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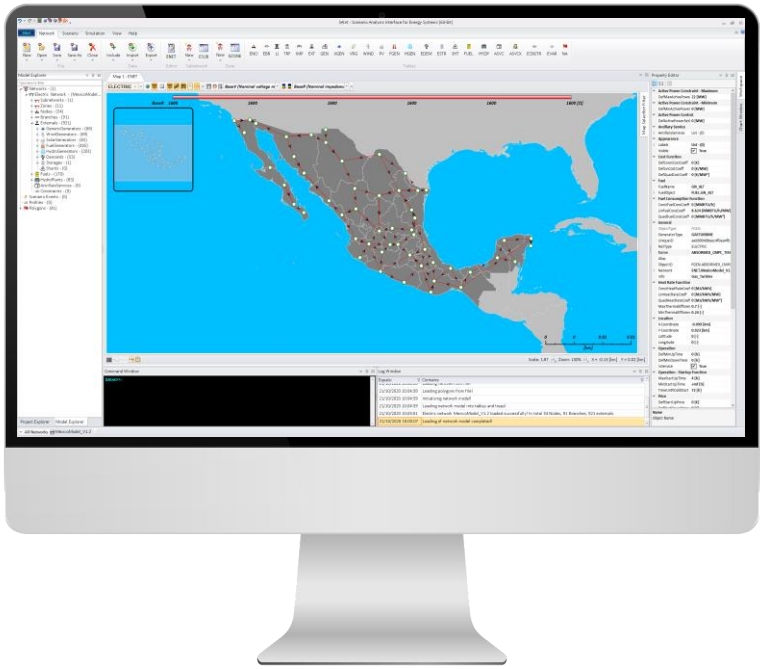
Coupling Energy Networks

Power System Production Cost Modeling to Inform Electricity Planning & Regulation



Presentation to EgyptERA

Dr. Carlo Brancucci

February 10th, 2021

About encoord

encoord is a software company based in Denver, CO, USA, and Essen, Germany.

Our core technology is the Scenario Analysis Interface for Energy Systems (SAInt), a software platform to model and plan energy networks & markets.

SAInt by encoord®

Applications

- Modeling of gas pipeline networks
- Modeling of coupled electricity and gas networks
- Modeling of electricity markets and of optimal power system operations

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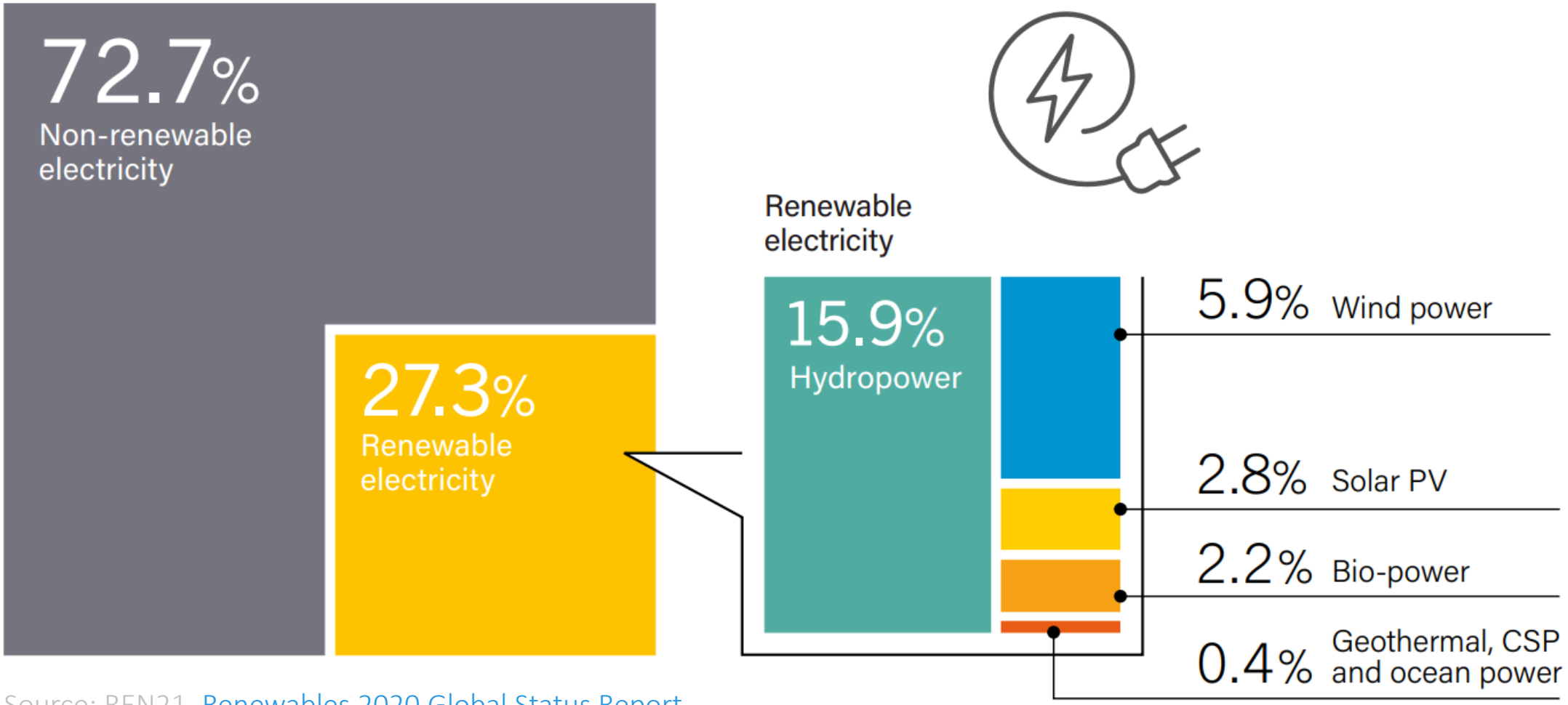
Global Electricity Generation

