





using the existing technology. Progressive research in this field should discover materials and technology that are capable of absorbing neutrinos.



Figure 2. Ice Cube Observatory, Antarctic

### *Neutrinos as a Sustainable Energy Source*

The high energy of the neutrinos can be converted into other forms of energy if harnessed. The energy generated through this source will be a renewable form of energy because it will not impact the environment or the Earth's natural resources. The sun in itself produces 100 billion neutrinos every second, and other galaxies, stars, and cosmic matter produce neutrinos as well ("Solar Neutrinos", n.d). The stream of neutrinos will therefore last forever, making it a sustainable energy source for our planet.

### *Neutrino Panel*

A theoretical Neutrino Panel can absorb the neutrino's internal energy, and the resulting heat energy due to the absorption can be converted into electricity. The conversion from heat energy to electricity can be done using heat-sensitive equipment like thermoelectric generators. The schematic diagram for the proposed Neutrino Panel is shown in [Fig. 3](#).

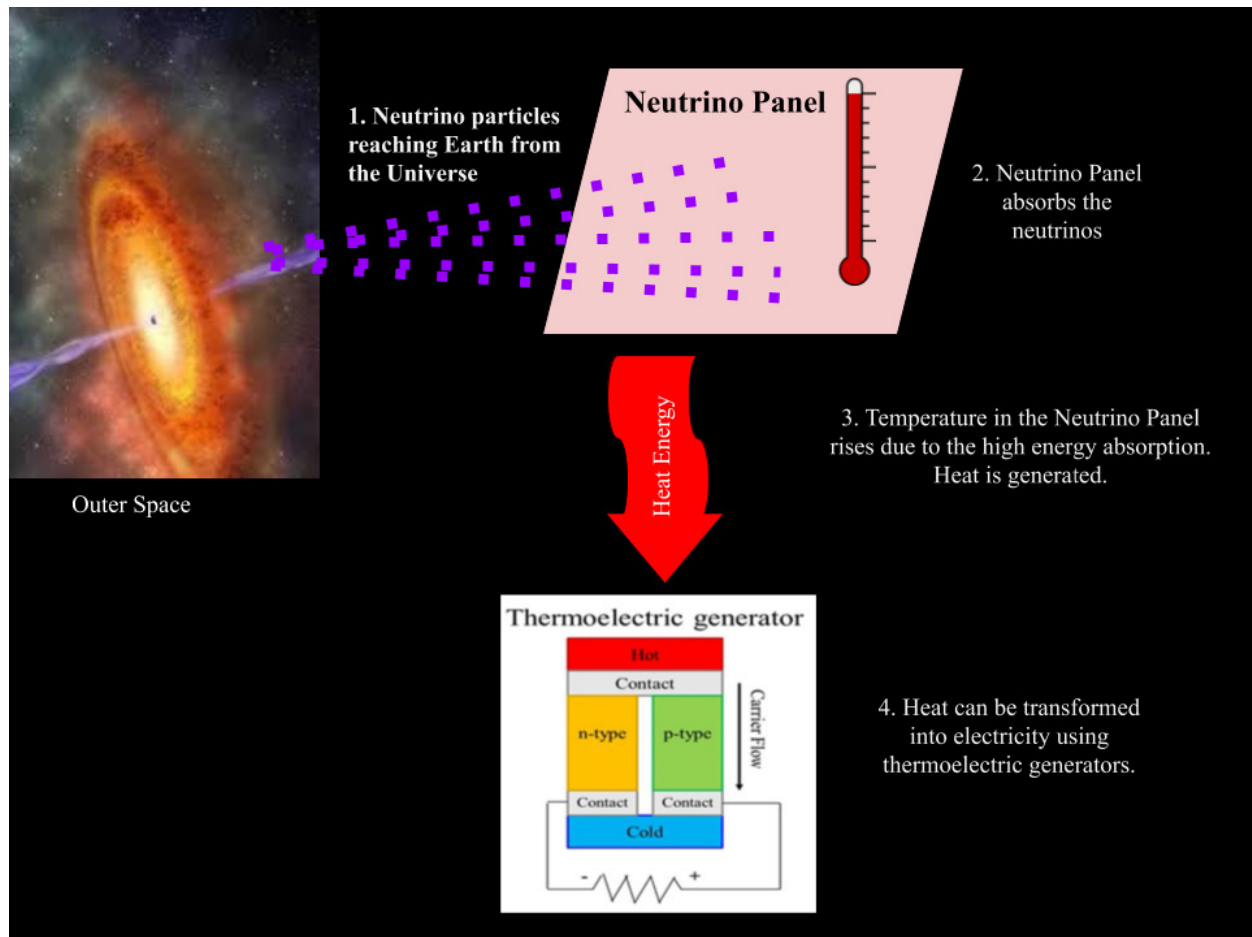


Figure 3. Schematic Diagram of the Neutrino Panel

### *Neutrino Panel - A Comparative Insight*

Finding efficient and cost-friendly renewable energy sources is one of the main challenges of the 21st century. There are a few solutions present to address this challenge- these include solar power, hydropower, wind-power, geothermal power, and nuclear power. However, these solutions come with certain constraints.

1. They require specific geographical locations, such as locations with lots of sunlight for Solar panels, and high winds for wind-turbines.
2. They are expensive to install to generate power.
  - a. Hydroelectric dams cost about \$20 billion to build (Parshley, 2018).
3. They generate various amounts of power depending on the environmental conditions.
  - a. Solar panels produce different amounts of power in different locations, even though the panel used may be the same (“How much output do you get from Solar panels?”, 2020).
4. They contribute indirectly to pollution

- a. Toxic products are released in the making and disposing of photovoltaic cells, and they are not biodegradable (Shellenberger, n.d).

However, the proposed Neutrino Panel will not depend on geographical location, and it will not be constrained by environmental factors. Even though the panel is a theoretical idea where the costs of implementation are still unknown, the high efficiency will likely compensate for the implementation costs. Moreover, the energy generated by the panel will mostly be consistent since there is always a steady shower of neutrinos on the planet (“What’s a neutrino”, n.d).

