A solar farm near Bologna - The effect of climate change

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Section 3 - Analyze effects of climate change

Which CC impacts pose a threat to the operation of solar plants and individual PV panels?

- Geographical location (Roberto)
- Air temperature increase (Roberto)
- Change in precipitation (Niklas)
- Average wind speed change (Yannick)
- Storms (Yannick)
- Sea level rise (Adrian)
- Flooding (Adrian)
- Wildfire (Adrian)
- Air quality (Matteo)

Geographical location

Robert
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There is a considerable amount of different criteria to be taken into account in the choice of the location for the installation of solar power plants: this makes solar energy planning very complex. The criteria can be grouped into three categories: environmental, social, and economic.

Environmental

Climate:
1. Radiation
2. Temperature
3. Altitude

Internal soil:
1. Soil fertility
2. Depth
3. Texture
4. Geology
5. Landslide risk

External soil:
1. Soil fertility
2. Depth
3. Texture
4. Geology
5. Landslide risk

Social

Landscape impact

Job opportunities

Rural development

Legal restrictions

Economic

Design:
1. Solar cells
2. Types of panels
3. Grid connection

Retail price

Initial capital cost

Lifetime of the projects

In order to select an area, a multiple-stages decision-making process must be done:

1. The first level of decision is determined by the political and legal conditions which establish if a solar power plant can be installed or not. Moreover, it must be taken into consideration also other environmental criteria which lead to exclusion are areas with risks involved (I.e. floods, landslides, geological characteristics that make the area unsuitable for installing the solar plant).
2. Once the areas not excluded are identified, there is a second decision level in which geographical location and socio-economic criteria are used. At the end, a number of high-potential areas for solar plants are obtained.
3. Going forward by excluding the areas that don' t meet the criteria, at the end a limited number of possible sites are obtained

Source:https://link.springer.com/article/10.1007/s10661-019-7871-8

For simplicity, in our exercise we hypothesized as a location a field in the countryside near Bologna, located in a flat area and facing south

Air Temperature increase

Robert
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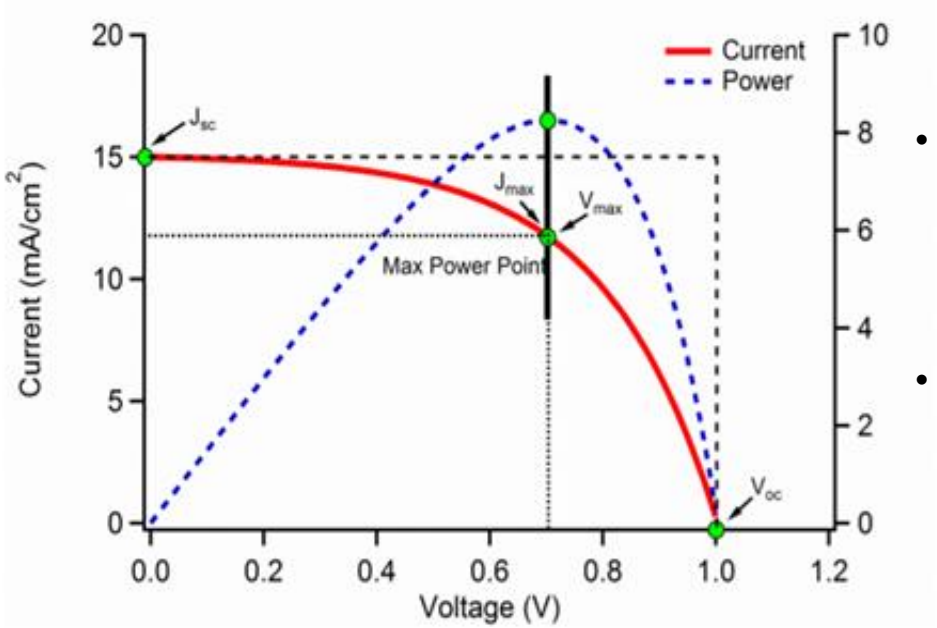
Generally it is expected that stronger the sun the more energy the solar panels produce, however this belief is false because excessive heat can cause a decrease in energy output from the solar panels.



