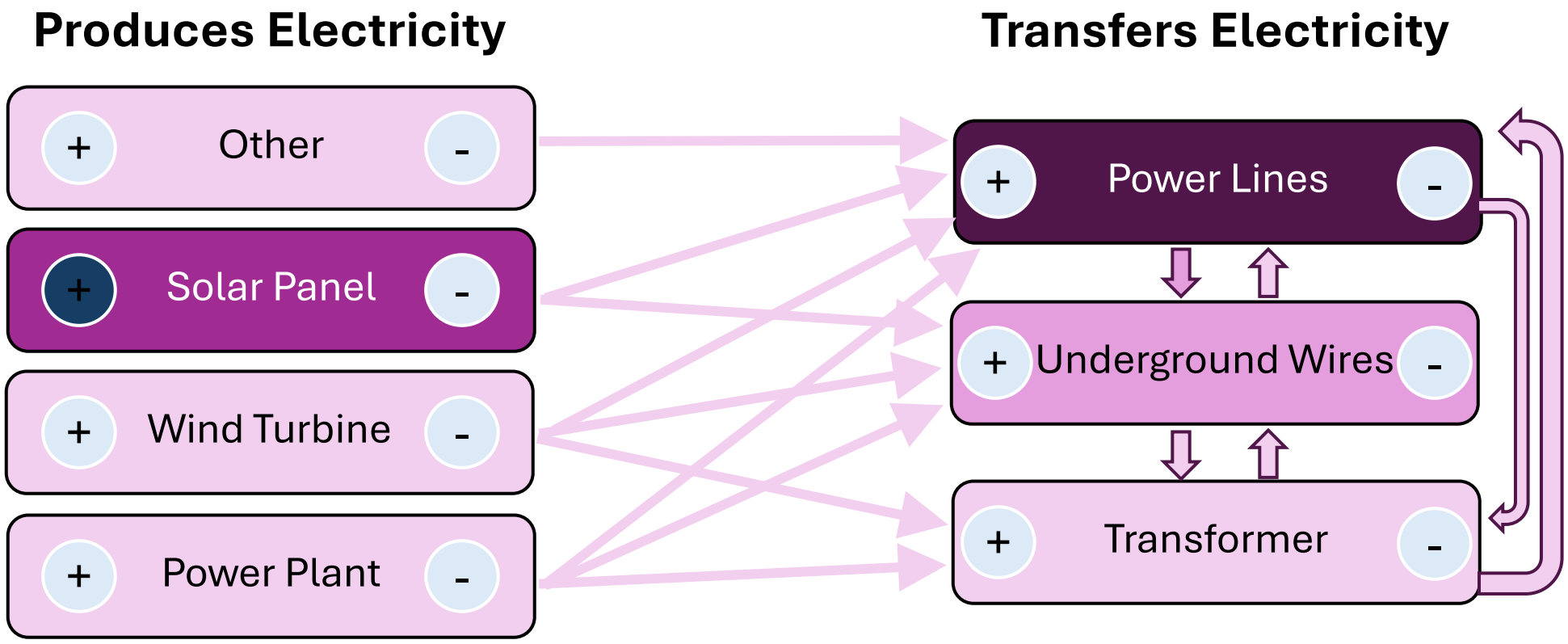
This diagram shows the detailed connections between produces Electricity and Transfers Electricity

Faith Post-Test Systems Model



This diagram shows the percent of students who coded the individual element (box) and energy flow connection (arrow) in the post-test in School 1, Faith's class.

