

The Nerdy Tree

Using *Picea glauca* Conifer Trees to Model Solar Energy Collection

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CWSF 5 Page Summary

Abstract

This project uses nature to design a system to collect an optimum level of solar energy using photovoltaic solar panels. The proposed system design is thus based on the mathematics of a spruce tree's (*Picea glauca*) south and southwest sides. Tests were run to see if the system would generate more power output than an average one-panel system with a rotating motor. Results proved that this system generated a maximum of 268% more power output, using a series circuit.

Background



The upward bending of branches is governed by the balanced interaction of growth hormones, the gibberellins and auxins. Gibberellins cause individual cells to expand and increase cell division in the apical and cambial meristems, which govern shoot elongation and branch diameter growth. Auxins act together with gibberellins. If cells in the tip meristem, sub-apical meristem, and cambial meristem grow more than the cells on the upper side of the branch, the branch grows at an upward angle.

Solar panels are made of silicon, a semiconductor material that absorbs light energy from the sun. This energy collides with electrons in the material,

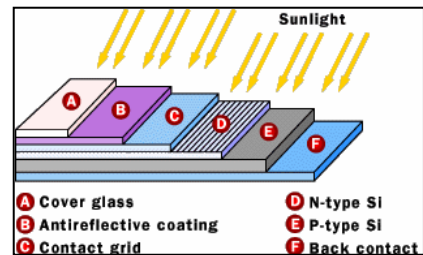
pushing them loose to cause movement within the atoms. Silicon atoms have

fourteen electrons each, arranged in three different shells. The inner two shells are filled with electrons. However, the outer shell has only four electrons, resulting in empty gaps. Impurities in the silicon such as phosphorous are added to fill up these spaces, creating a crystalline structure. This allows for one positive proton and electron to remain unattached. This is known as Negative-type silicon.

Positive-type silicon is made using boron atoms, which have three electrons each. Since there are extra electron spaces, the positive charge can be carried. An electric field is formed at a junction point of the two types of silicon. This acts as a diode that creates an external current path for an electrical current to pass through. This causes disruptions in electrical neutrality, and generates voltage throughout the panel.

Problem and Purpose

Currently, solar energy collectors are inefficient, as they require motors to allow panels to follow the sun, with the panel aligning itself to be at an angle perpendicular to the sun's rays. This is impractical, as the cost of tracking the sun with energy-wasting



motors outweighs the cost of a simple stationary mechanical assembly that could function self-sufficiently.

Collecting solar energy is an important task to continue to improve on, as it proves to be environmentally conscious. Solar panels are helping to decrease society's reliance on oil and gas. In this generation, an energy crisis continues to grow due to the fact that such non-renewable resources are becoming more difficult to obtain easily.

Hypotheses

1. Branches on the south side of a coniferous spruce tree will most likely be at or above 90°, where they can capture as much incident radiation as possible.
2. If the morphology of coniferous spruce trees is able to collect solar energy efficiently, then the same design could be adapted for use in solar panel arrangements.
3. Such a new solar panel arrangement should be more efficient than other systems. The series circuit is hypothesized to have a higher power output than a parallel-series circuit due to a higher voltage ratio.

Materials (for Data Collection)

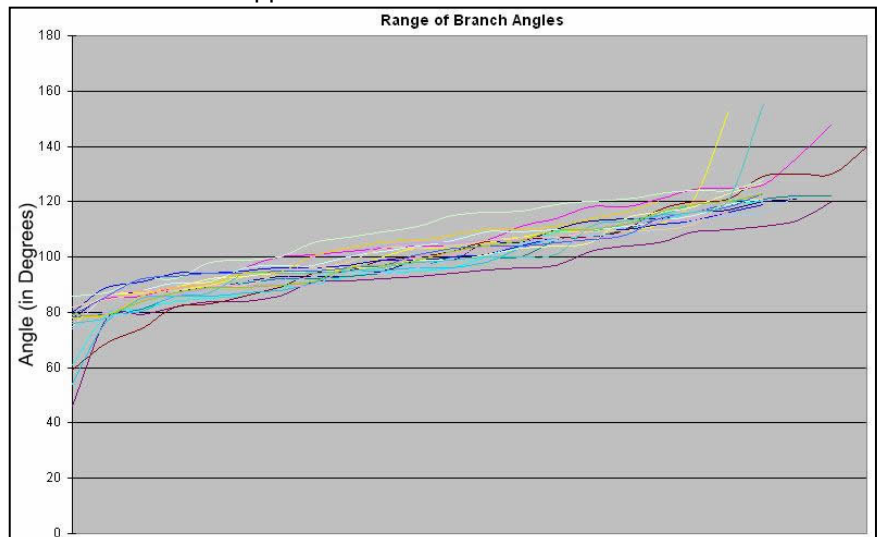
- High Resolution Digital Camera
- 180° Angle Measurement Ruler
- Standard Geometry Kit
Protractor
- 25-foot Measuring Tape
- Magnetic Compass
- Colour Computer Printer

