Solar PV Mapping With Remotely Sensed Data, and Prospects for the less GHG Emission Society Based on the Efficient Strategy of Solar Power Production

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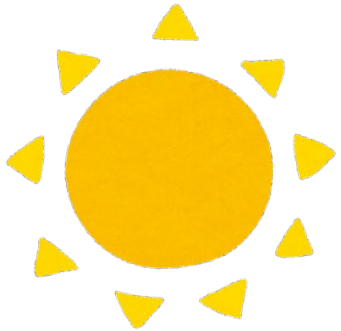
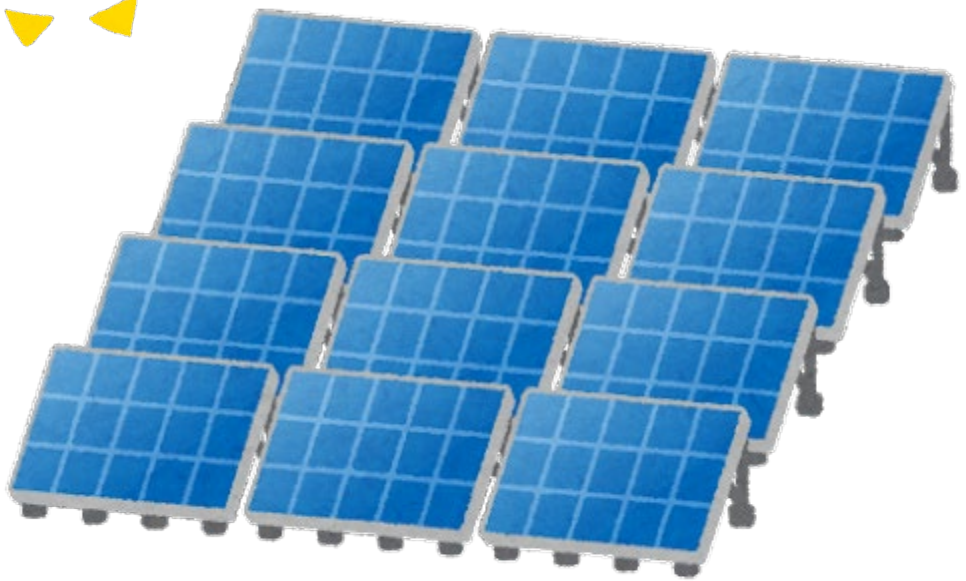
Today's content

1. Characteristics of solar power, advantages and limitations
2. The current situation of solar PV installation in the world
3. The importance and applications of solar PV inventory
4. Solar PV mapping and database creation
5. Toward the less GHG emission society using solar PV
6. Conclusion and future work

1. Characteristics of solar power, advantages and limitations (Advantage and disadvantage)

- Solar Power is classified as the renewable and green energy.
- **Advantage**
  - ➢Unlimited energy resource
  - ➢No Green House Gas (GHG) emission
  - ➢Available anywhere in the world
  - ➢Independent energy production system
- **Disadvantage**
  - ➢Only available in daytime
  - ➢Energy production is affected by weather