- There is an inverse relationship between the power(P) produced by a solar cell and the voltage (V). Let' s assume that the power is calculated from the current(J) and voltage with the following equation:

$$P = JV$$

where P is the power produced, J is the current and V is the voltage.

- Without getting too much into the math details, when the solar cell is heated, the current, J will increase, but the voltage, V, will decrease faster than the current increases, the result is that the overall efficiency decreases and therefore the overall power produced is less.

- Example: The temperature coefficient indicates by how much solar panels decrease in maximum energy output per each increase of 1°C. It has been estimated by Renvu, which is a solar plant producer in California, that a particular brand of panels could have a Temperature Coefficient of -0.43% / °C. If these solar panels heat up to 45°C , that means they are 20°C above the testing temperature (25 °C), the lost energy can be computed as follows:

Lost energy % = 20 x -0.43 = -8.6%

Sources: 1. http://www.scienceline.ucsb.edu/images/solarTempDepend
2. Nelson, Jenny. The Physics of Solar Cells. London: Imperial College, 2003. Print
3. https://www.renvu.com/Learn/How-Temperature-Affects-Solar-Panel-Efficiency

Effects of climate change

- The city of Bologna is aware of climate change:
- In collaboration with EU: Bologna Local Urban Environment Adaptation Plan (BLUEAP)
- Therefore: Local Climate Profile (LCP) of Emilia Romagna

http://www.pdc.minambiente.it/sites/default/files/progetti/profilo_climatico_locale.pdf

Future rainfall changes according to LCP

Niklas

- Decrease of overall annual rainfall
- Winter: increase in the maximum number of consecutive days without rain → draughts
- Summer: increase in the frequency of days with intense rainfall → floods
- Cascading effect of dry soil and heavy rain

Effects of rainfall on our solar farm

Niklas

- No mechanical harm
- Rain might even clean dirty panels
- Clouds reduce output
- Floods can be a problem, especially for surrounding (electric) infrastructure