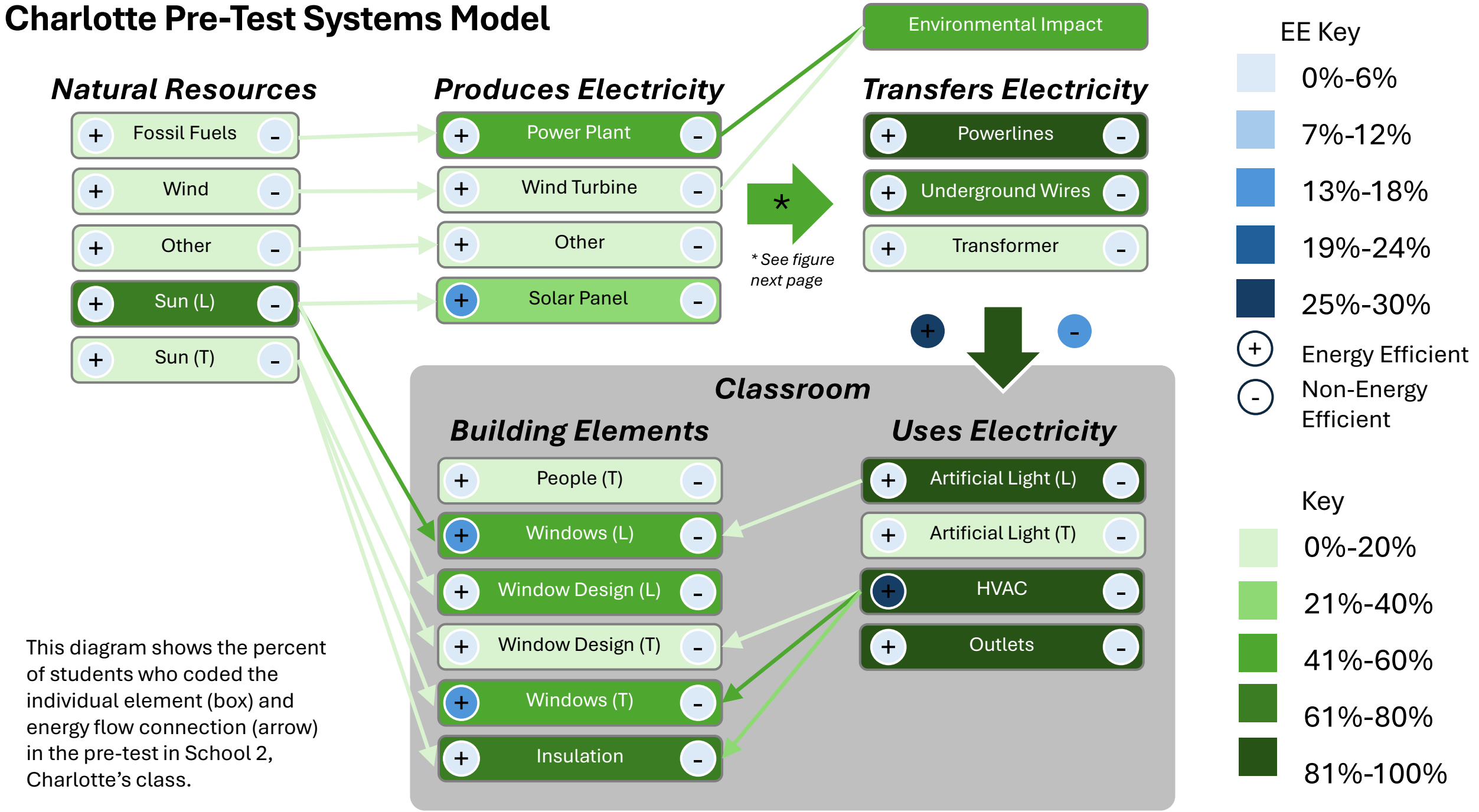
*Faith Pre-Test Connections between Produces Electricity and Transfers Electricity



This diagram shows the detailed connections between produces Electricity and Transfers Electricity