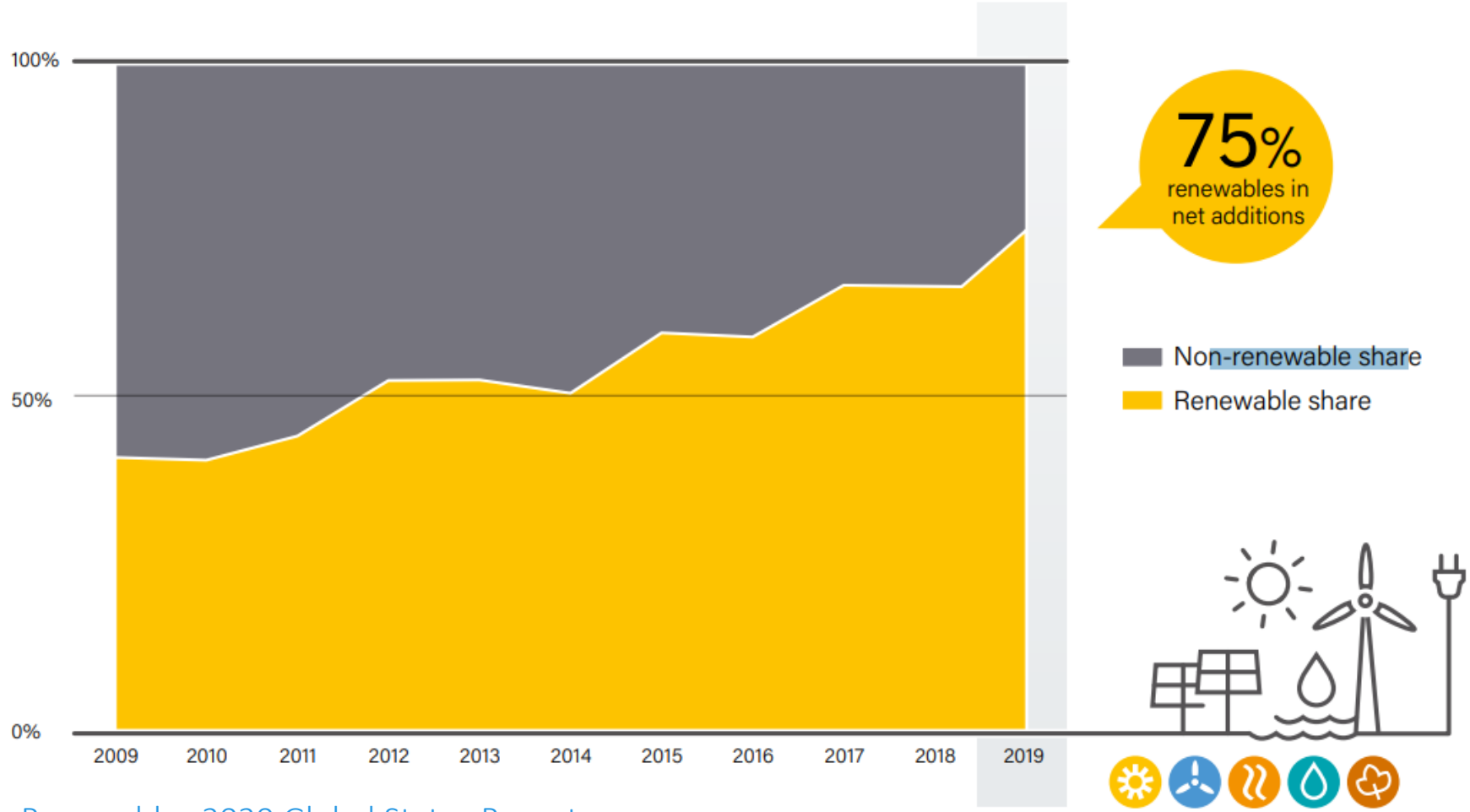
Estimated Renewable Energy Share of Global Electricity Production, End-2019