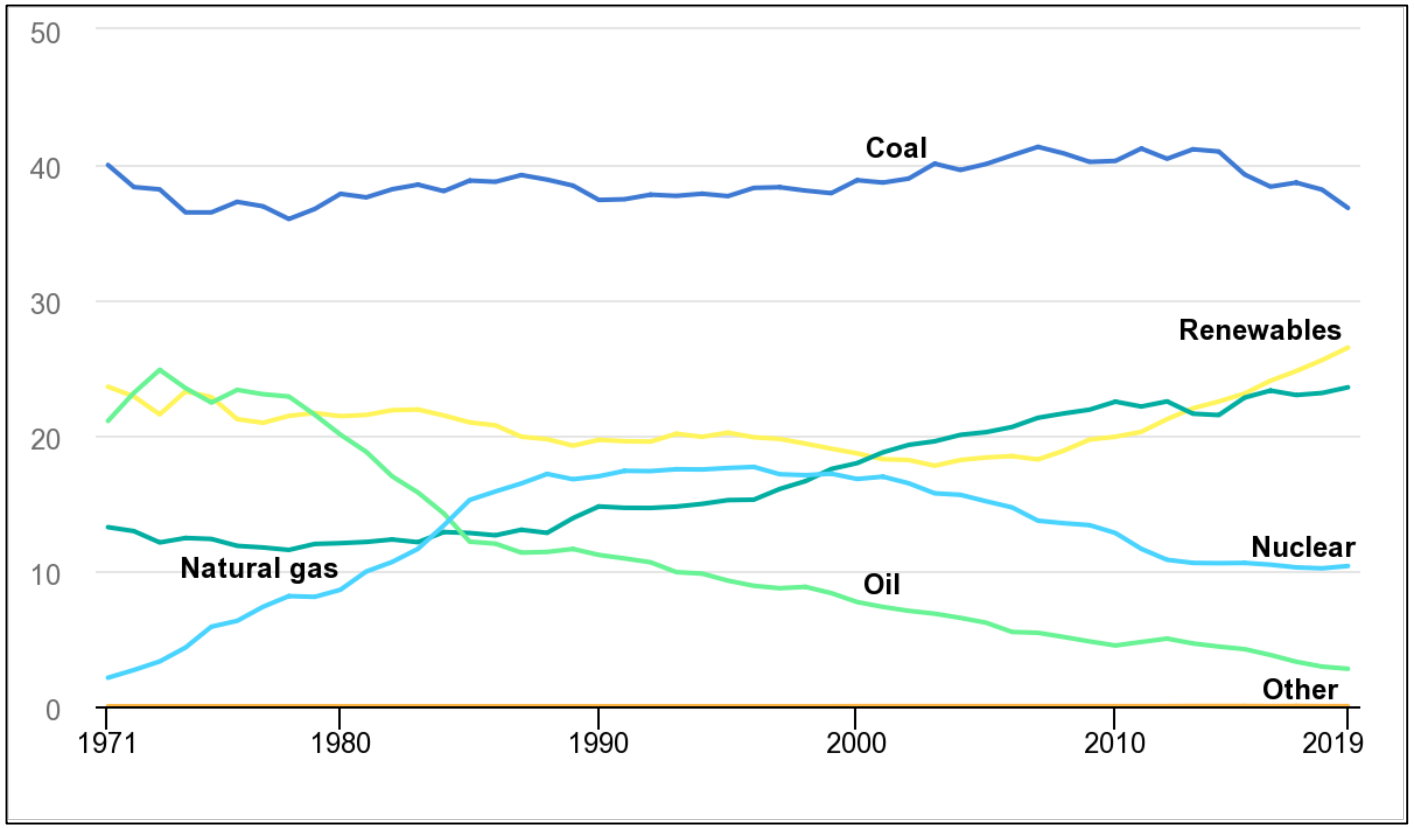




2. The current situation of solar PV installation in the world (Share of the solar power in energy production)

- The renewable energy production has been growing.

-> 26.49% comes from renewable in 2019, and **solar power is the third-largest renewable electricity technology** behind hydropower and onshore wind.

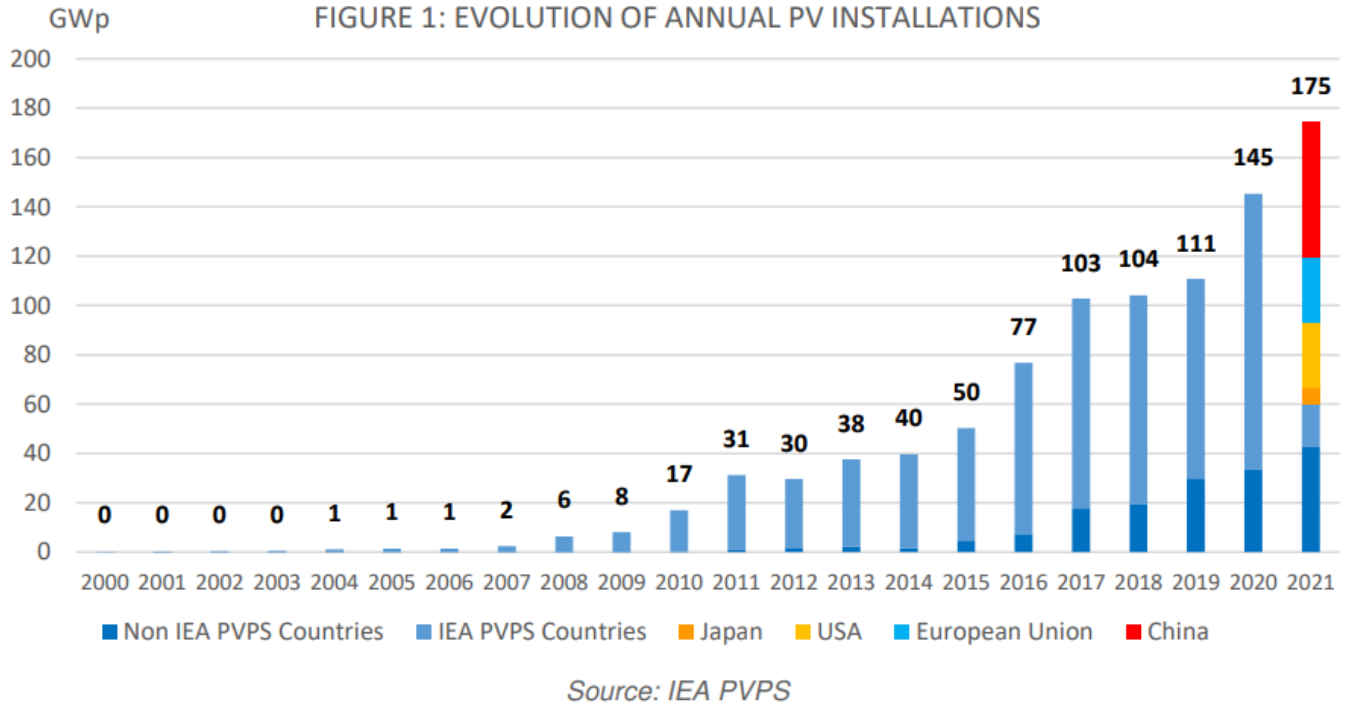


World electricity generation mix by fuel, 1971-2019, IEA, 2019

2. The current situation of solar PV installation in the world (Growth of solar power)

- Solar power has grown dramatically in the last ten years.

