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Solar Cell Technology: Knowns, Unknowns, and the AI

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Abstract

Alternative energy is a key issue today. But so is also artificial intelligence. Search for alternative energy sources and optimizing use is a reoccurring event within the context of energy saving and climate preservation. Solar energy takes a central place in this search. It has numerous positive traits going all the way from low cost and accessibility to mobility and relative ease of application. Yet it has a long way to go to reach higher productivity and wider spread. And here comes artificial intelligence.

Emerging AI technologies could prove conducive to enhancing the productivity of solar cells, inducing wider applications and open the doors for virgin innovations.

This will be the focus of the following article.
The article starts with an outline of the current parameters of solar cell technology. An analysis follows. An analytical context is provided by the so called "Rumsfeld Matrix ", or the "Known knowns and unknown unknown's 'matrix". It relates present day solar and AI technologies to a future era of unknown dimensions of both concepts.

The article concludes with a set of hypotheses reflecting the outcome of this analytical model.

Keywords: Solar Technologies, Artificial Intelligence, Known technologies, Unknown Technologies, Rumsfeld

Solar Cell Technology Today

Photovoltaic (PV) solar cells employ semiconductor material to generate a flow of electricity when exposed to sunlight. The technology is well developed and reliable. Currently, only two types of solar technology exist that can convert the sun's energy into a source of power: solar thermal and photovoltaic. Solar thermal collectors absorb the sun's radiation to heat a home or water. Photovoltaic devices use sunlight to replace or supplement the electricity provided on the utility grid.

In contrast to other renewable energy sources, solar PV is available in almost infinite quantities, and in almost any location. In the United States, National Renewable Energy Laboratory data shows annual mean available solar PV kWh per day for all locations in the United States. Solar PV can be employed anywhere. Cells are typically mounted in modular panels, which are installed in arrays that can be mounted in a variety of ways, sizes and stretches.

Solar energy is abundant and accessible. It faces, however, a serious challenge: efficiency. Solar cells convert a small percentage of the available solar power into usable energy. The level varies according to the type of cell, yet the level remains low (see following table).

Table: Types of Solar Panel Efficiency

Type of solar panel	Efficiency (%)
Monocrystalline	15-20%
Polycrystalline	15-17%
Thin film	15-20%

Source: Greenmatch, how efficient solar panels are, Nov 2, 2023

Solar photovoltaics cells will, in the longer term, be among the cheapest sources of energy according to some predictions. Declining cost, and prices, deliver the estimates that solar systems could supply 5% of global electricity consumption by the year 2030, A higher level of 16% is projected for the year 2050. This would require increasing the global capacity of solar energy from 150 gigawatts in 2014 to 4,600 gigawatts by 2050 leading to a decline in emission of six billion tons of carbon dioxide annually [1].

The Analytical "Knowns and Unknowns" Model

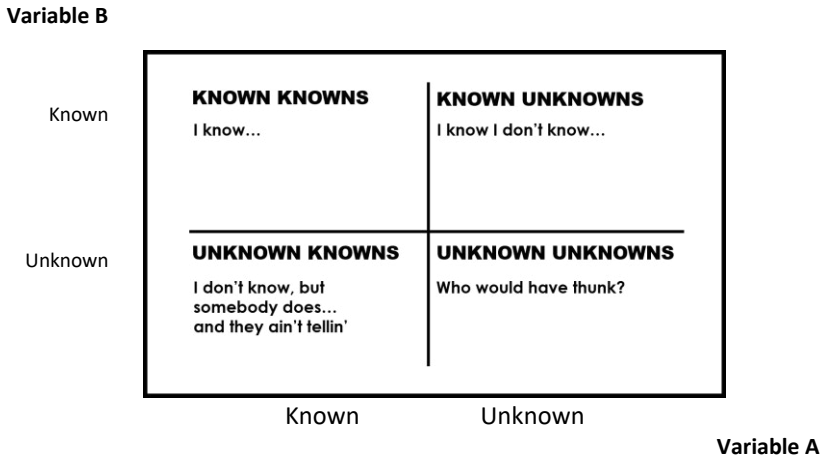
The following analysis will rely on an analytical model known as the known unknown model or concept. A concept promoted by the US secretary of defense Rumsfeld although it has roots in behavioral sciences. What this concept conveys is the existence, in terms of knowledge, of a known and unknown state for any variable under consideration. Much could be revealed, and prospects could be explored, if those variable-specific knowns and unknowns are unmasked in terms of genre, texture and impact. And if those revelations are related to each other.