Source: REN21, Renewables 2020 Global Status Report

New Generation Capacity

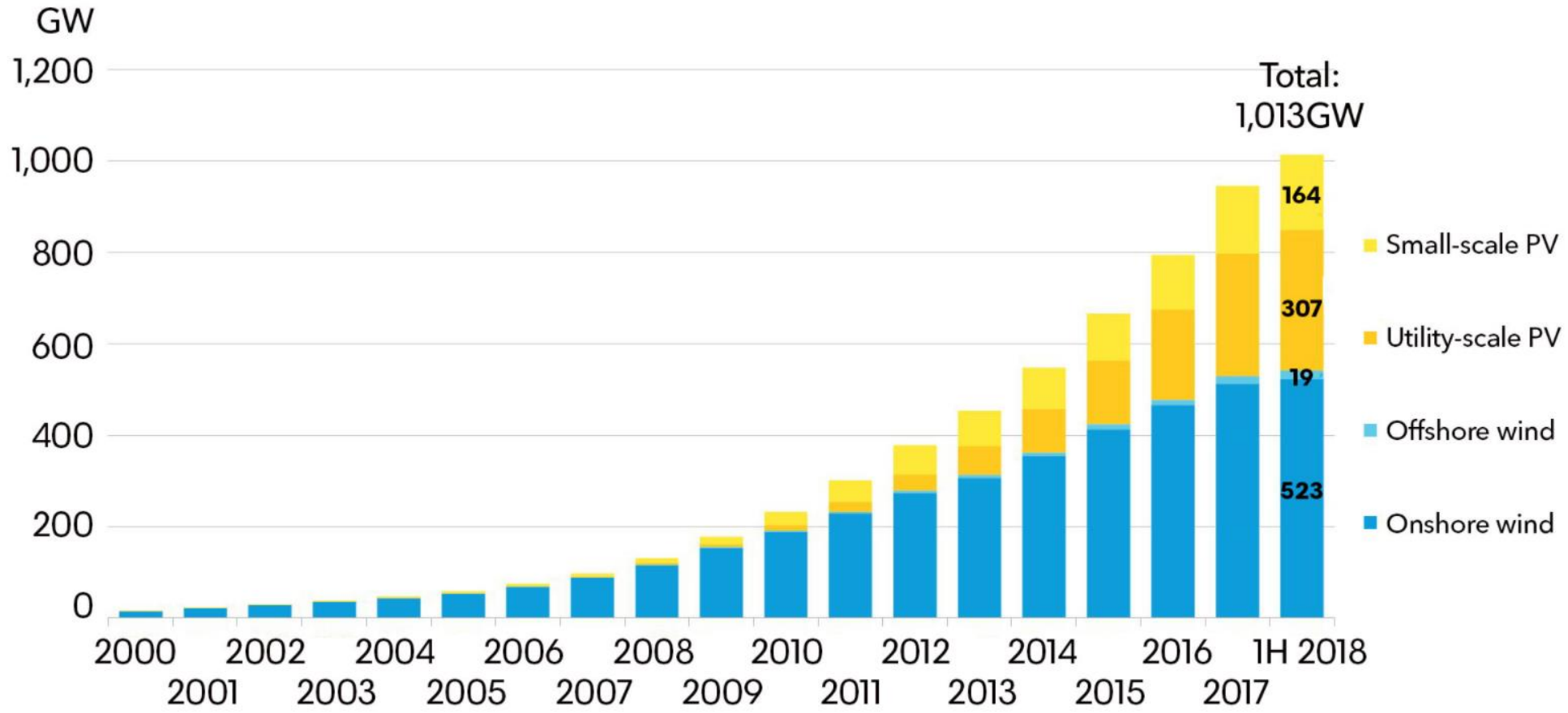
Renewable and Non-renewable Shares of Net Annual Additions in Power Generating Capacity