-> Asia pacific region countries are reading the PV growth.



FOR CUMULATIVE CAPACITY

1	China	308,5 GW
(2)	European Union*	178,7 GW
2	USA	123 GW
3	Japan	78,2 GW
4	India	60,4 GW
5	Germany	59,2 GW
6	Australia	25,4 GW
7	Italy	22,6 GW
8	Korea	21,5 GW
9	Spain	18,5 GW
10	Vietnam	17,4 GW

IEA-PVPS, Snapshot of global PV market 2022

3. The importance and applications of solar PV inventory (Energy production & Hazard risk monitoring)

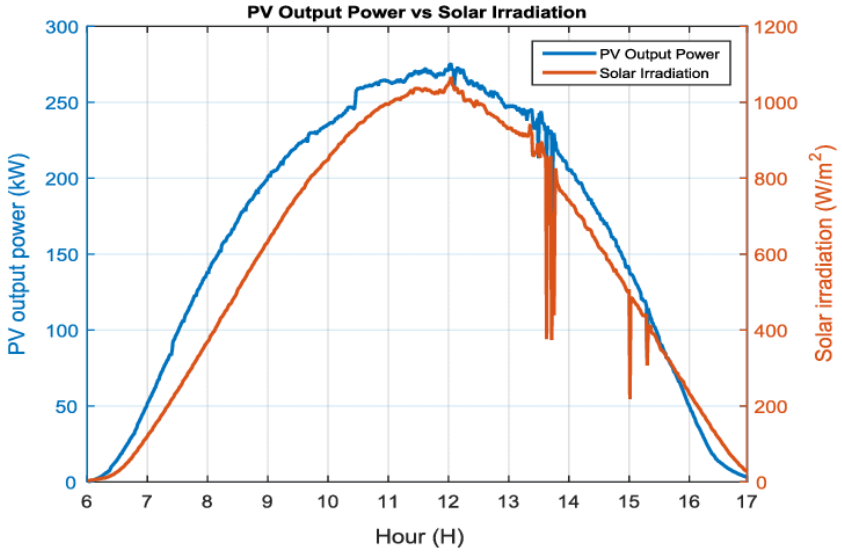
- **Asset level datasets of the solar energy system** are crucial for the operation of increasingly renewables-based electricity systems [1].

-> Energy production from solar PVs can be predicted using a PV database.

- Those can also be used **for disaster risk evaluation** on the assets since some solar PVs are built near or inside hazardous zones [2].

-> Especially in Japan, some solar PVs are built near steep slopes or flood prone areas.

-> Appropriate risk mitigation works can be done based on the PV database.



Muhammad *et al*, Solar Energy, 2016

(a) Case 1 (Heavy rain)

(b) Case 2 (Typhoon)

(c) Case 3 (Typhoon)

(d) Case 4 (Typhoon)

Mori *et al*, energies, 2020

3. The importance and applications of solar PV inventory (Land cover change monitoring)

- A large-scale solar PV power station changes LULC dramatically.

-> LULC changes related to the PV installation can be tracked using a solar PV database.