Procedure (for Data Collection)

1. Find open-grown spruce trees in areas that receive sunlight consistently in Calgary, Alberta.
2. Use the compass to find south.
3. Take pictures of the tree's south side.
4. Place the angle measurement ruler along the main trunk of the tree and to the area where it connects with the branch to measure the angle.
5. Estimate the height of the tree by leaning the measuring tape along the tree trunk.
6. Measure the lengths of the branches.
7. Repeat this process for 19 other trees. Five trees should be measured from each quadrant of the city.
8. Use the protractor to measure some additional angles from the photographs.

Variables (for Data Collection)

- Manipulated Variable: Different Trees and their Environment
- Responding Variables: Branch Angles, Branch Lengths, Approximate Tree Height, Amount of Bare Branch (due to shed needles)
- Controlled Variables: Measurement Methods, Approximate Location of Calgary, Tree Species (*Picea glauca*), Morphologically Similar Tree Appearance



Results (for Data Collection)

The diagram (see previous page) summarizes the range of branch angles over 20 different trees. Other observations (not included in this report) were also noted.

Tukey's Post-Hoc Test

There is no significant difference in branch angles between trees. The data is 96.4% accurate in terms of the trees in an individual quadrant. It is 99% certain that angles are within ten degrees of each other, 52% certain that angles are within five degrees and 6.5% certain that they are within one.

One Sample T-Test (Mean MU = 90)

There is a 99.9% chance that the mean of all the angles is close to 90°.

Conclusion (Part 1)

Tree age does not affect growth. Once angles are determined at the branching point of a tree, a ratio keeps growth consistent in terms of tree height and branch length. A mathematical formula can be generated to calculate a *Picea glauca* tree's height:

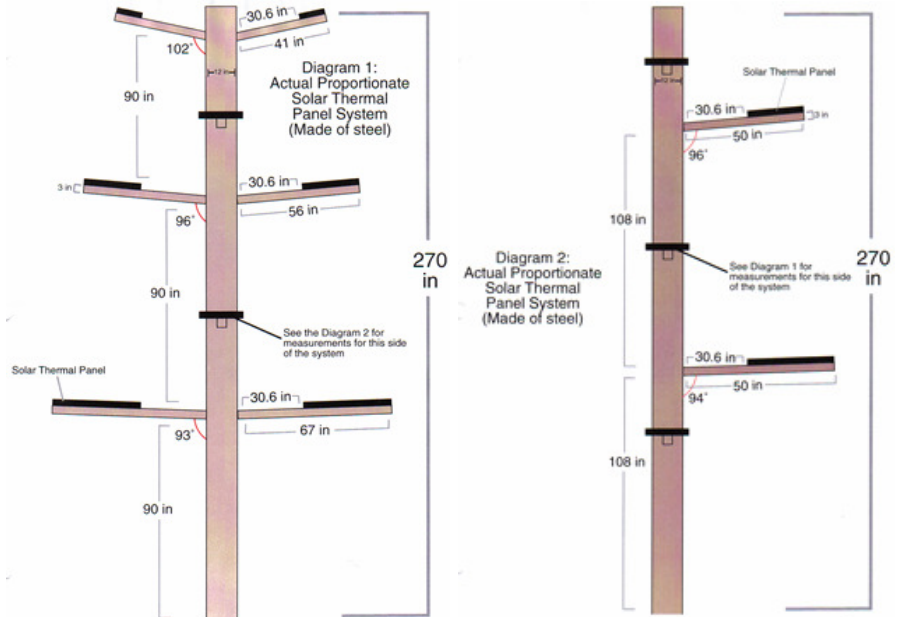
$$(Average\ Branch\ Length\ in\ Inches) \times 0.426118209 = (Approximate\ Tree\ Height\ in\ Feet)$$