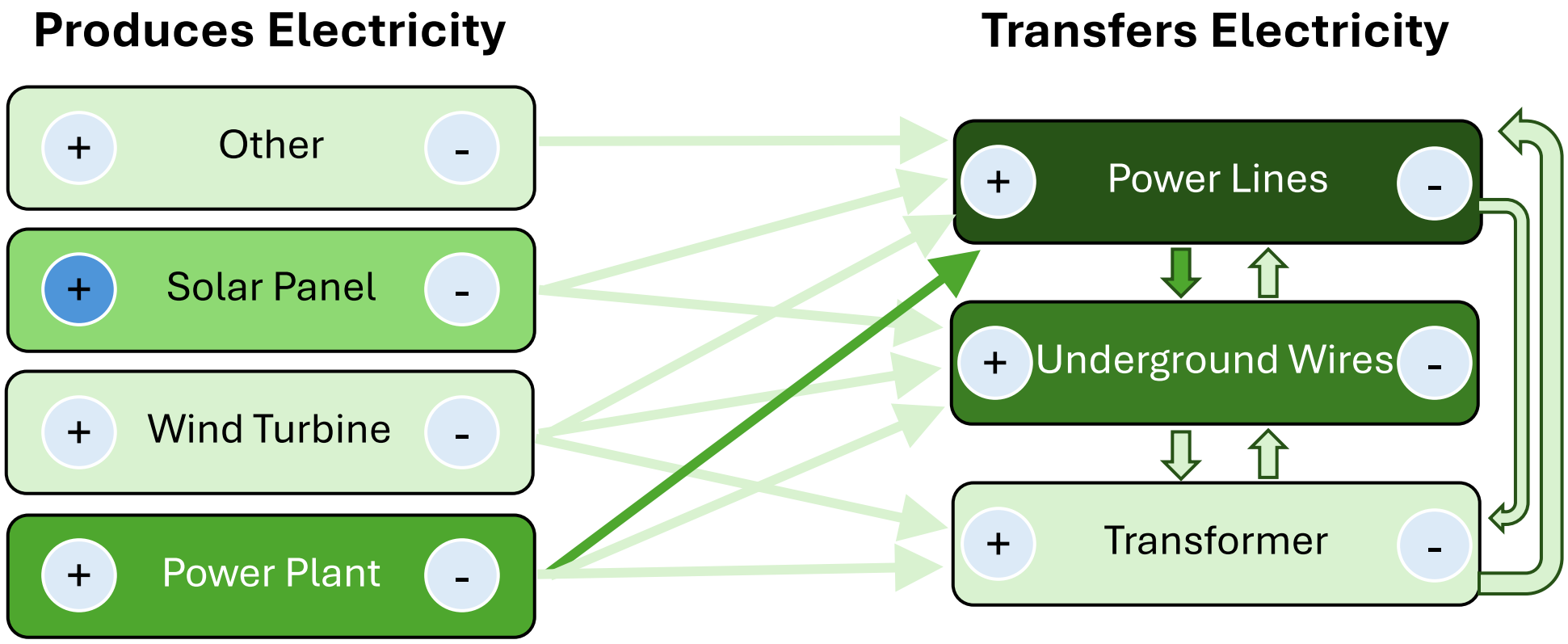
School 2
Charlotte

Charlotte Pre-Test Systems Model



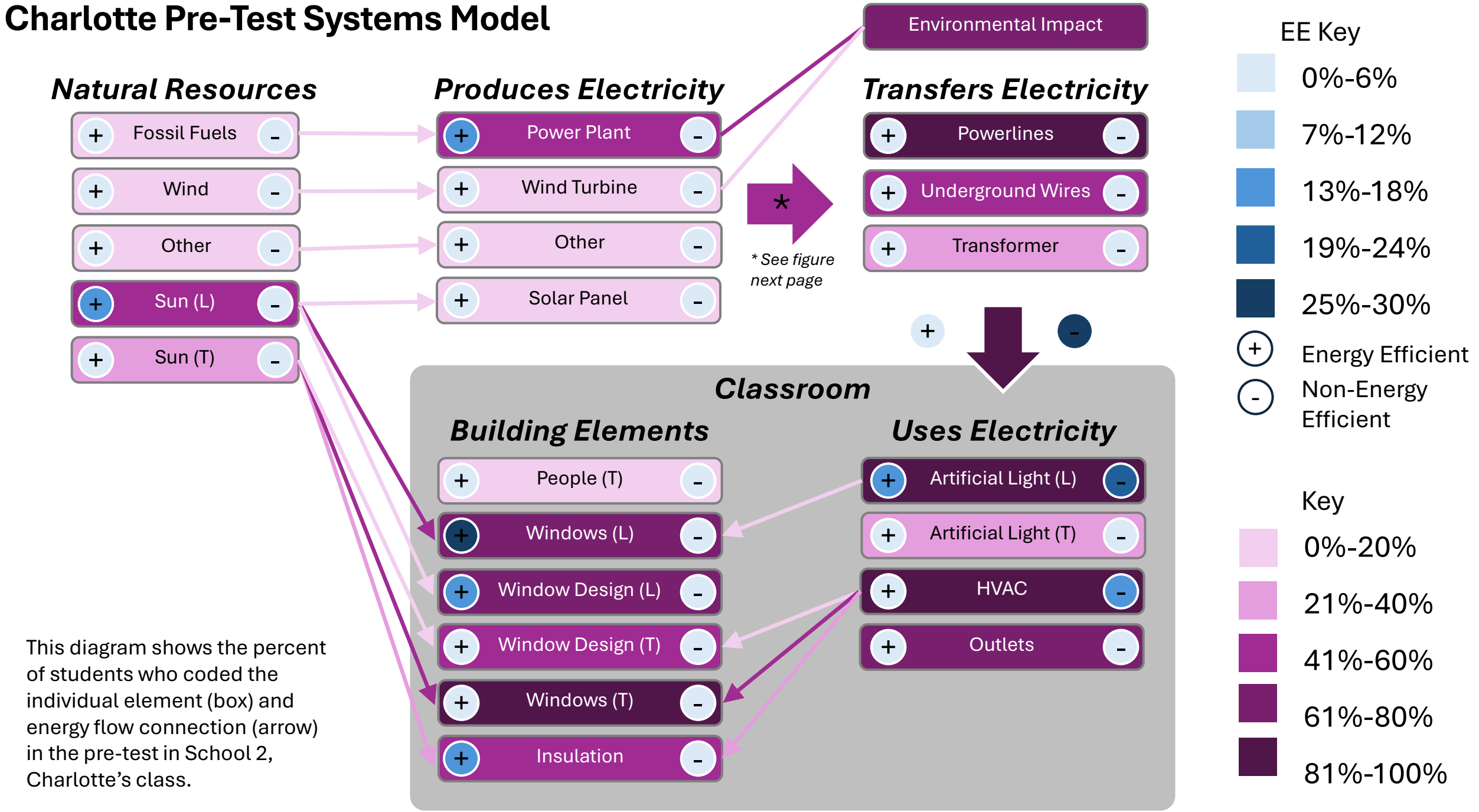
This diagram shows the percent of students who coded the individual element (box) and energy flow connection (arrow) in the pre-test in School 2, Charlotte's class.