→ Rainfall is a factor to be considered

Considered time horizon

Yannick

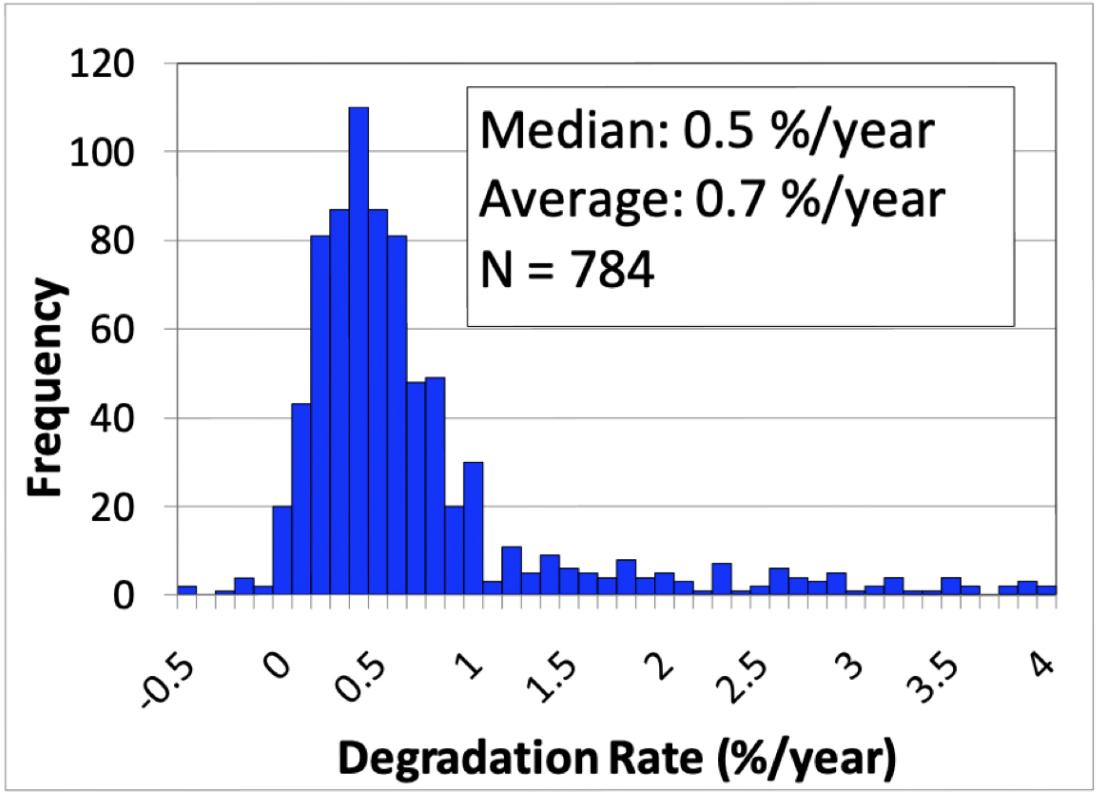


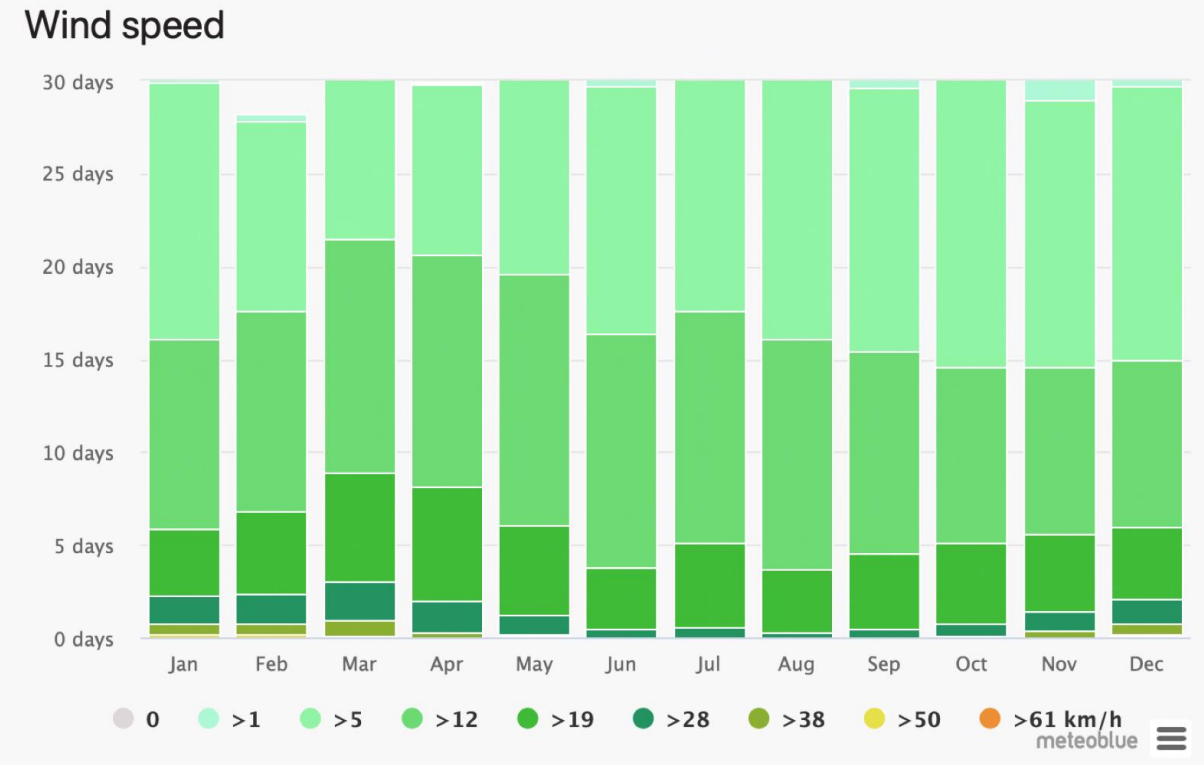
Figure 1 Histogram of published degradation rates.