The following matrix illustrates this phenomenon. It projects generic cause and effect relationship between two variables projected along the Y and x axis of the matrix. Each variable assumes two states: known state and unknown state. The first state, the "known" state, implies presence and even knowledge of the relevant or pertinent subject data and attributes. The second state or the "unknown" indicates non knowledge or even awareness of the respective data base and data attributes.

The outcome are four matrix "boxes" each representing an outcome of a relationship.

- First relationship "Two variables Known Knowns relationship".
- Second relationship "Two variables Known Unknowns relationship"
- Third relationship: "Two variables Unknown Knowns relationship".
- Fourth relationship "Two variables Unknown Unknown relationship"

Figure: The knowledge matrix.



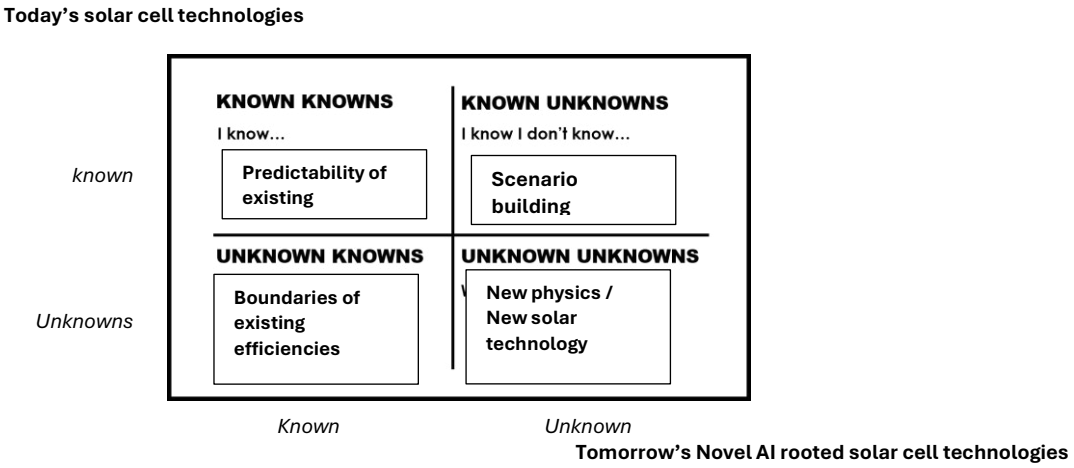
Source: Based on How to Use the "Knowns" and "Unknowns" Technique to Manage Assumptions·, The Persimmon Group [2].

AI and the Future of Solar Technology: Knowns and Unknowns' Analysis

It is the author's contention that artificial intelligence will have a strong bearing on the alternative energy industry as a whole and the solar cell segment. This impact could be explored by resort to the "the knowns and unknowns' model alluded to above. Solar cells provide two variables worth exploration: today's solar cell technologies and novel solar-based new science technologies.

AI is likely to have a wide impact within the solar scenarios we are exploring here. The following analysis will focus on those two states.

Figure : The known unknown application



Tomorrow's Novel AI Rooted Solar Cell Technologies

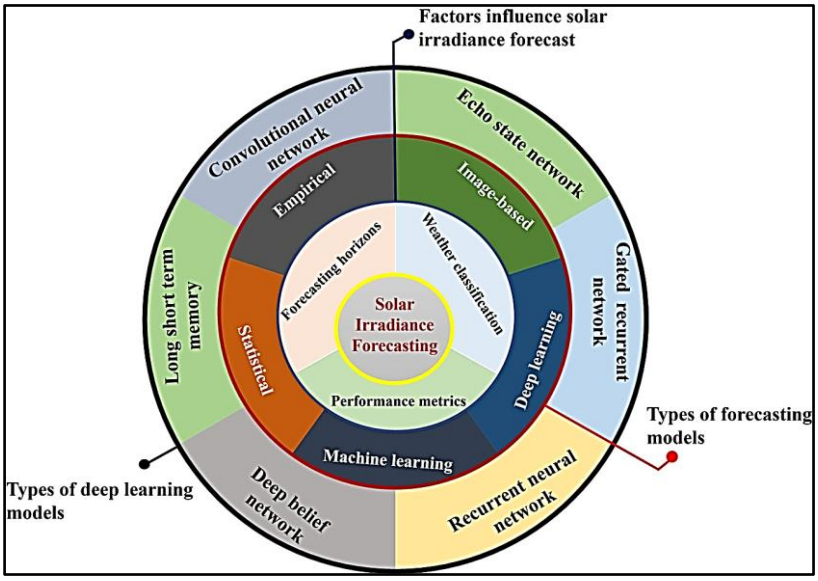
Resorting to historical data is one of the "known knowns" modes of AI intervention that could lead to predictive values of future solar cell efficiency.