*Charlotte Pre-Test Connections between Produces Electricity and Transfers Electricity



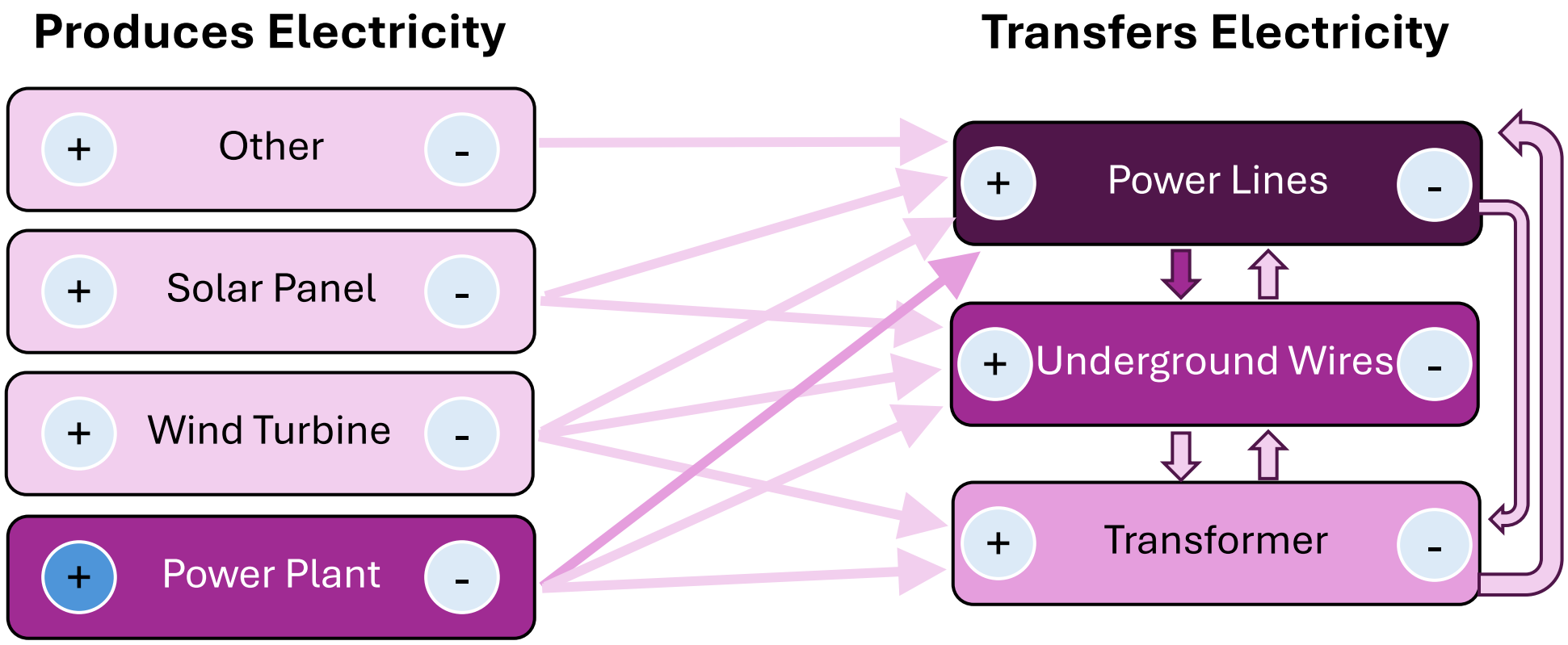
This diagram shows the detailed connections between produces Electricity and Transfers Electricity

