Thermodynamics and Heat Transfer
Lecture 9: Renewable Energy

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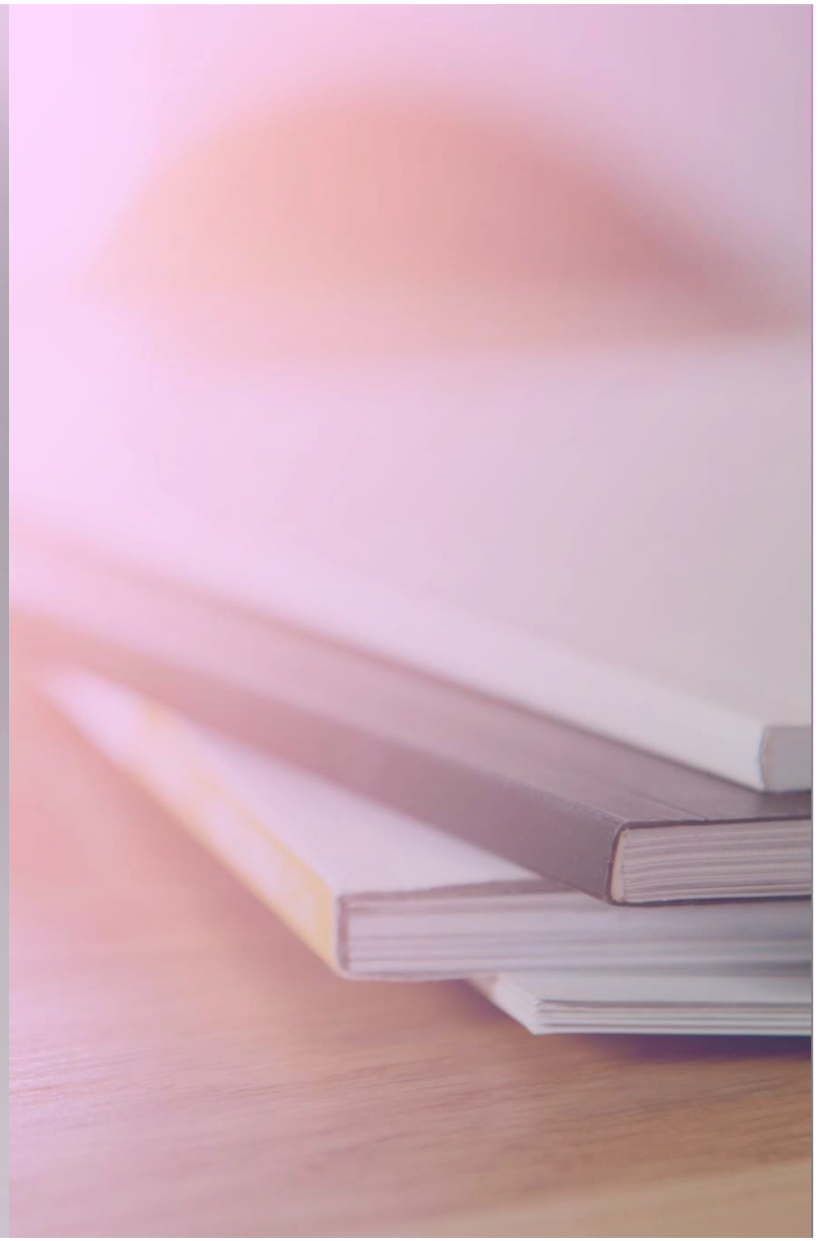
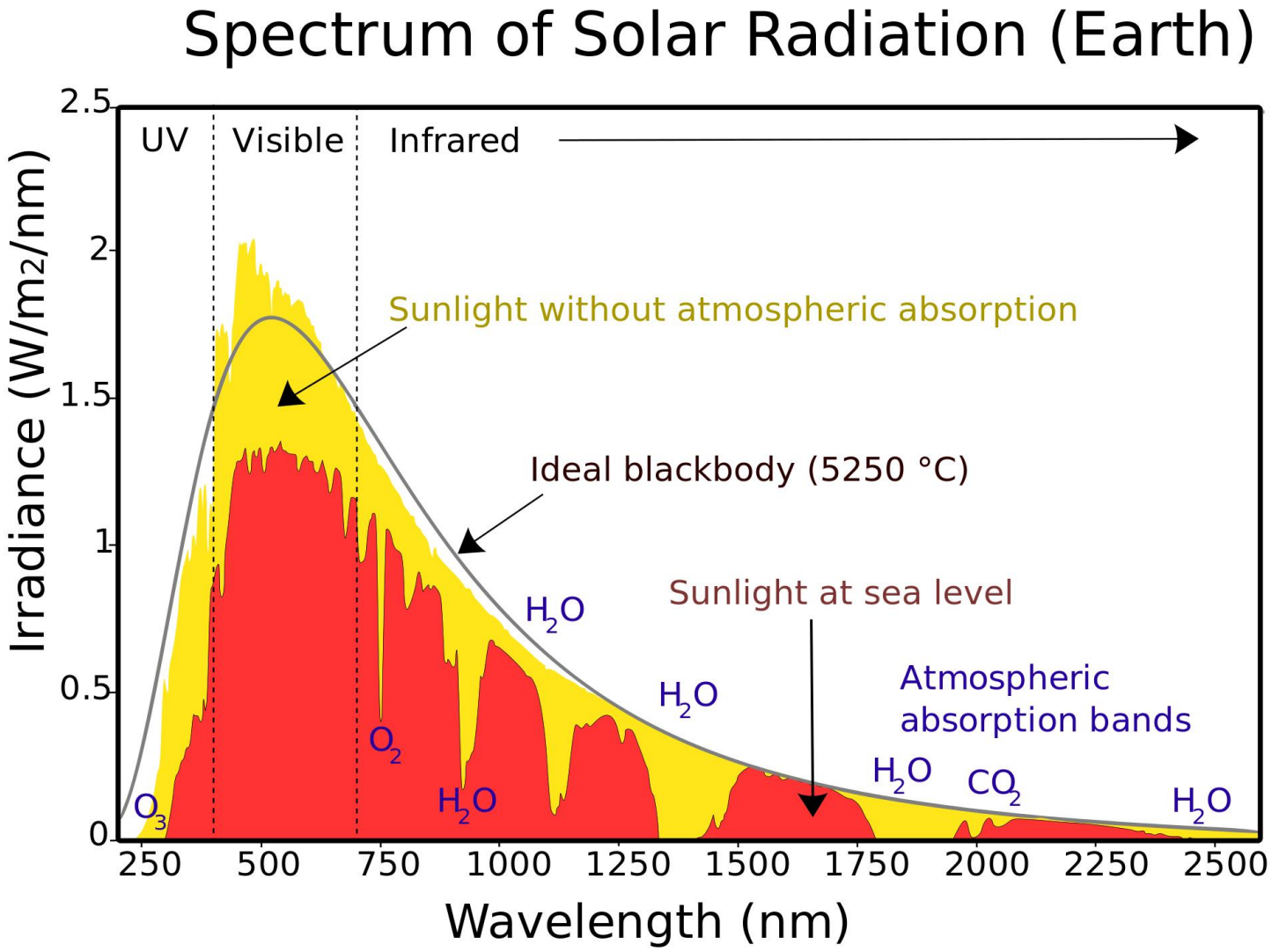
Learning outcomes:

- What Is Solar PV and How Do We Access it?
- Penetration and Future of Solar PV
- Wind Energy
- Renewables Ninja
- System Advisor Model (SAM, NREL)



The Basics of Solar

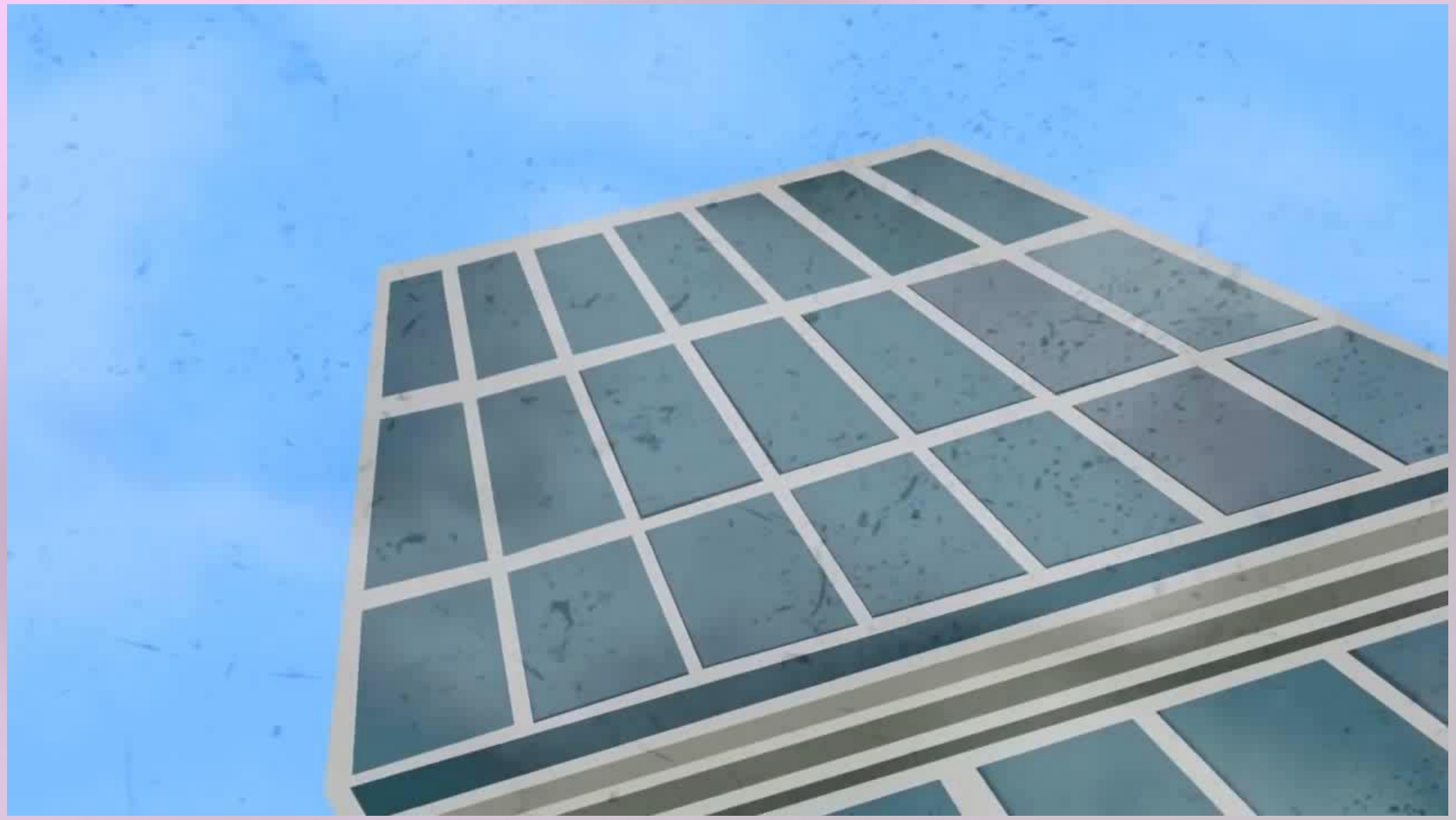
- Imagine an energy source that is practically limitless, has no fuel cost, and has no carbon dioxide emissions.
- What if I told you that we already have it?!It's called the sun!
- We all know where it comes from, but what is it? And how much of it does the earth receive?
- Solar energy comes in the form of electromagnetic radiation, which is basically waves of heat and light radiating from the sun.