Historical solar energy data could lead to a process of data prediction. Historical data representing real systems are taken as a base for the analysis and the deriving of machine learning and deep learning logarithms that would lead to predictions. Historical data are known. Predictive outcomes from derived algorithms are unknown.

Historical data holds the key here. They are collected, cleansed, labelled, and augmented. They are also encoded or transformed into machine-readable formats. Features are then extracted and scaled to ensure equal contribution to model training. Feature engineering follows to create new features or transformations to enhance the dataset's predictive power. Data imputation is meanwhile done to fill in missing values with estimates based on existing data. The final phase is data integration or the combination of datasets from multiple sources to create a unified data set.

There are a lot of deep learning-based solar irradiance forecasting models available in literature. The deep architecture of these models helps in extracting the high-level and non-linear complex features from solar data (see figure) [3].

Figure : Solar forecasting



Source: Pratima Kumari*, Durga Toshniwal, Deep learning models for solar irradiance forecasting: A comprehensive review, Journal of Cleaner Production, Volume 318, 10 October 2021, 128566

The Knowns and Unknowns of Solar Cell Technologies

The solar cell industry, an established branch of alternative energy, does provide an illustration here. Photovoltaic (PV) solar cells employ semiconductor material to generate a flow of electricity when exposed to sunlight. The technology is well developed and reliable.

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convert the sun's energy into a source of power: solar thermal and photovoltaic. Solar thermal collectors absorb the sun's radiation to heat a home or water. Photovoltaic devices use sunlight to replace or supplement the electricity provided on the utility grid.

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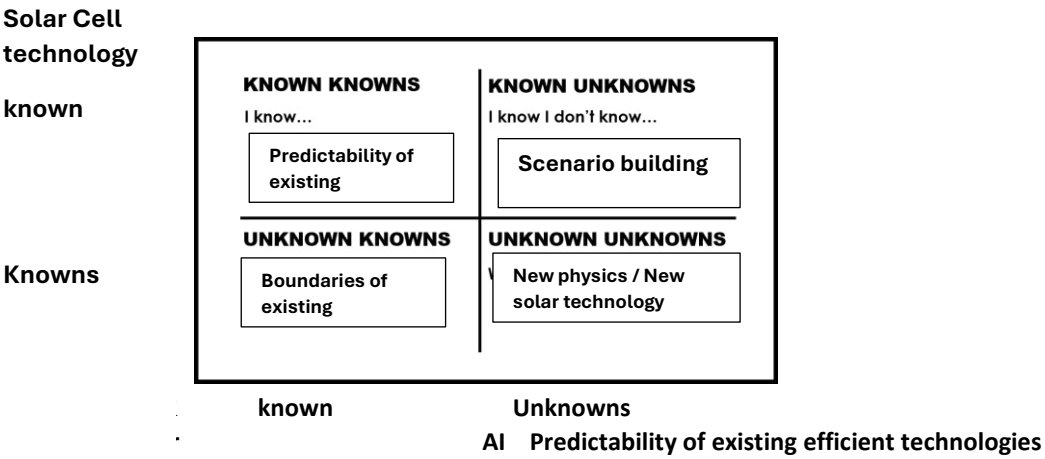
Solar energy is abundant and accessible. It faces, however, a serious challenge: efficiency. Solar cells convert a small percentage of the available solar power into usable energy. The level varies according to the type of cell, yet the level remains low.