Charlotte Pre-Test Systems Model



This diagram shows the percent of students who coded the individual element (box) and energy flow connection (arrow) in the pre-test in School 2, Charlotte's class.

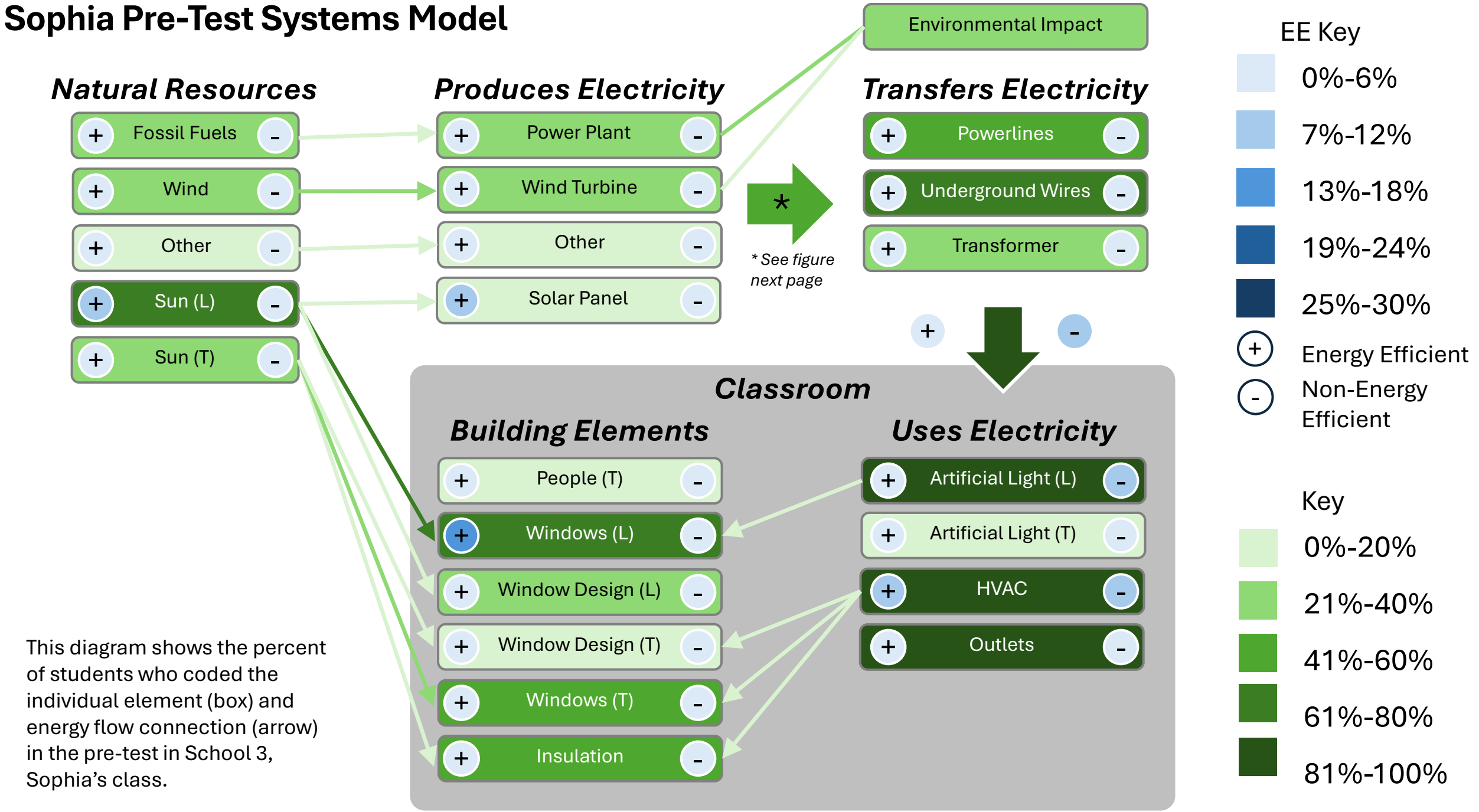
*Charlotte Post-Test Connections between Produces Electricity and Transfers Electricity