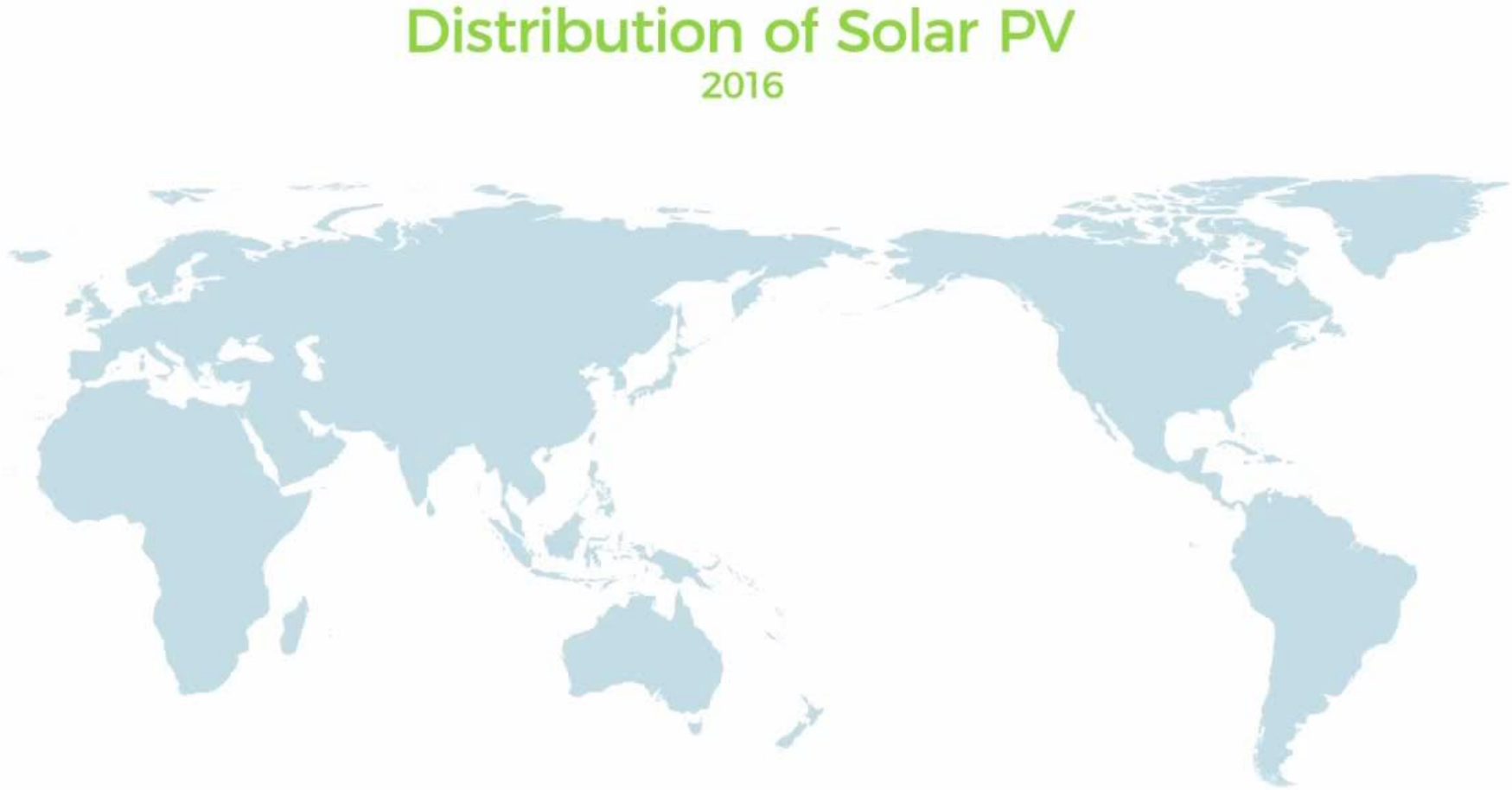
Now, how much do we receive?

- Every square meter on the earth's surface receives about 140 Watts of direct sunlight on average.
- To put that into perspective, each square meter of the earth's surface receives, on average, enough power annually to run your average ceiling fan, while two square meters might receive enough to run a plasma TV, and three-square meters might run a small washing machine.
- So, we know that we receive an enormous amount of solar energy every day, but how can we harness it?
- Well, there are currently several ways: passive use, active use, photovoltaics and concentrated solar thermal.

What Is Solar PV and How Do We Access It?