Due to the high energy and geographical presence of neutrinos everywhere on the planet, Neutrino Panels can become the forefront of sustainable and renewable energy for future generations.

### Neutrino Energy Efficiency Calculations

The data and the calculations shown below prove the energy efficiency of the Neutrino Panel. It supports the claim that a panel with a surface area of 454 m<sup>2</sup>, after having absorbed neutrinos for a day, will have the capacity to power the city of New York for one day.

The following data forms the basis for the calculations :

1. Each of the 3 million billion neutrinos that strike every square meter of Earth’s surface every second carries about 10 billion electron volts (“Ghostlike Neutrinos”, n.d) (Bahcall, Serenelli, Basu, n.d).
2. New York uses 11 billion Watt-Hours in a day (Steinberg, 2012).
3. The most efficient Solar panel producing the highest wattage is considered for comparison of calculations (Powers, n.d) between Solar panel and Neutrino Panel.

The following assumption is made for the purpose of calculations: The Neutrino Panel has 100% absorption efficiency.

$$11 \times 10^9 \frac{Wh}{day} \div 24 hrs = 4.583 \times 10^8 \frac{Wh}{hour}$$

$$4.583 \times 10^8 \frac{Wh}{hour} = 2.86 \times 10^{27} \frac{ev}{second}$$

$$2.86 \times 10^{27} \frac{ev}{second} = \text{desired power}$$

**Equation 1:**  $C \times N = S$  where ;

$$C = \text{Charge}_{\text{neutrinos}} = 10^{11} \text{ ev}$$

$$N = \text{number of neutrinos/second} * \text{cm}^2 = 63 * 10^9 / \text{cm}^2 \text{ s}$$

$$S = \text{charge/second} * \text{cm}^2$$

$$(10 \times 10^9) \text{ ev} \times \frac{(63 \times 10^9)}{\text{cm}^2 \times \text{s}} = 6.3 \times 10^{20} \frac{\text{ev}}{\text{cm}^2 \times \text{s}}$$

$$6.3 \times 10^{20} \frac{\text{ev}}{\text{cm}^2 \times \text{s}} = \text{Charge of neutrinos/second} * \text{cm}^2$$

**Equation 2:**  $P = S \times A$  where;

$$P = \text{desired power} = 2.86 * 10^{27} \text{ ev / s}$$

$$S = \text{charge/second} * \text{cm}^2 = 6.3 * 10^{20} \text{ ev/cm}^2 \text{ s}$$

$$A = \text{area of the panel}$$

$$2.86 \times 10^{27} \frac{ev}{second} = 6.3 \times 10^{20} \frac{ev}{cm^2} \times area$$

$$Area = \frac{2.86 \times 10^{27} ev / second}{6.3 \times 10^{20} ev/cm^2 s}$$

$$Area = 4,539,682.5 cm^2 = 454 m^2$$

These calculations prove that a panel size of 454m<sup>2</sup>, assuming 100% absorption efficiency, can generate energy to power the city of New York for one day. After a full day of charging the 454 m<sup>2</sup> panel, can generate about 11 billion Watt-Hours of power.

