Some research challenge for Photovoltaic Solar Energy - A collaboration with KNUST in Ghana

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Why looking at solar energy?

- The world need more clean energy
- The opportunistic reasons:
  - Political correctness and easier access to funding.
  - Students like it.

But why solar energy?

- Solar energy is the most promising short term solution.
- Industrial use of large scale photovoltaic converting of solar energy to electricity is relatively new and need research.

Our Ghanian partners

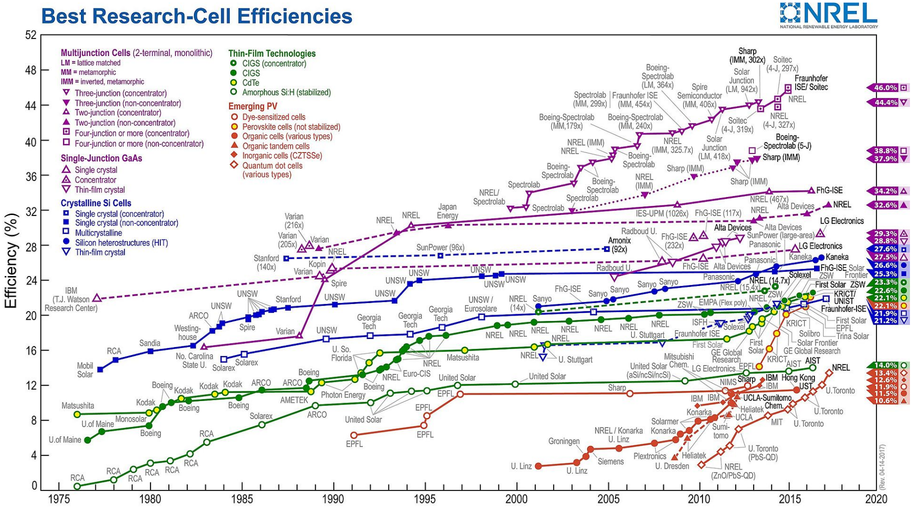
KWAME NKRUMAH UNIVERSITY
OF SCIENCE & TECHNOLOGY

National Institute for Mathematical Sciences (NIMS)

The project

-Funded by a small travel grant from UiB-BKK
-Started (from scratch) in 2016. (We are all new to this topic.)
-So far focus on getting up to speed and zooming in on some topics where we may contribute.
-2 visits from KNUST in Bergen and one from UiB to Kumasi, Ghana.
-The team: UiB 1 prof. + 4 masterstudents, KNUST: 1 prof. + 4 masterstudents.

Efficiency of various type of PV-panels

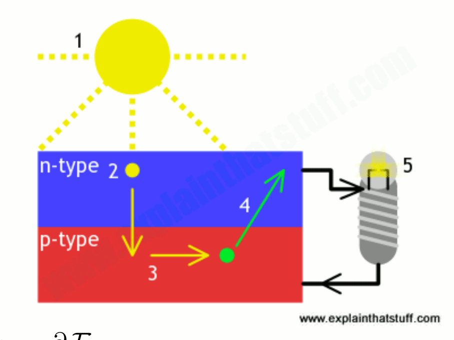


Some research challenges

- How to produce more efficient solar panels cheaper?
- How to arrange a farm of solar panels for a large electricity plant?
- How to incorporate PV-generated electricity into the grid?

In various ways mathematical computation can be a tool for (partial) answers to these questions.

From photon to electricity



$$
\begin{aligned}
\frac{\partial n}{\partial t} + \frac{\partial \mathcal{F}_n}{\partial x} &= 0 \\
\frac{\partial p}{\partial t} + \frac{\partial \mathcal{F}_p}{\partial x} &= 0 \\
\frac{\partial}{\partial x}\left(\varepsilon \frac{\partial \phi}{\partial x}\right) &= q(n-p) \\
\mathcal{F}_n &= -D_n\left(\frac{\partial n}{\partial x} + \frac{1}{kT} n \frac{\partial \Psi_n}{\partial x}\right)
\end{aligned}
$$

Optimal configuration of panels in a solar farm

- For a particular panel optimal electricity production is proportional to irradiation.
- Irradiation = direct+reflected. Depends on the panel angle/tilt, shading, reflection and weather.

Known formulas for clear sky, no shading, fixed geographic position and fixed time of day/time of year.
With historic weather data you can compute annual/daily average. (See http://pvwatts.nrel.gov)
Further complications:

- On a limited area; How to balance maximum number of solar panels with little shading?
- What about cost and maintenance?
- .....

Integrating Solar power into the grid

We have a set of users with a combined demand for electricity. This demand must be met by a total production at the same level.

The demand is time dependent. (It is neither deterministic nor random).

Electricity company has a long experience with estimating the demand. Thus we may assume that they do have a *Demand function* $D(t)$.

Classical production of electricity, fossil fueled based (oil,gas,coal) and hydro electric can be tuned to meet demand. (Provided we have sufficient storage of water,oil,gas or coal).

What happen when uncontrolled production enter the stage?

As it is free of cost and not possible to store it should always be used to full extent$\Rightarrow$

Production from controllable sources must be adjusted to satisfy $D(t) - PV(t) \Rightarrow$

We should have a forecasting of $PV(t)$ as it takes some time from decision to effect when altering the production level.

Forecasting PV-production

More or less equivalent to forecasting solar irradiation. Most important unknown factor is the cloud cover. Two techniques:

NWP: Readily available, but:

- A course grid. Lots of clouds/blue sky between grid points.
- Temp, wind, rain, pressure of little interest. **Clouds** is what matters.

imagery: Satellite images. You need to:

- Identify clouds from pictures in the vicinity of your solar plant
- Determine a “motion vector”
- Make prediction based on current cloud cover + motion vector

As of today: Imaging best for short term (0-6 hours).

Some questions further down the road

- How much PV-electricity can be cost effectivly introduced into the grid? Do we need $PV(t) < D(t); \forall t$?
- Transportation of electricity costs. Building expensive high voltage power lines and loss of energy. Where to put your power plant?
- What if we introduce "batteries" to even out the daily production/the seasonal variation?
- More exotic models then the drift-diffusion model we used.