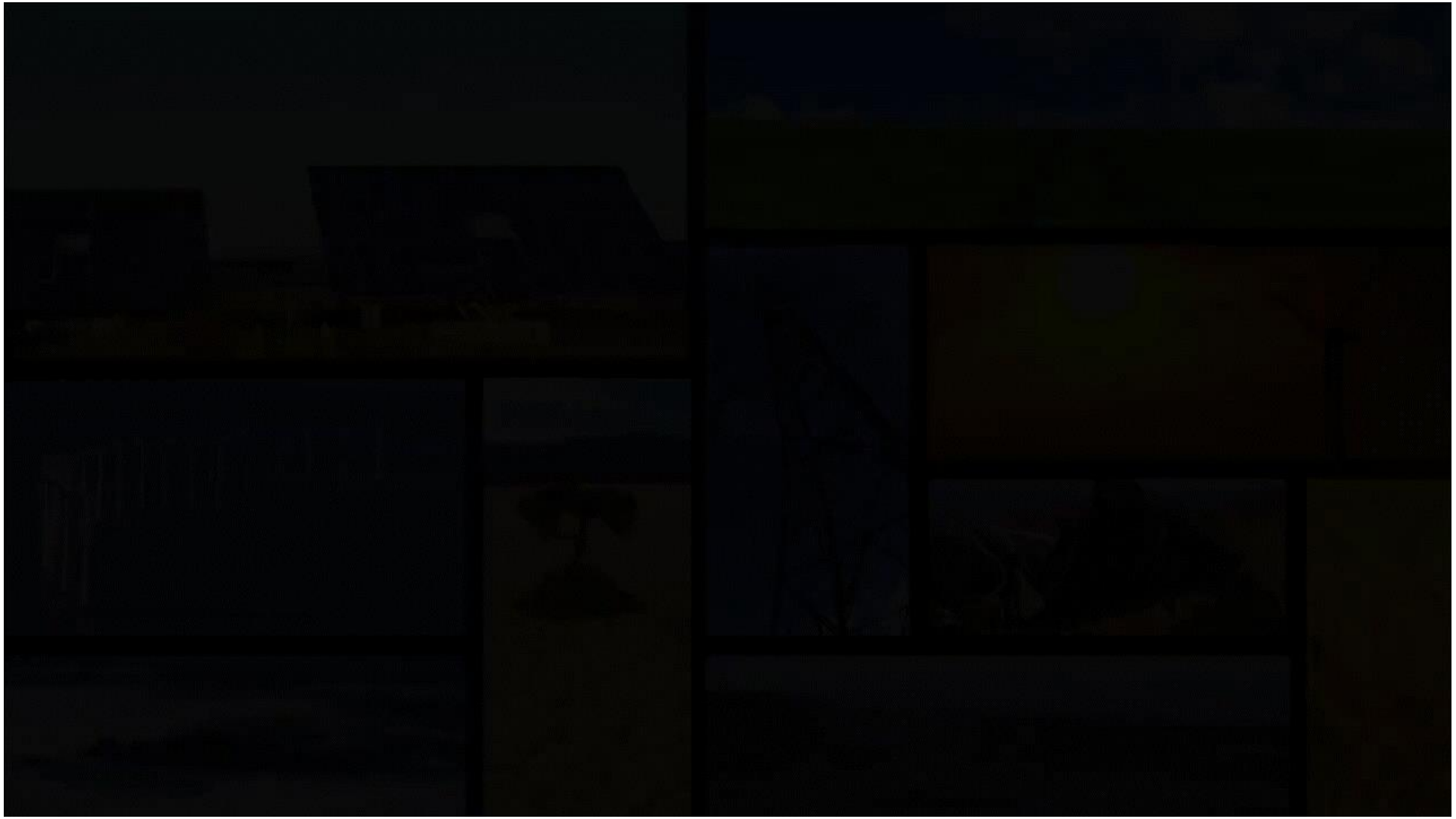
Penetration of Solar PV



The Future of Solar PV

- Accelerated solar PV deployment coupled with deep electrification could deliver 21% of the CO_2 emission reductions (nearly 4.9 gigatonnes annually) by 2050.
- Solar PV could cover a quarter of global electricity needs by mid-century, becoming the second largest generation source after wind.
- Global capacity must reach 18 times current levels, or more than 8 000 gigawatts by 2050.
- Asia would continue to dominate solar PV use, with over 50% of installed capacity, followed by North America (20%) and Europe (10%).
- Solar PV project costs, already below marginal fossil-fuel costs in global terms, are set to decline further in the decades ahead.
- Mobilising finance will be key, with IRENA's roadmap estimates implying a 68% increase in average annual solar PV investment until 2050.
- Rooftop solar PV systems have spread rapidly thanks to supporting policies, such as net metering and fiscal incentives.
- Energy transformation brings socio-economic benefits. The global solar industry could employ over 18 million people by 2050.