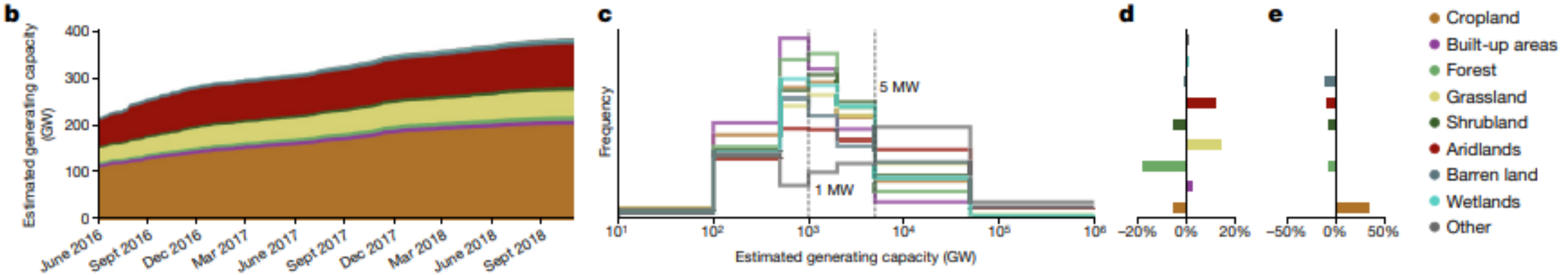


Fig. 3 | Pre-existing land cover for new solar PV installations. a–e, Panels show the location of installations (**a**); the time series of installations (**b**); the distribution of installation sizes by land cover (**c**); local bias (**d**) between PV land cover and local land covers, where the local land covers are those lying within the same 0.5° × 0.5° grid pixel; and global bias (**e**) between the global land-cover distribution and the distribution of all PV-containing pixels. A positive bias indicates that PV is preferentially installed on this land-cover type; a negative bias indicates this land-cover type is avoided. Country-level analysis is available in Supplementary Fig. 10.

Kruitwagen, et al, Nature, 2021

4. Solar PV mapping and database creation (How can we map and create a solar PV database)

- **How can we map and create a solar PV database?**

1. Hand digitization of PV sites using satellite or aerial images
2. Reports from the companies that operate PV sites
3. Internet information-based inquiry
4. Machine-learning based classification scheme

Advantage

- No need for painstaking manual digitization process
- Wide coverage (country scale ~ global scale)

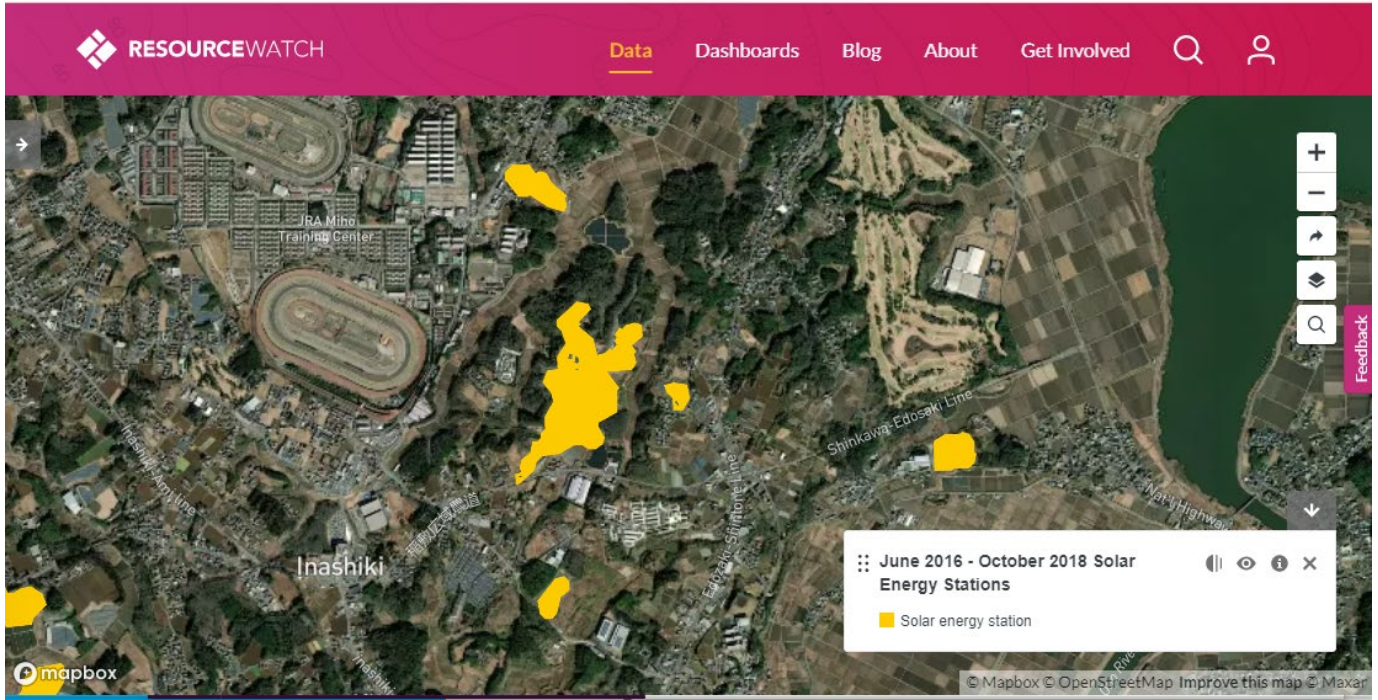
Disadvantage

- Some information is not possible to estimate
- Errors related to machine learning prediction

4. Solar PV mapping and database creation (Machine learning models)

-> **Many famous ML models have been tested for solar PV detection tasks.**

1. Convolutional Neural Network (CNN) [1,3,4,5,6]
2. Support Vector Machine (SVM) [7]
3. Random Forest (RF) [8]



June 2016 - October 2018 Solar Energy Stations

Kruitwagen, et al, Nature, 2021

4. Solar PV mapping and database creation (My past research contributions)

- **I have done some studies of detecting solar PVs using satellite imagery by focusing on the following points.**