This diagram shows the detailed connections between produces Electricity and Transfers Electricity

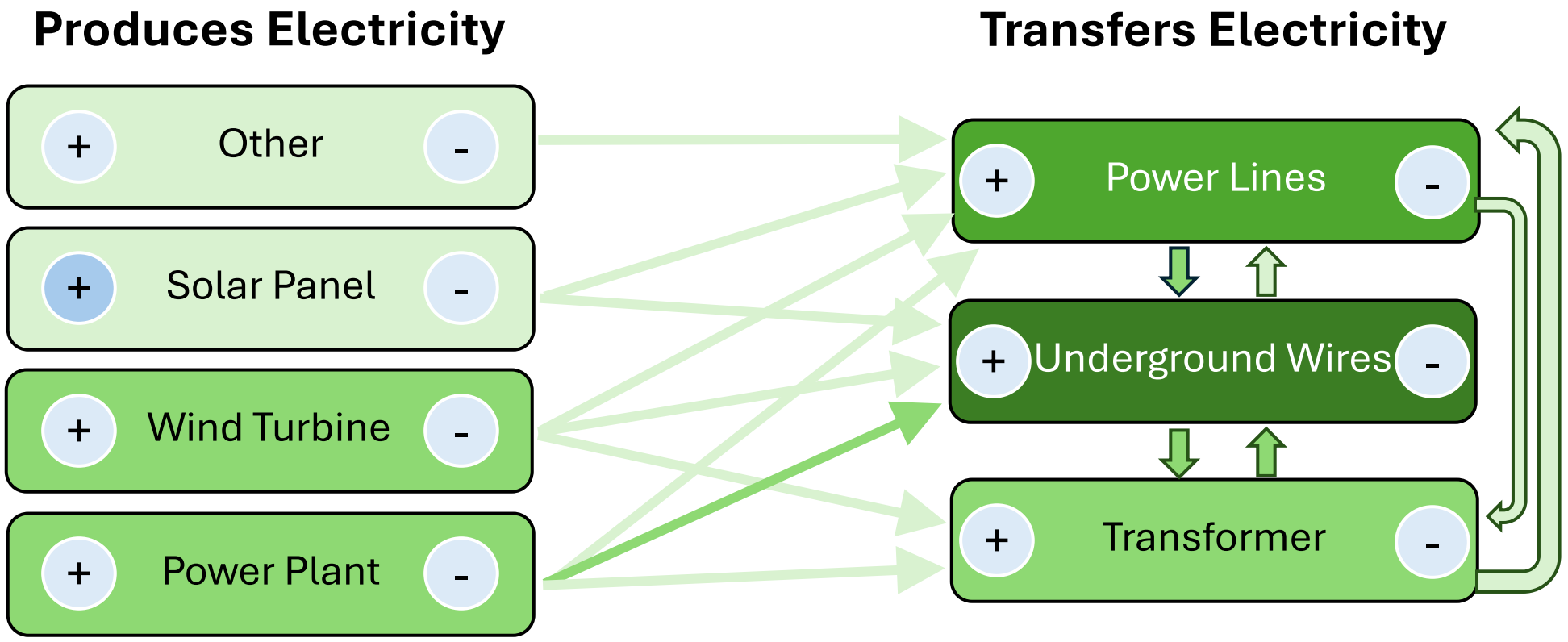
School 3
Sophia

Sophia Pre-Test Systems Model