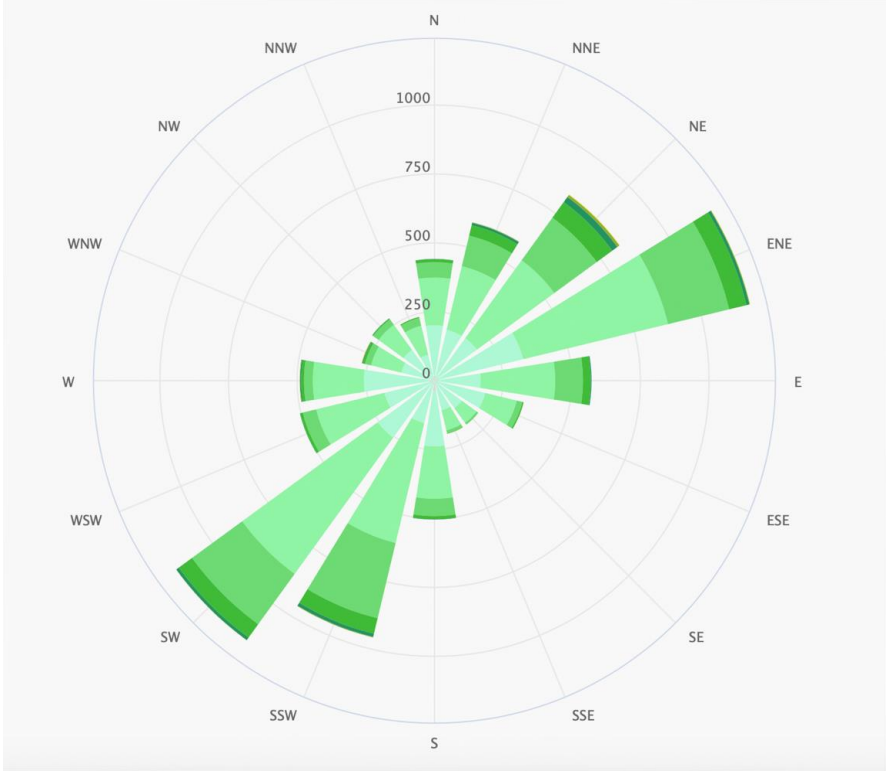
Source: Jordan, Dirk C., et al. "Outdoor PV degradation comparison." 2010 35th IEEE Photovoltaic Specialists Conference. IEEE, 2010.

- System degradation by average of 0.5%/year
- Resulting in an 80% efficiency in 45 years
- Transformers are usually not replaced
- Rule of thumb: live span of 25-30 years

Current situation of wind in Bologna

Yannick





Source: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/bologna_italy_3181928