1. Use of Freely available data
2. Improvement of the detection accuracy
3. Use of SAR data for the input values
4. Application of solar PV database

- **This is the list of my past research contributions.**

1. Shoki Shimada and Wataru Takeuchi, “Detection and Disaster Risk Evaluation of Solar Photovoltaic Cells in Satellite Remote Sensing Data”, Journal of The Remote Sensing Society of Japan
2. Shoki Shimada ans Wataru Takeuchi, “Analysis of the relationship between land-use-land-cover change and the insallation of solar photovoltaic power in southern Vietnam using remotely sensed data from 2019 to 2021”, International Symposium on Remote Sensing 2022
3. Shoki Shimada and Wataru Takeuchi, “A machine-learning based scheme for solar PV detection using medium-resolution satellite images in Vietnam”, International Geoscience and Remote Sensing Symposium 2022

4. Solar PV mapping and database creation (My past research contributions)

- **Key findings in my past studies**

1. Coherence value derived from the SAR data characterizes solar PVs
2. Random Forest and Neural Network both work well and achieve high accuracy for PV detection
3. By combining multiple PV detection results, detection errors are reduced
4. In Vietnam, barren lands and forests are preferred for solar PV installation
5. Freely available satellite images would be useful for updating solar PV database

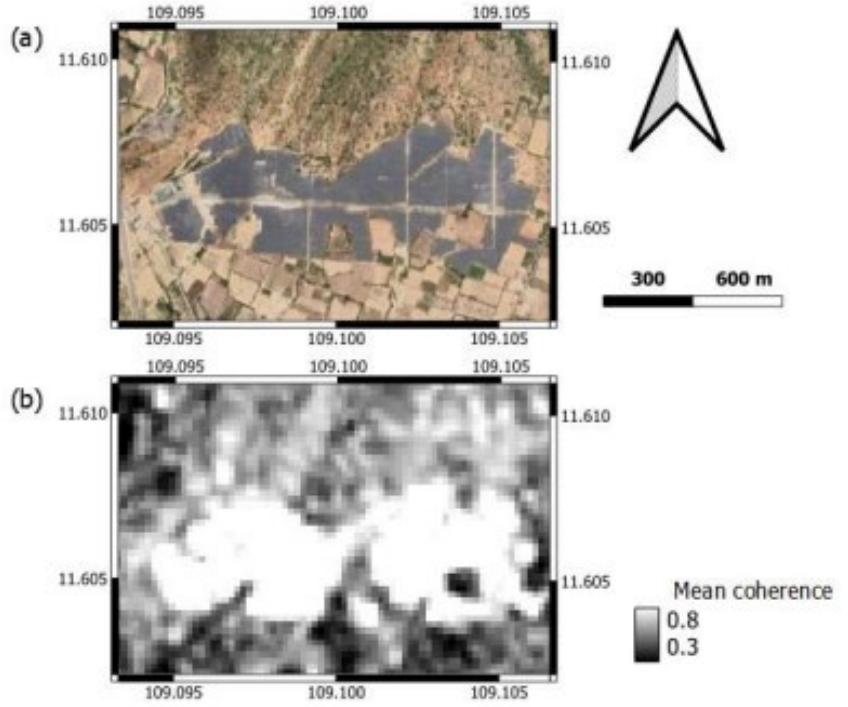


Fig. 3. (a): A high-resolution image of a large solar PV site on Google Earth QGIS plugin, (b): Temporal mean coherence image of the site