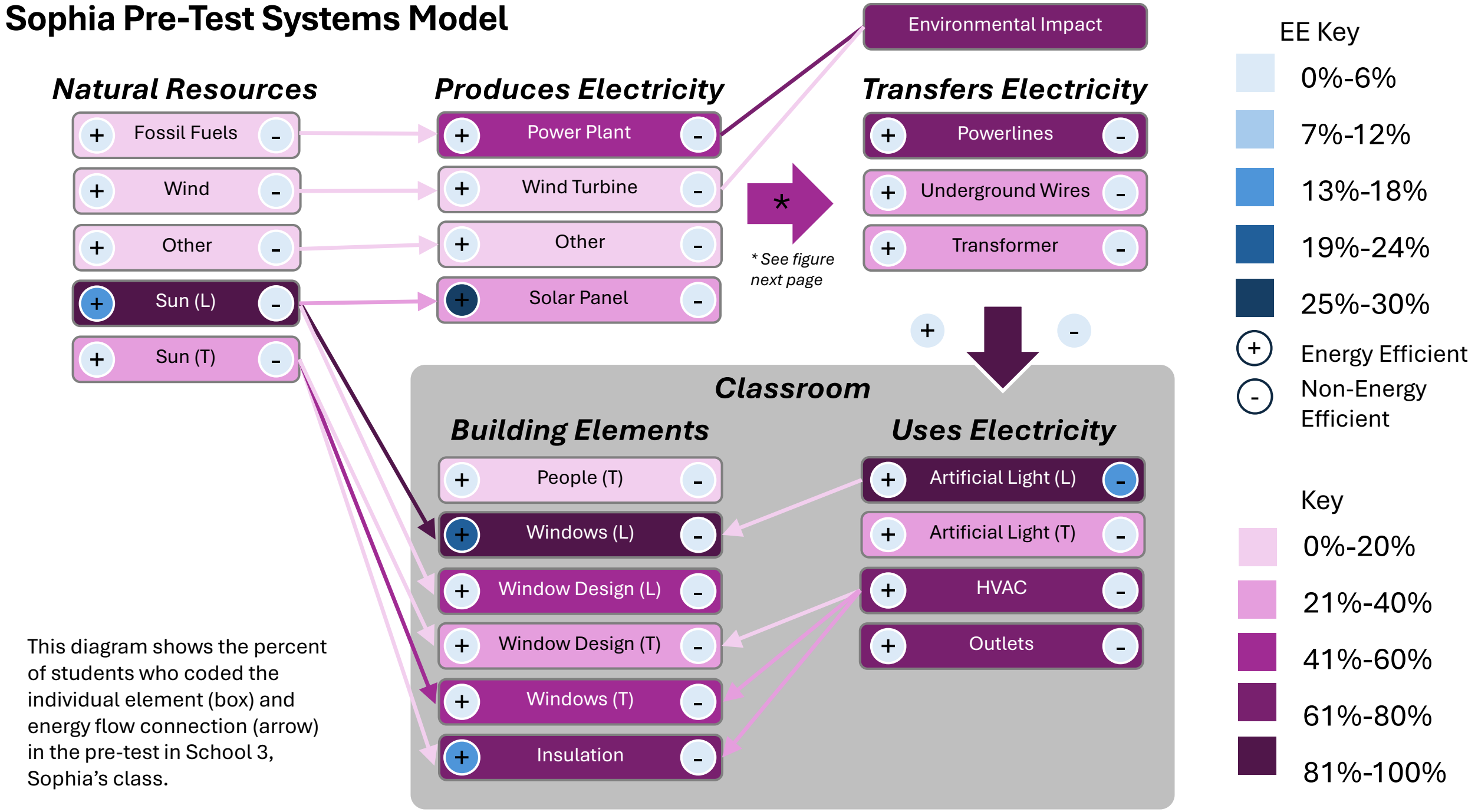
This diagram shows the percent of students who coded the individual element (box) and energy flow connection (arrow) in the pre-test in School 3, Sophia's class.