Global wind speed changes

Yannick

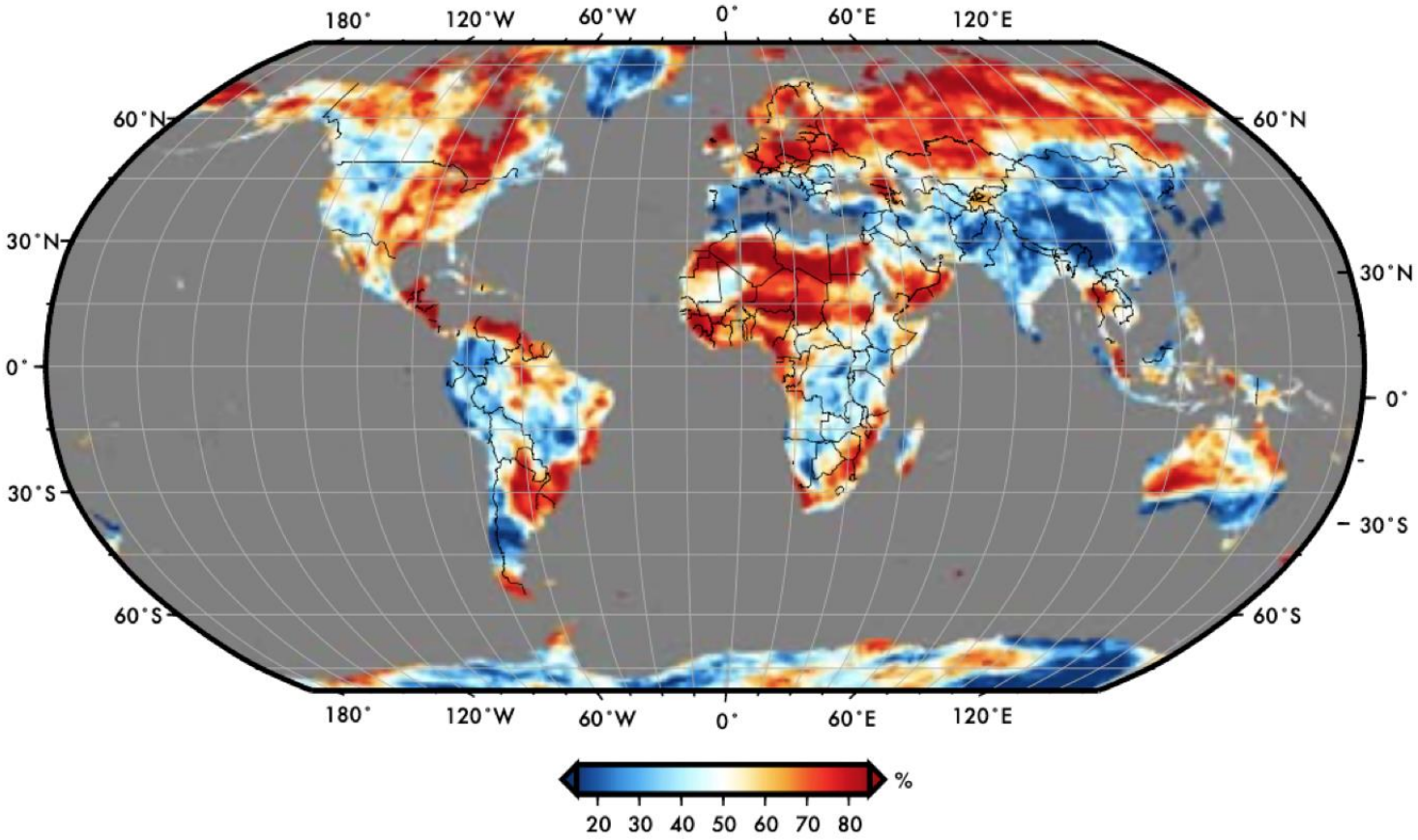


Figure 1: Percentage Of Global Climate Models Showing Increased Annual-Mean Wind Speed Values In 2050.

Source: Eichelberger, S., et al. "Climate change effects on wind speed." North American Windpower 7 (2008): 68-72.

Effects of wind to solar farms

Yannick

Positive

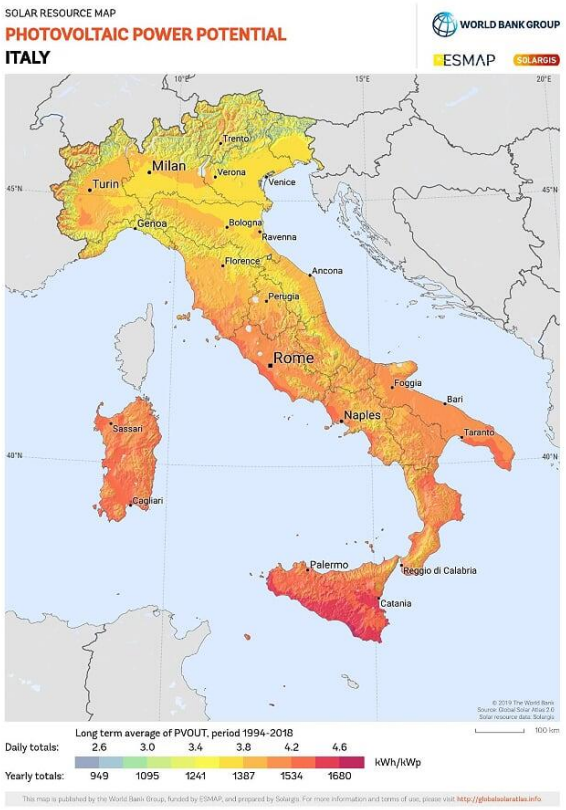
- Cloudiness and wind speed are weakly anti-correlated
- Winds have a cooling effect on solar panels and increase therefor efficiency