Angles are kept constant to maintain photosynthetic efficiency. This proves that the first hypothesis is correct, as many of the angles are at or near 90°. Higher branches should have an angle range from 90° to 100°, while lower branches should have a range of 80° to 90°, allowing for good exposure to the sun. The angles are morphological phenotypes that have been genetically inherited. This has been concluded because of the similarities between

different trees, indicating that the gibberellin and auxin hormones are controlled before branching occurs. Coordination and response to these specific hormones are a result of natural selection processes.

In conclusion, the *Picea glauca* tree is definitely a species that has the ideal mathematics for optimal solar energy collection. Therefore, such mathematics can be adapted to create a new arrangement for photovoltaic solar cells.

Blueprints for the Solar Tree System



Materials (for Model System Construction)

- 1.5 in x 2.6 in Polycrystalline Photovoltaic Solar Cells (1 Volt or 400 milliAmps) x 8
- 1.5 in x 1.5 in x 32 in Wood Piece
- 0.4 in x 8 in x 1 in Wood Pieces x 2
- 0.4 in x 6.5 in x 1 in Wood Pieces x 2
- 0.4 in x 5 in x 1 in Wood Pieces x 2
- 0.4 in x 6 in x 1 in Wood Piece
- 0.4 in x 7 in x 1 in Wood Piece
- 8 in long Electrical Wire Pieces x 8

Procedure (for System Testing)

1. Set the system in an area where direct sunlight reaches all eight panels, facing the south.
2. Connect the open ends of the model system to the positive and negative ends of the multimeter.
3. Read the value provided for the total power output of the system.
4. Repeat the above steps for the other systems: the solar tree system, eight separate panels, and one large panel in both parallel-series and series circuits.

Variables (for System Testing)

- Manipulated Variable: System Tested
- Responding Variables: Voltage, Amperage
- Controlled Variables: Time of Day, Multimeter Used, Test Location, CSA Approval of Panels

Results (for System Testing)

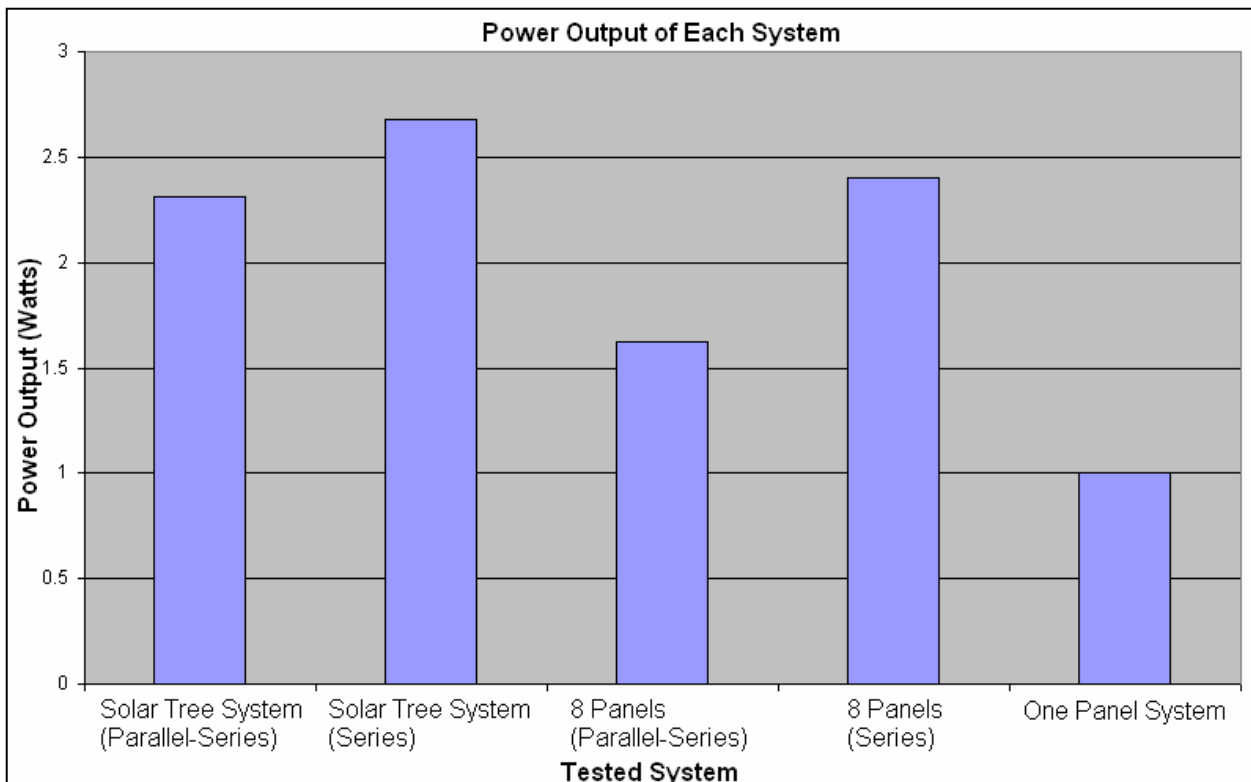
The graph below shows that the solar tree arrangement in a series circuit is most effective, but