4. Solar PV mapping and database creation (My current plans to improve the detection performance)

- **The coherence values are found to be helpful in my past studies.**

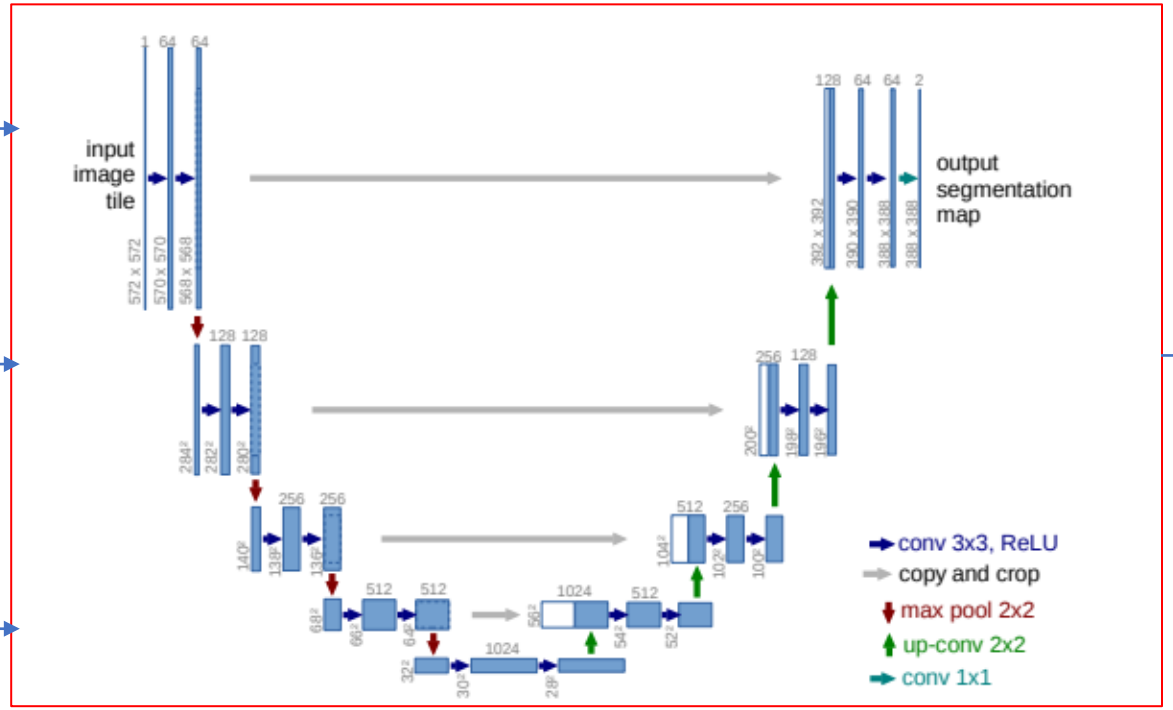
-> By supplying the coherence data and optical data (Sentinel-2) to more advanced machine learning models, the detection performance would be much improved.

-> Deep segmentation models (ex. U-net) are under consideration right now.

Sentinel-2 imagery

Sentinel-1 coherence data

Other satellite imagery



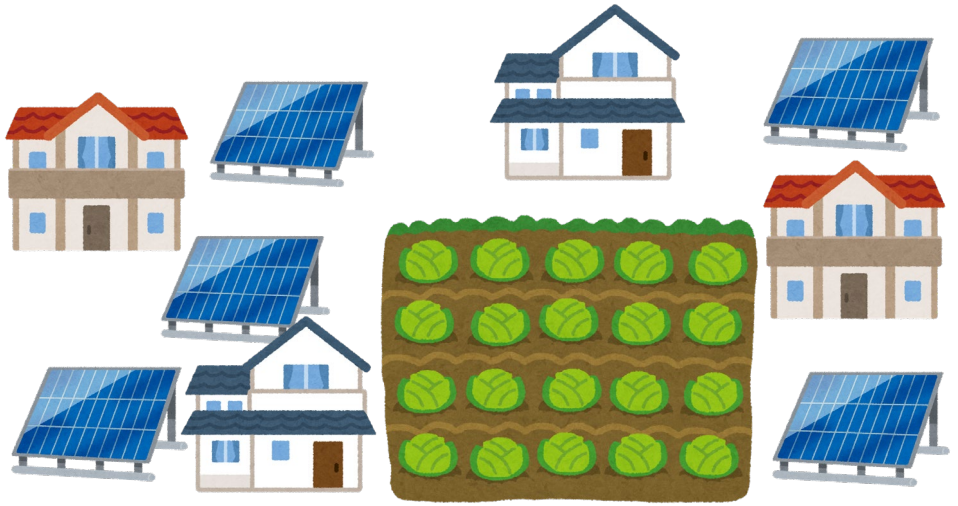
Solar PV database

5. Toward the less GHG emission society using solar PV (How can we use solar PV database?)

- Solar power is characterized by the decentralized nature of its electricity generation systems.
- It's hard to install the monitoring devices on all the solar PV in a country.
- Remote sensing is suitable for this kind of wide-area analysis.