Negative

- Storms may cause severe damages
- Increases in pollination may lead to higher maintenance effort
- Difficult/ expensive to protect against wind
- Loses in attractiveness as wind parks achieve higher outputs

SLR and Flooding

Italian solar power potential may correlate with SLR exposure



Flooding a potential problem to panels, inverters and closeby transformers

- Flood risk should be part of planning process
- Soil sealing has been increasing flood intensity in Emilia-Romagna (Pistocchi et al., 2015)
- Increased rainfall in summer months expected

Wildfires

- 30% of Italian peninsula covered by forests
  - More than 10,000 wildfires per year in Italy
  - Climate change exacerbates the conditions in which they

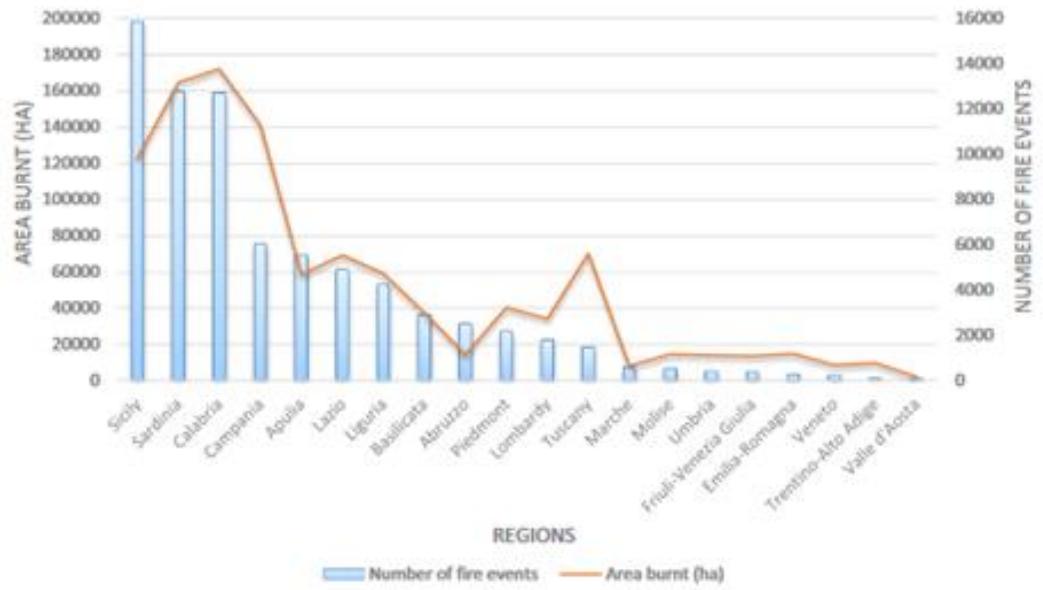


Fig. 1 Total number of fire events and area burnt between 2000 and 2011 across Italian regions