*Sophia Pre-Test Connections between Produces Electricity and Transfers Electricity



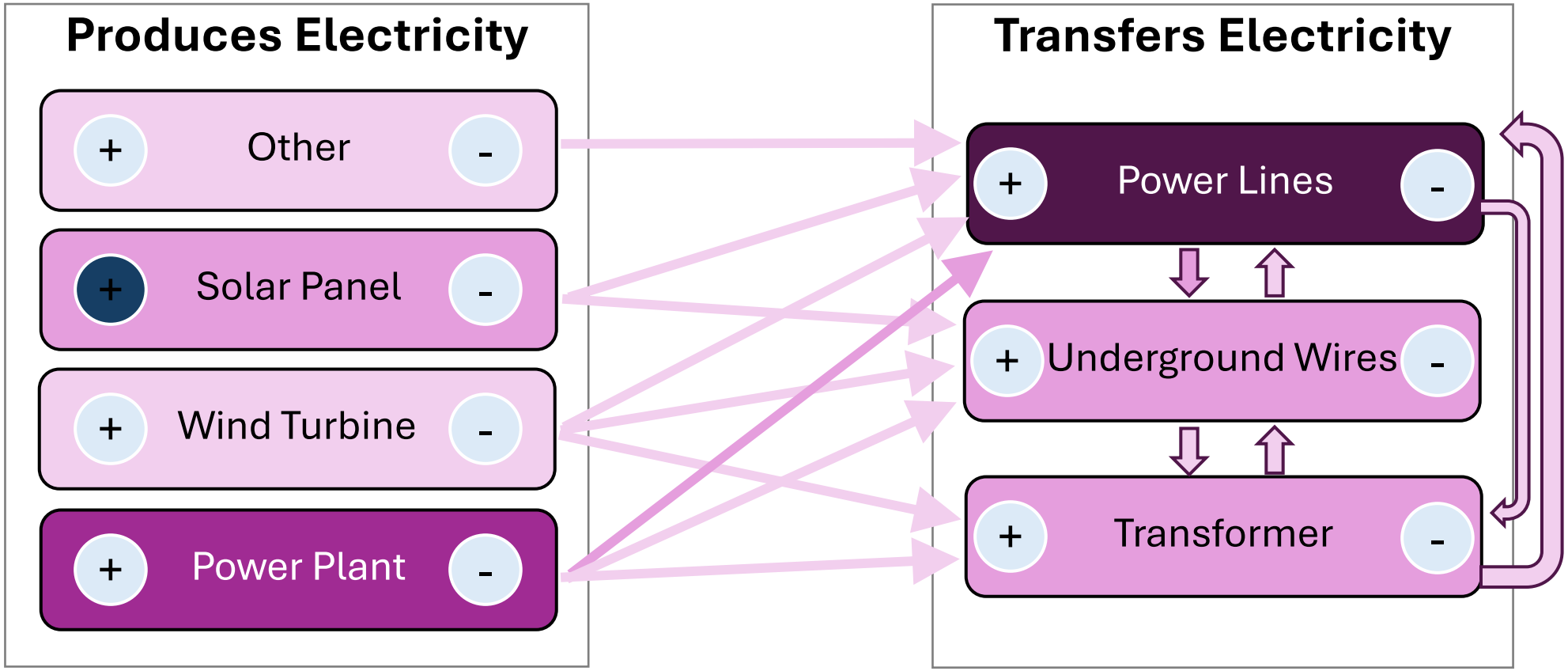
This diagram shows the detailed connections between produces Electricity and Transfers Electricity

Sophia Pre-Test Systems Model



This diagram shows the percent of students who coded the individual element (box) and energy flow connection (arrow) in the pre-test in School 3, Sophia's class.

*Sophia Pre-Test Connections between Produces Electricity and Transfers Electricity



This diagram shows the detailed connections between produces Electricity and Transfers Electricity