Next, the same calculations are performed to show the size of a Solar panel required to generate 11 billion Watt-Hours after being charged for a day. The Solar panel used for the calculations is SunPower 415, the most powerful solar cell in the world which generates 415 watts every hour (Powers, n.d).

11 billion Watt-Hours in a day = 4.583 \* 10<sup>8</sup> Watt-Hours/hour = 2.86 \* 10<sup>27</sup> ev /second

$$2.86 * 10^{27} ev / second = \text{desired power}$$

1 SunPower 415 watt/hour Solar panel produces:

$$415 \text{ WattHours/ day}$$

$$415 \frac{WattHours}{Days} \times \frac{1 \text{ Day}}{24 \text{ hours}} = 17.29 \text{ Watts} = 17.29 \frac{Joules}{second}$$

$$17.29 \frac{Joules}{second} \times 6.242 * 10^{18} \frac{ev}{Joules} = 1.07 * 10^{20} \frac{ev}{s}$$

$$\text{Size of 1 panel: } 41 \text{ in} \times 62 \text{ in} = 16400 \text{ cm}^2$$

$$\text{Equation 3: } \frac{X}{Z} = Y$$

$$X = \text{power in ev/seconds the Solar panel produces} = 1.07 * 10^{20} \frac{ev}{s}$$

$$Z = 16400 \text{ cm}^2$$

Y = power in ev/second \* cm<sup>2</sup> the Solar panel produces

$$1.07 * 10^{20} \frac{ev}{s} \div 16400 \text{ cm}^2 = 6.58 * 10^{15} ev/second \times \text{cm}^2$$

1 SunPower 415 watt Solar panel produces 6.58 \* 10<sup>15</sup> ev/second \* cm<sup>2</sup>.

**Equation 4:** P = Y \* N where ;

$$P = 2.86 * 10^{27} ev / second$$

$$Y = \text{power in ev/second * cm}^2 \text{ the Solar panel produces} = 6.58 * 10^{15} ev/second \times \text{cm}^2$$

N = total area of Solar panels

$$2.86 * 10^{27} ev/second = N \times (6.58 * 10^{15} ev/second \times \text{cm}^2)$$

$$N = \frac{2.86 * 10^{27} ev/second}{6.58 * 10^{15} ev/second \times \text{cm}^2}$$

$$N = 4.35 * 10^{11} \text{ cm}^2 = 4.35 * 10^7 \text{ m}^2 \text{ of Solar panel}$$

$$454 \text{ m}^2 \text{ (Neutrino panel)} < 4.3 * 10^7 \text{ m}^2 \text{ (Solar panel)}$$

The results above show that the area of Solar panels (which is 43 million square meters assuming the best Solar panel in the industry) required to generate 11 billion Watt-hours in a day is far higher than the area of a Neutrino Panel (assuming 100% efficiency) required to generate the same amount of power in a day.

## Limitations

The Neutrino Panel as explained in the schematic diagram in Fig.3 is a theoretical model. Building the panel to collect the experimental data was not possible in this research article because of the limitation that the materials that absorb neutrinos are yet to be discovered. The research to discover materials that are capable of absorbing neutrinos is underway. Once such discovery is made, it will open doors to possibilities to engineer, design, and build efficient Neutrino Panels, for a sustainable future.

## Conclusion

The astonishing amounts of energy from neutrinos can be used to the greatest advantage, without affecting the Earth's natural resources. Even though the materials that can absorb neutrinos are yet to be discovered, future research in this field is crucial to understand the ways to capture the neutrinos. Since neutrinos have high energy and a universal presence, Neutrino Panels that harness this energy will become the forefront of sustainable green energy for the future.

## Further Research

Further research in this field can include exploring and experimenting with materials that may have the ability to absorb the neutrinos. More possibilities include researching other potential structures and designs for the Neutrino Panel to validate its efficiency, challenges, and solutions.