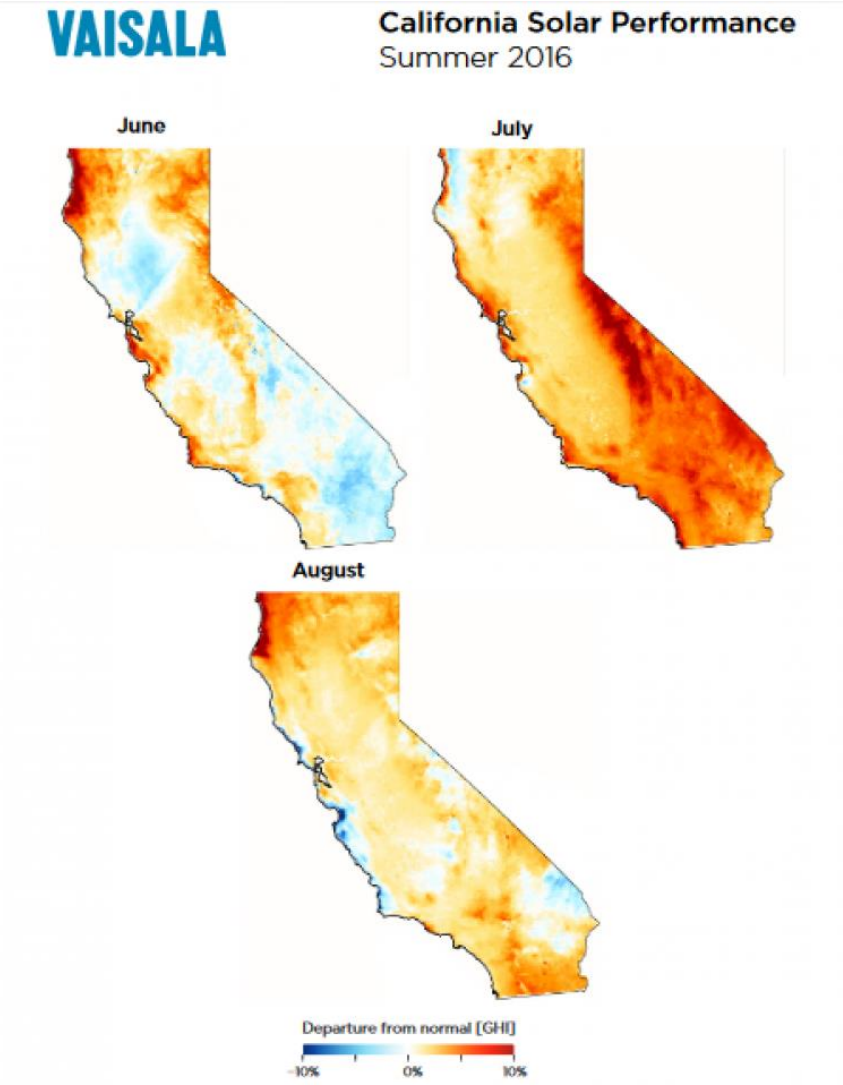
- South of Italy most affected

BUT

- period 2016-2035: "Fire events in the north [and] central-north projected to increase by 11–12% [and] 16%, respectively", relative to the period 2000–2005.
- (Michetti and Pinar, 2019)

Wildfires II

What's at risk?