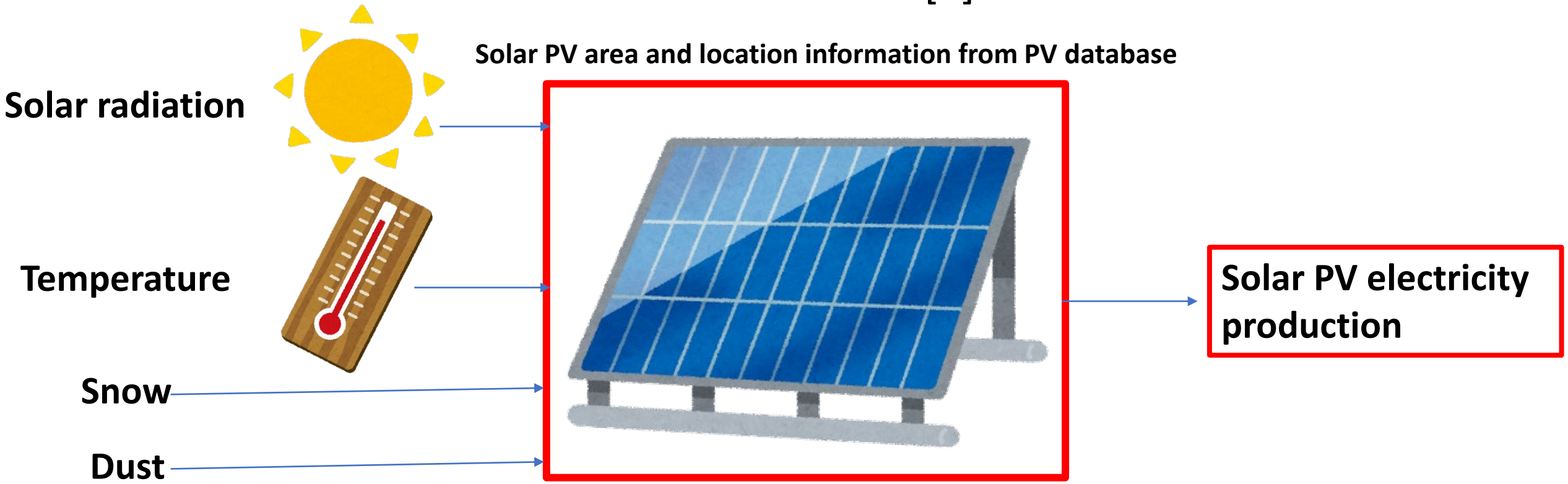
Traditional power plants

Solar power



5. Toward the less GHG emission society using solar PV (How can we use solar PV database?)

- The solar PV database can be used to estimate the electricity production by using environmental variables such as solar radiation [9].



$$P'_{PV} = A_{cell}\,\eta\,R'(1 - \overline{\Delta\eta_t} - \overline{\Delta\eta_d} - \overline{\Delta\eta_s})$$

5. Toward the less GHG emission society using solar PV (Solar power energy-demand balance evaluation)

- The estimated solar power electricity production curve can be compared to the energy demand.
- The amount of excessive electricity production which could go to waste would be known.