a parallel-series circuit is still more efficient than most standard arrangements of panels.

Conclusion (Part 2)

The constructed solar tree system and the single panel system were both tested for their power output in direct sunlight. Based on further calculations, the solar tree model in a parallel-series circuit theoretically produces totals 72532.8 kilowatt-hours per year. In a series circuit, the solar tree system produces 84516.48 kilowatt-hours per year. Since a series circuit in the solar tree arrangement produces the most power output, it will be the preferred method of wiring.

This shows that the solar tree in a series circuit produces 268% more power than the single solar panel system and 11% more power than the eight-panel system set up in the same manner. The solar tree in a parallel-series circuit is 142% more effective than the eight-panel system wired in series, and



263% more effective against a single solar panel system. Therefore, the second and third hypotheses are correct.

As tests were only done for a minimal amount of time, this does not show results for long term use. This designed system could be used year-round for twelve months if placed in a consistently sunny location. With such an incredible difference of power output, adapting the tree arrangement is definitely more efficient than the single panel with a rotating motor. If such potential has already been unlocked in this scale model of this solar tree arrangement, one should consider the greater increase of effectiveness when using actual size measurements.

Applications

- The system could be used mainly as a new method of alternative energy collection, as photovoltaics are already commonly used. A solar tree forest could be created for a concentrated area of optimal energy collection.
- The results of the data collection could help determine the perfect morphology for a tree. They could be engineered to collect more solar energy to photosynthesize efficiently to release more oxygen into the atmosphere. This could further lead to explorations of terraformation techniques in astrobiology.
- The formula for calculating tree height can be used in environmental field studies.
- If further testing is done on this arrangement of solar panels, it may change conventional knowledge about the concept.

Sources of Error

Measurements may have been off slightly, which is natural human error due to parallax. Precise

measurements were attempted, but it is difficult when there is wind, coldness and other branches to affect one's measuring ability. This was not a significant difference in data for much inaccuracy, as statistically proven. Readings on the multimeter may have also been affected due to perspective.

Some of the gluing connections may have affected the angle of the branch, changing the original measurements slightly. However, this is not a significant difference. Electrical connections may also be not as well joined. It may also be affected by the electrical tape creating a slight amount of resistance. This is not an important amount of energy loss.

Acknowledgements

Bruce, Shelly and Vivian Full: My family, who helped with general project organization, and gave support.

Jack Phu: My grandfather, for his help with the construction of my model system.

Dr. Richard Pharis: Of the University of Calgary, for being a great project mentor.

Kathleen Ang: My friend, for her major unconditional support and help.

Dr. Christopher Hunter and Dr. Rod Blais: Of the University of Calgary, for their help with the statistical analysis.

Solarbotics Ltd.: For their discounts on my purchase for solar panels and for providing electrical wire to me free of charge.

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