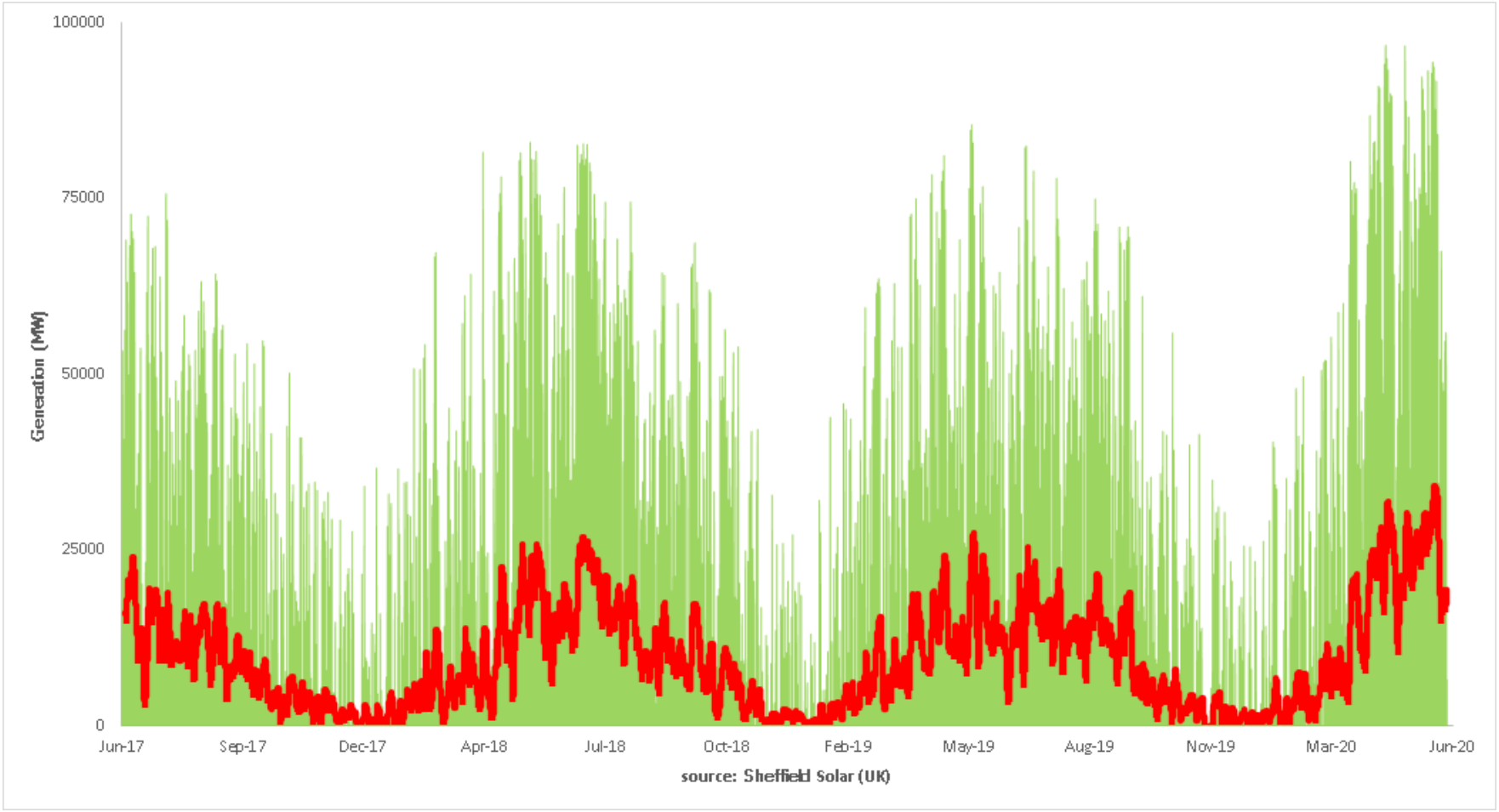
Destruction of the
power lines, transf

losses through
ver or safety
s

Bad air quality weakness solar plant output

- Negative impact in efficiency and sunlight time. Estimates of 17-25% for a highly polluted environment (China, India). This gap will affect ROI, turning investment unprofitable.
- China: If sunlight levels from the 1960s were restored SP would have generated 12% more saving $2 bln costs (maintenance, lack of reliability, more fossils).
- Reducing pollution to 1960s levels: estimated the benefit of 51-74 TWh/y. (Sweerts et al, *Nature energy*, July 2019)
- The newer the material, the more detrimental the effect (perovskite). Studies on adapting for pollution solar panels.

During lockdown production skyrocketed.



Forecast of air quality up to 20 y

- Air quality in the region significantly improved from the 90s. Drivers: citizens' awareness, de-industrialization, increased public transportation, pollution tax.
- Forecasted increase of 5-10% output, thanks to better environment. For longer Time, higher uncertainty.
- A generalized more polluted rest-of-the-World: stricter policies and decreased output of other SF and renewable plants. Plausible increase in energy price, so in the profitability of our plant. (10% increase WRT previous point)
- Indirect effects: difficult to sell energy produced in such a polluted area-fewer people willing to live here-difficulty at recruiting and maintaining qualified staff.

Sources

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