Wind Energy



Vide Credit: The University of Queensland, Australia, Full Course at: https://www.edx.org/

Exercises 1:

Designing solar PV system (1 MW) for 5 different locations in Finland:

1. Calculate the best tilt and azimuth angle for each case study

https://www.youtube.com/watch?v=hGPKie9QOBI

2. Compare capacity factor and power generation of the PV system for each case study.

3. Compare tracking system with non-tracking system for each case study.

4. The results can be compared with the other Nordic countries and Germany (optional).

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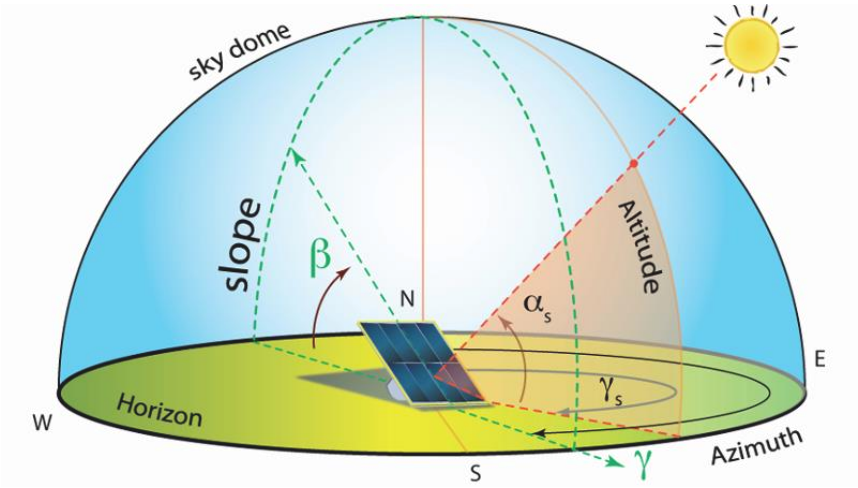


Capacity factor is the ratio between what a generation unit is capable of generating at maximum output versus the unit's actual generation output over a period of time.

Renewables.ninja

Point | Country

Search by location | Search

Lat | Lon

Solar PV

Dataset: MERRA-2 (global)

Select a year of data: 2019

Capacity (kW): 1

System loss (fraction): 0.1

Tracking: None

Tilt (°): 35

Azimuth (°): 180

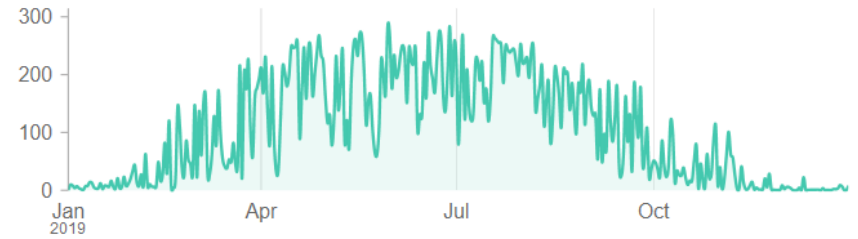
☐ Include raw data

Tick this box to include additional columns with the underlying weather data used in the model, rather than just the model output itself. Raw weather data is included in the downloadable output file but not visualized in the web application.