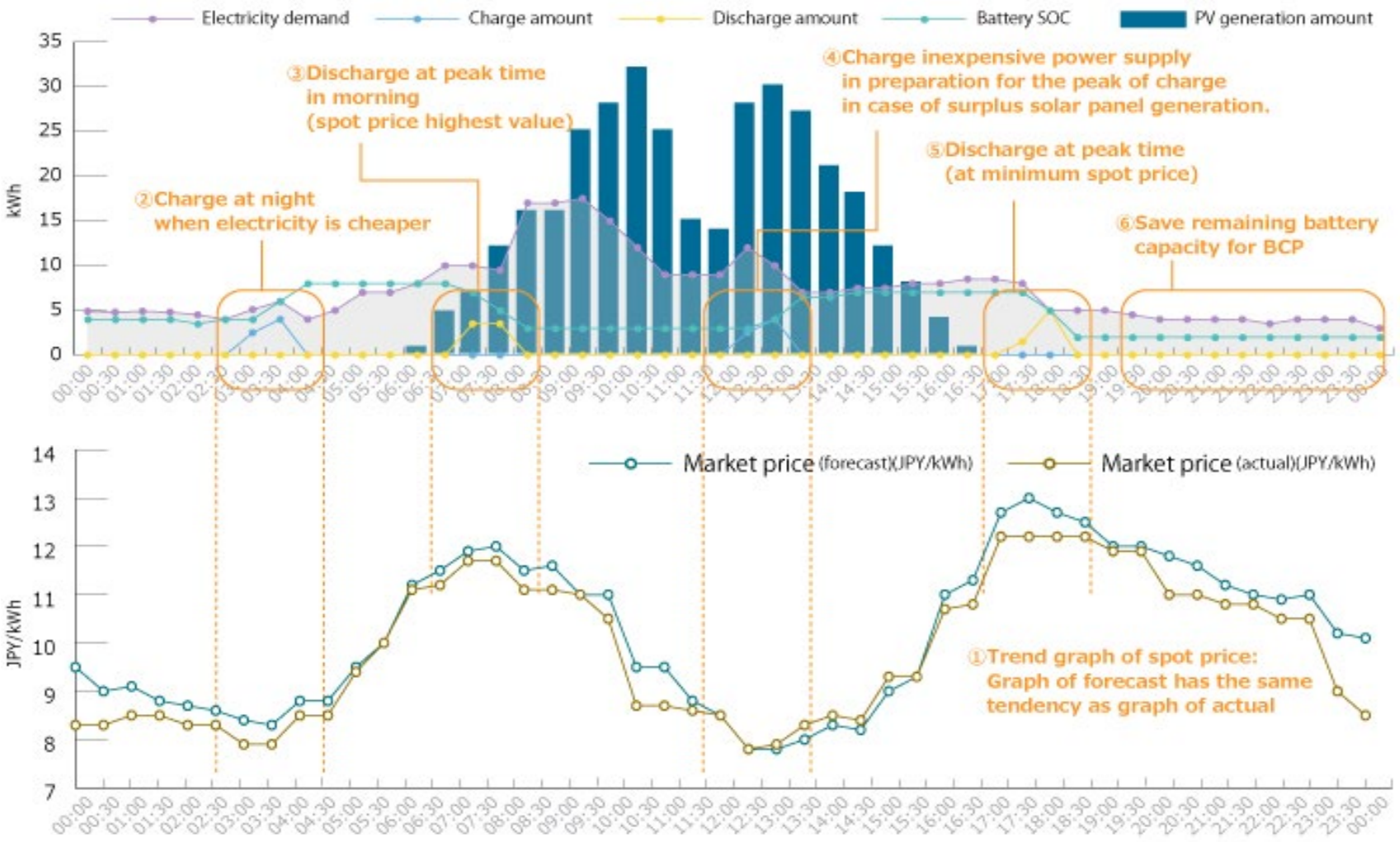


Image source: https://www.toshiba-energy.com/en/renewable-energy/image/03-06-007.jpg

5. Toward the less GHG emission society using solar PV (Problem of solar power production)

- As more and more solar PVs are installed, the problem of excessive energy production is becoming clear.

-> Some of the green energy from solar power is not utilized

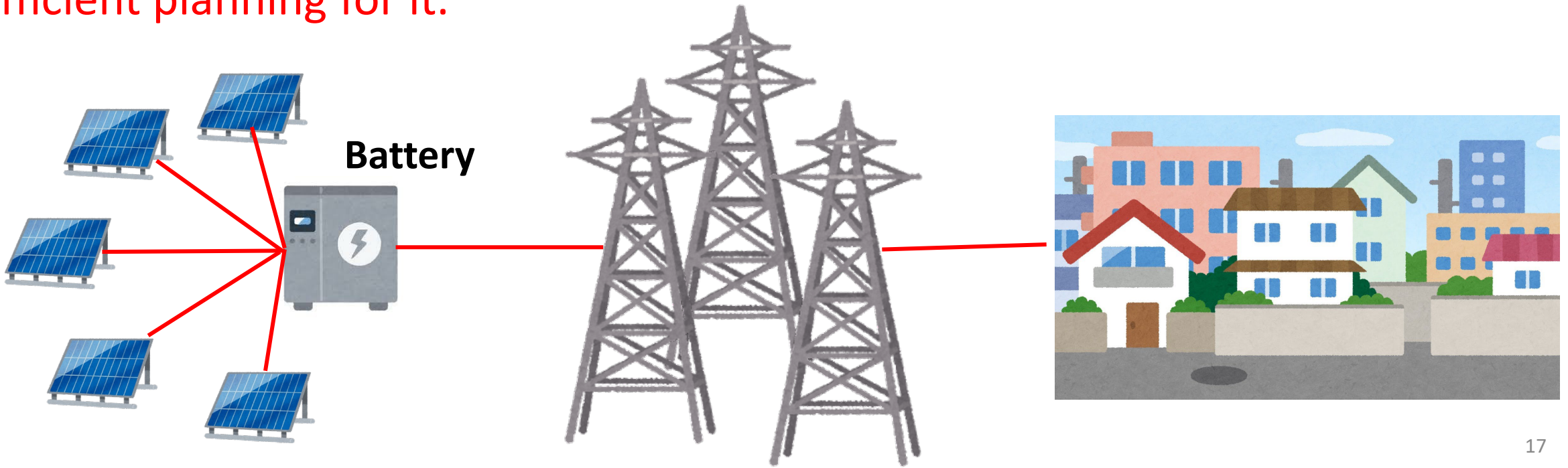
-> Thermal power plants are still common ways of conpensating the fluctuations of solar energy production

We should be able to reduce more GHG emission by fully utilizing the full potential of solar power

5. Toward the less GHG emission society using solar PV (Use of energy storage means)

- The excessive electricity production at the daytime can be stored in a buttery, and it can be extracted for use during nighttime.

-> It’s better to know how much excess energy is expected in a certain area to plan a battery-solar power systems. The solar PV output prediction data would enable efficient planning for it.



7. Conclusion and future work

- **Conclusion**

➢Freely available satellite imagery (Sentinel series) works well to get a solar PV distribution map.

➢Through my past research, coherence values are found to characterize solar PVs.

➢The solar PV database is already useful to quantitatively assess LULC and other environmental changes.

- **Future works**

➢Deep Learning models should improve the accuracy and coverage of solar PV database by combining both SAR and optical data.

➢The solar PV database will be the foundation of my future study to estimate excessive electricity production from existing solar PVs.

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[3] Yu, Jiafan, et al., "DeepSolar: A machine learning framework to efficiently construct a solar deployment database in the United States.", Joule, vol 2, pp.2605-2617, 2018.

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[6] Kausika, Bala Bhavya, et al., "GeoAI for detection of solar photovoltaic installations in the Netherlands.", Energy and AI, vol 6, 2021.

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