## Acknowledgments

I would like to express my special thanks to my research mentors Ellen Torres Thompson and Lawrence Edmond IV for their exceptional guidance, encouragement, and valuable support during my research work. My mentors are undergraduates pursuing Astrophysics at the University of California, Berkeley. Ellen Torres Thompson's primary research interest is high energy astrophysics, and Lawrence Edmond IV's research focus is on stellar astrophysics, cosmology, and quantum mechanics. My mentors' knowledge and experience have been an inspiration for me and their insightful feedback from the start helped me at every stage of the research process.

I would like to express my sincere gratitude to my science teacher Ms. Nicole Della Santina at Lynbrook High School for her feedback and support in helping me with my research article.

## Bibliography

Webmaster@icecube.wisc.edu, Ice Cube Collaboration. *A First Look at How the Earth Stops High-Energy Neutrinos in Their Tracks*. 22 Nov. 2017, <https://icecube.wisc.edu/news/view/546>.

Big Bang neutrinos. (n.d.). Retrieved September 07, 2020, from <https://neutrinos.fnal.gov/sources/big-bang-neutrinos/>

CERN Accelerating science. (n.d.). Retrieved September 07, 2020, from <https://home.cern/science/physics/standard-model>

Climate Change. (n.d.). Retrieved September 07, 2020, from <https://www.un.org/en/sections/issues-depth/climate-change/>

“Cosmic Neutrinos.”, All Things Neutrinos, <https://neutrinos.fnal.gov/sources/cosmic-neutrinos/>.

Finding the 'ghost particles' might be more challenging than we thought. (2017, March 21). Retrieved September 07, 2020, from <https://www.sciencedaily.com/releases/2017/03/170321092628.htm>

Ghostlike Neutrinos. (n.d.). Retrieved September 07, 2020, from [https://ase.tufts.edu/cosmos/view\\_chapter.asp?id=37](https://ase.tufts.edu/cosmos/view_chapter.asp?id=37)

How much does a neutrino weigh? (n.d.). Retrieved September 07, 2020, from <https://neutrinos.fnal.gov/mysteries/mass/>

Beiser, E. (2015, March). [IceCube Laboratory in the Amundsen-Scott South Pole Station]. Retrieved September 13, 2020, from <https://theconversation.com/the-icecube-observatory-detects-neutrino-and-discovers-a-blazar-as-its-source-99720>

Orwig, J. (n.d.). How to make a neutrino beam. Retrieved September 07, 2020, from <https://www.symmetrymagazine.org/article/november-2012/how-to-make-a-neutrino-beam>

Neutrino energies. (n.d.). Retrieved September 07, 2020, from <https://neutrinos.fnal.gov/types/energies/>

Renewable Energy Poster [Digital image]. (n.d.). Retrieved September 13, 2020, from <https://www.teachstarter.com/us/teaching-resource/renewable-energy-poster-us/>

Scientific American. *What Is a Neutrino?* 7 Sept. 1999, [www.scientificamerican.com/article/what-is-a-neutrino/](http://www.scientificamerican.com/article/what-is-a-neutrino/).

*Solar Neutrinos*. University of Colorado, [jila.colorado.edu/~pja/astr3730/lecture21.pdf](http://jila.colorado.edu/~pja/astr3730/lecture21.pdf)

SunPower. “Which Solar Panels Are the Most Efficient?: SunPower Solar Blog.” *SunPower*, SunPower, 21 Feb. 2020, [us.sunpower.com/blog/2020/02/14/which-solar-panels-are-most-efficient](http://us.sunpower.com/blog/2020/02/14/which-solar-panels-are-most-efficient).



Rogers, S. (n.d.). What Is Green Energy? Retrieved September 07, 2020, from <https://www.treehugger.com/what-is-green-energy-4864279>

Staff, S. (n.d.). What Are Neutrinos? Retrieved September 07, 2020, from <https://www.sciencealert.com/neutrinos>

Rogers, S. (n.d.). What Is Green Energy? Retrieved September 07, 2020, from <https://www.treehugger.com/what-is-green-energy-4864279>

What is a neutrino? (1999, September 07). Retrieved September 07, 2020, from <https://www.scientificamerican.com/article/what-is-a-neutrino/>

Beacom, J. (2015, October 16). What are neutrinos? Retrieved September 13, 2020, from <https://earth-sky.org/earth/what-are-neutrinos#:~:text=Though%20neutrin-nos%20are%20not%20constituents.through%20your%20eyes%20every%20second.>

Yoksoulian, L. (2018, July 18). What is a neutrino and why do they matter? Retrieved September 07, 2020, from <https://news.illinois.edu/view/6367/672678>