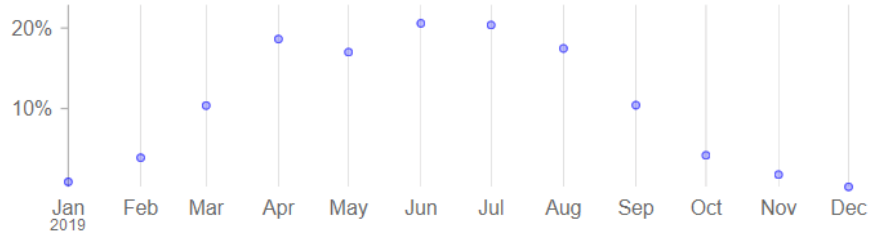
Run

Results

Daily mean



Monthly capacity factor



Total mean capacity factor: 10.5%

Save hourly output as CSV

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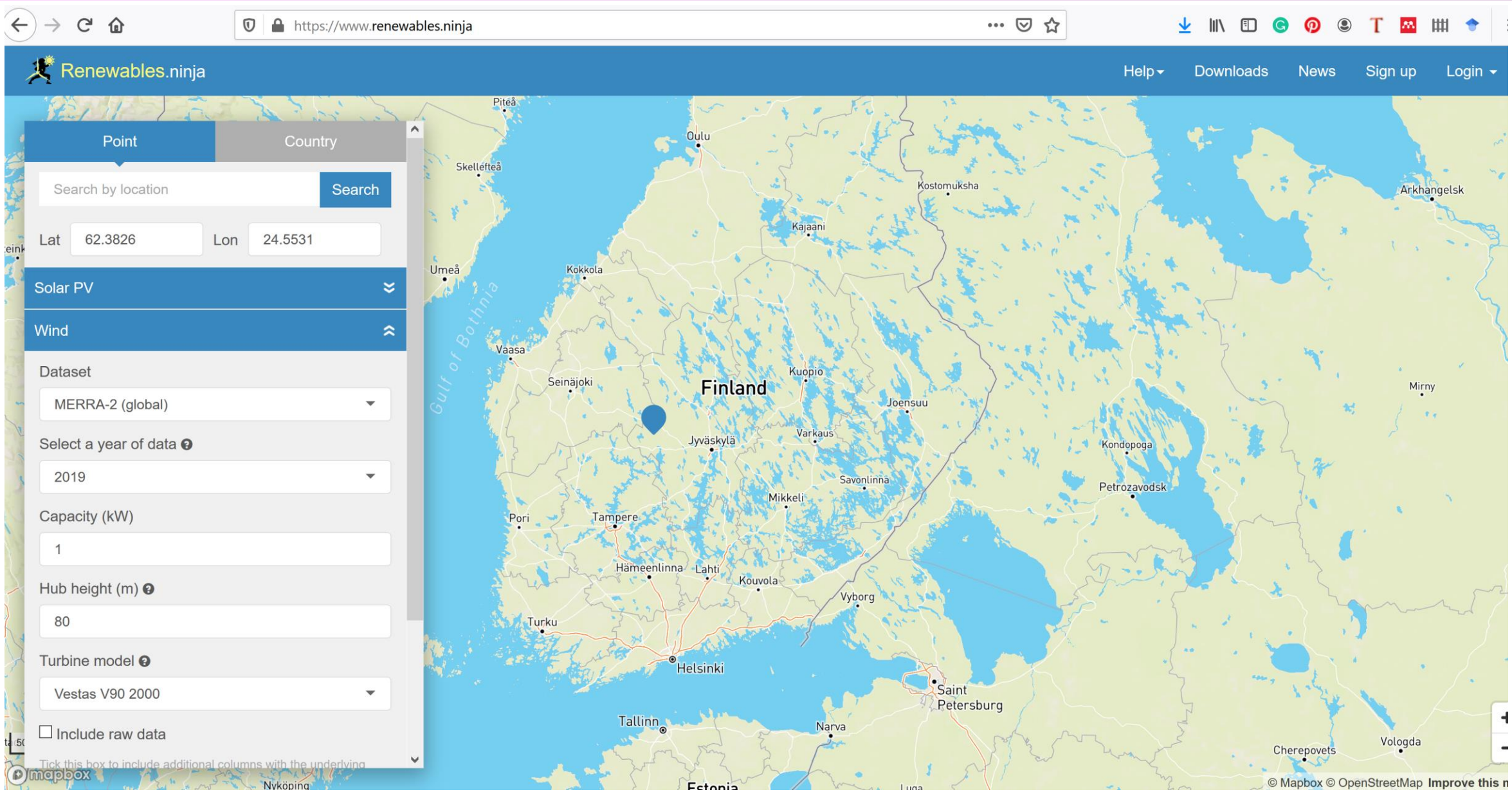
Citation: Pfenninger and Staffell (2016)

Exercises 2:

Design a wind farm (1 MW, 3 types of wind turbine) for 3 different locations in Finland:

1. Compare capacity factor and power generation of each wind turbine for each case study.
2. The results can be compared with the other Nordic countries (optional).


https://www.renewables.ninja
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Help
Downloads
News
Sign up
Login
Point
Country
Search by location
Search
Lat
62.3826
Lon
24.5531
Solar PV
Wind
Dataset
MERRA-2 (global)
Select a year of data
2019
Capacity (kW)
1
Hub height (m)
80
Turbine model
Vestas V90 2000
Include raw data
Tick this box to include additional columns with the underlying
Finland
Oulu
Piteå
Skellefteå
Umeå
Kokkola
Vaasa
Seinäjoki
Kuopio
Joensuu
Jyväskylä
Varkaus
Savonlinna
Mikkeli
Pori
Tampere
Hämeenlinna
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Saint Petersburg
Tallinn
Narva
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Welcome

Webinar Supporting Materials

- Presentation slides (PDF 1.4 MB)
- Q&A transcript (PDF 81 KB)

What is SAM?

The System Advisor Model (SAM) is a free techno-economic software model that facilitates decision-making for people in the renewable energy industry:

Thank you
Ali Khosravi