AI is having right now and is likely to have in the longer term a wide impact within the solar energy industry. There are, in the author's view, two approaches to the measurement of the longer-term impact. The first is predictive analytics thus revealing new sources and optimizing the use of existing resources. The second is exploring areas of science that are unexplored or unknown within the alternative energy field to identify new alternative energy sources. The two issues belong to the known knowns and the unknown unknowns of the "Rumsfeld Matrix". The following analysis will focus on those two states.

Figure : The known unknown application



Resorting to historical data is one of the "known knowns" modes of AI intervention that could lead to predictive values of future solar cell efficiency. Historical solar energy data could lead to a process of data prediction. Historical data representing real systems are taken as a base for the analysis and the deriving of machine learning and deep learning logarithms that would lead to predictions. Historical data are known. Predictive outcomes from derived algorithms are unknown.

Historical data holds the key here. They are collected, cleansed, labelled, and augmented. They are also encoded or transformed into machine-readable formats. Features are then extracted and scaled to ensure equal contribution to model training. Feature engineering follows to create new features or transformations to enhance the dataset's predictive power. Data imputation is meanwhile done to fill in missing values with estimates based on existing data. The final phase is data integration or the combination of datasets from multiple sources to create a unified data set.

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The Unknown Unknowns: New Physics and New AI Science Roots

The unknown unknowns in the case of AI and solar cell energy could boil down to the science roots of artificial intelligence and the extent to which artificial intelligence could evolve in new unknown directions as much as the emerging new dimensions of sciences as new physics.

It is the author's contention that what we know today as artificial intelligence is in fact a blend of several sciences. Each science provides an input and each input blends with, yet another one drawn from another science. The synergy produces what we call today artificial intelligence. The blend relates sciences such as physics, neurology, mathematics, and psychology to each other and produces artificial intelligence conceptual and operational frameworks.

Science is also going into an unknown dimension as well. Differentiable physics, for example, is going to provide new capabilities for the simulations of engineered systems. Differentiable solar cell simulators are an example of differentiable physics providing new capabilities to optimize solar cell device performance. predicts solar cell efficiency and how to improve it [4].

Silicon substitutes are yet another current unknown. "Perovskites," are a leading candidate for eventually replacing silicon as the material of choice for solar panels. Reducing cell material for low-cost, low-temperature manufacturing of ultrathin, lightweight flexible cells, but so far, their efficiency at converting sunlight to electricity has lagged that of silicon and some other alternatives [5].

All these unknown concepts within artificial intelligence as much as new sciences could have a long-term impact on both AI and the alternative energy framework. And the question arises, then, how the unknowns of these science roots could deliver an answer to the unknowns of solar energy as an alternative energy framework [6-8].

A Derived Set of Hypotheses

Analysis Conducted Above Could Lead to Two Hypotheses

The first: There is a long way to go for solar cell energy to reach higher productivity and wider spread.

The second: Emerging AI technologies could prove conducive to enhancing the productivity of solar cells, inducing wider applications and open the doors for virgin innovations.

Summary and Conclusions

Alternative energy is a key issue today. But so is also artificial intelligence. Search for alternative energy sources and optimizing use is a reoccurring event within the context of energy saving and climate preservation. Cost economies of modes of alternative energy are a core issue as well. "Artificial intelligence is a similar core issue resembling alternative energy and, possibly, exceeding it." ("AI and Alternative Energy: The Case of the Solar Cell Industry") Penetration of artificial intelligence in all aspects of industry and consumption is a daily occurrence. The implications are far and wide [9-11].

How do the equally momentous issues relate to each other??? And how could artificial intelligence influence alternative energy? And could solar energy illustrate this potential impact?

These are some of the issues dealt with in this article.

The article relies on research done on both issues. It starts with a definition of artificial intelligence as a system. Alternative energy is assigned to segments and parameters. The possible impact of artificial intelligence technologies on the alternative energy spectrum is illustrated by taking solar cell industry as a case. The so called "Rumsfeld Matrix ", or the "Known knowns and unknown unknowns' matrix": provides the analytical vehicle. Analysis touches the known knowns and the unknown unknowns. Known knowns focus on data analytics and the outcome of this analysis in terms of prospectives and predictive. The unknown unknown focuses on new scientific developments and the impact of new sciences as new physics on both artificial intelligence and solar energy technologies [12-15].

The article ends with a set of hypotheses that should be subject to future research.

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