Source: REN21, Renewables 2020 Global Status Report

Solar PV and Wind Installations

Global wind and solar installations, cumulative to June 30, 2018



Source: Bloomberg NEF. Note: 1H 2018 figures for onshore wind are based on a conservative estimate; the true figure will be higher. BNEF tyipcally does not publish mid-year installation numbers.

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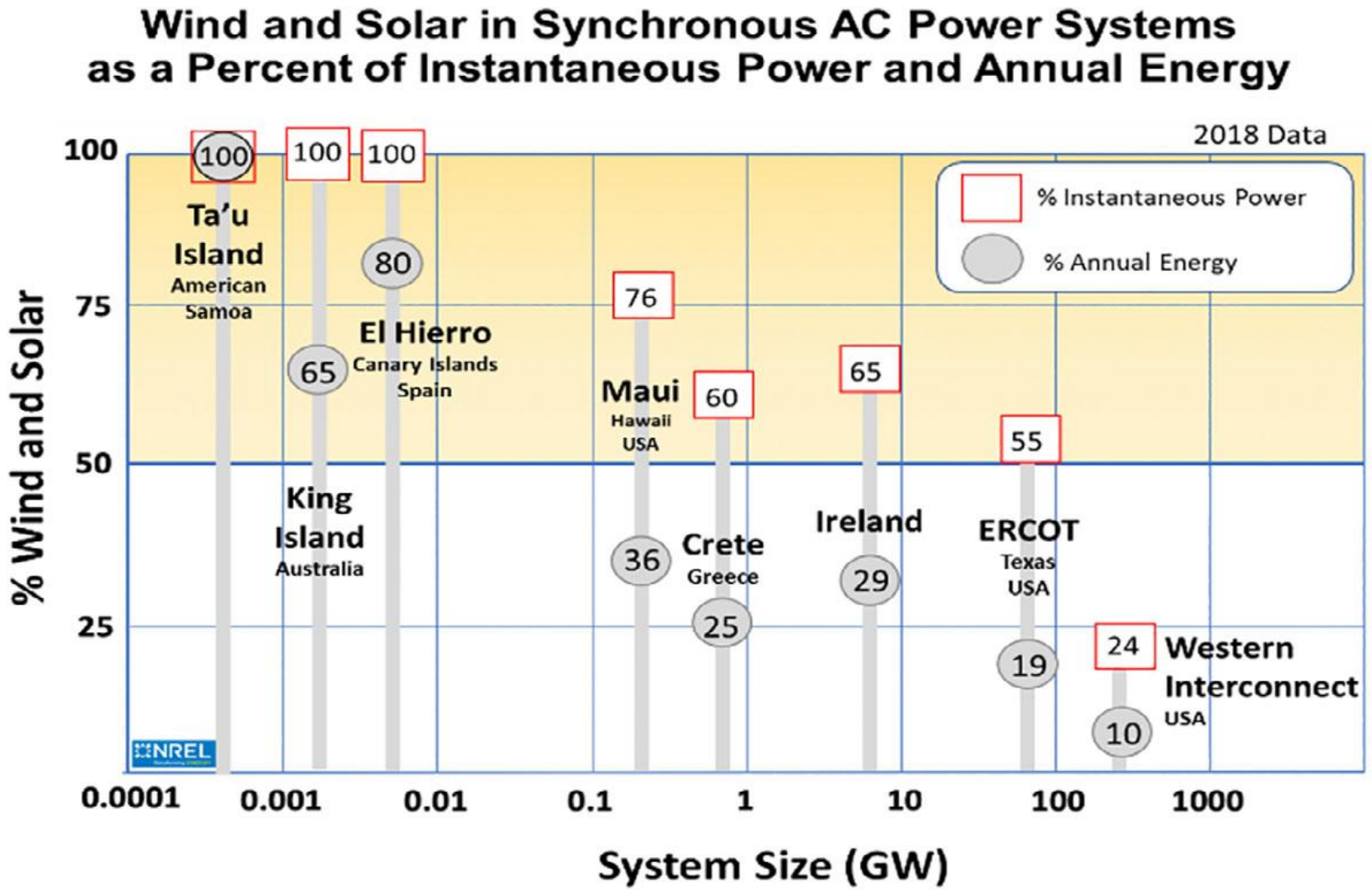
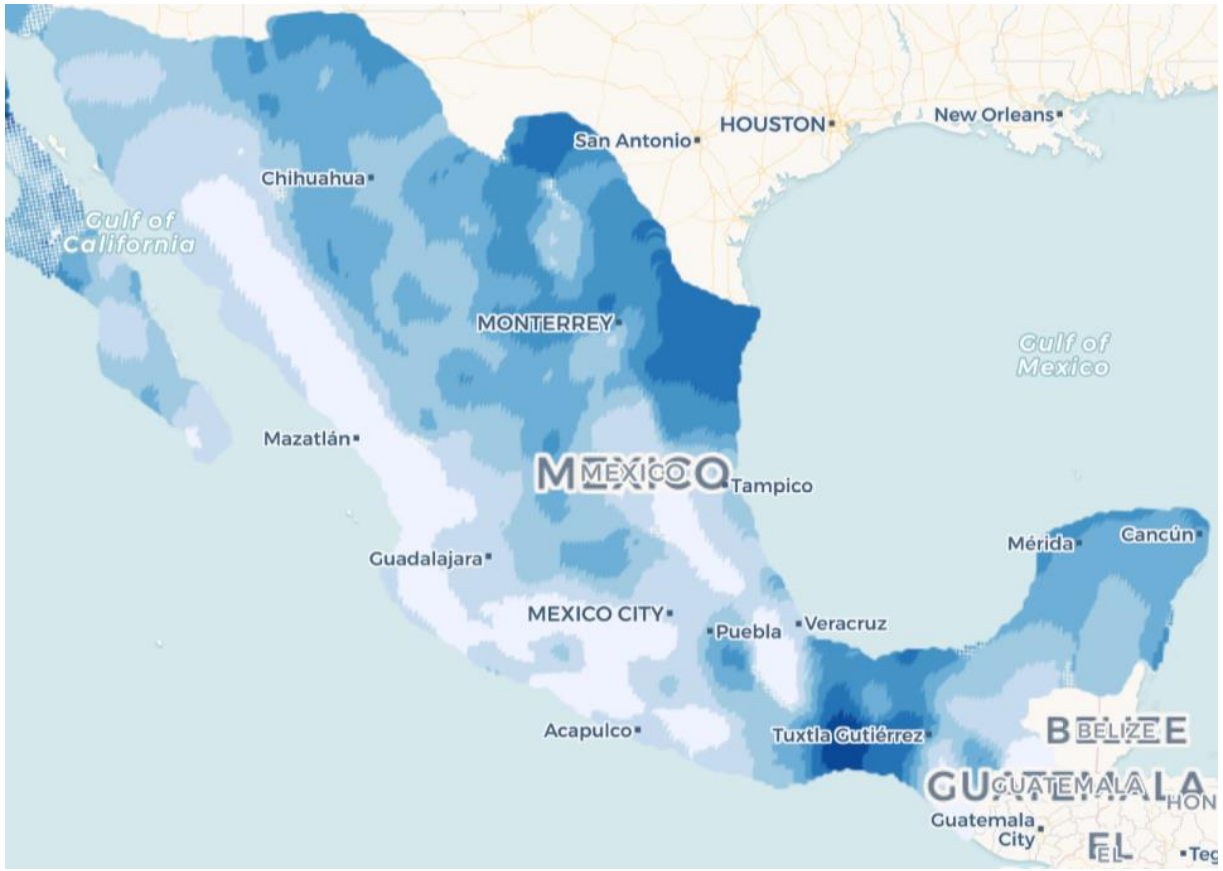
Solar PV and Wind Penetrations



Source: Hodge et al., Addressing technical challenges in 100% variable inverter-based renewable energy power systems, WIRES Energy and Environment, 2020.

Which are the major challenges of integrating higher penetrations of wind and solar energy in a power system?

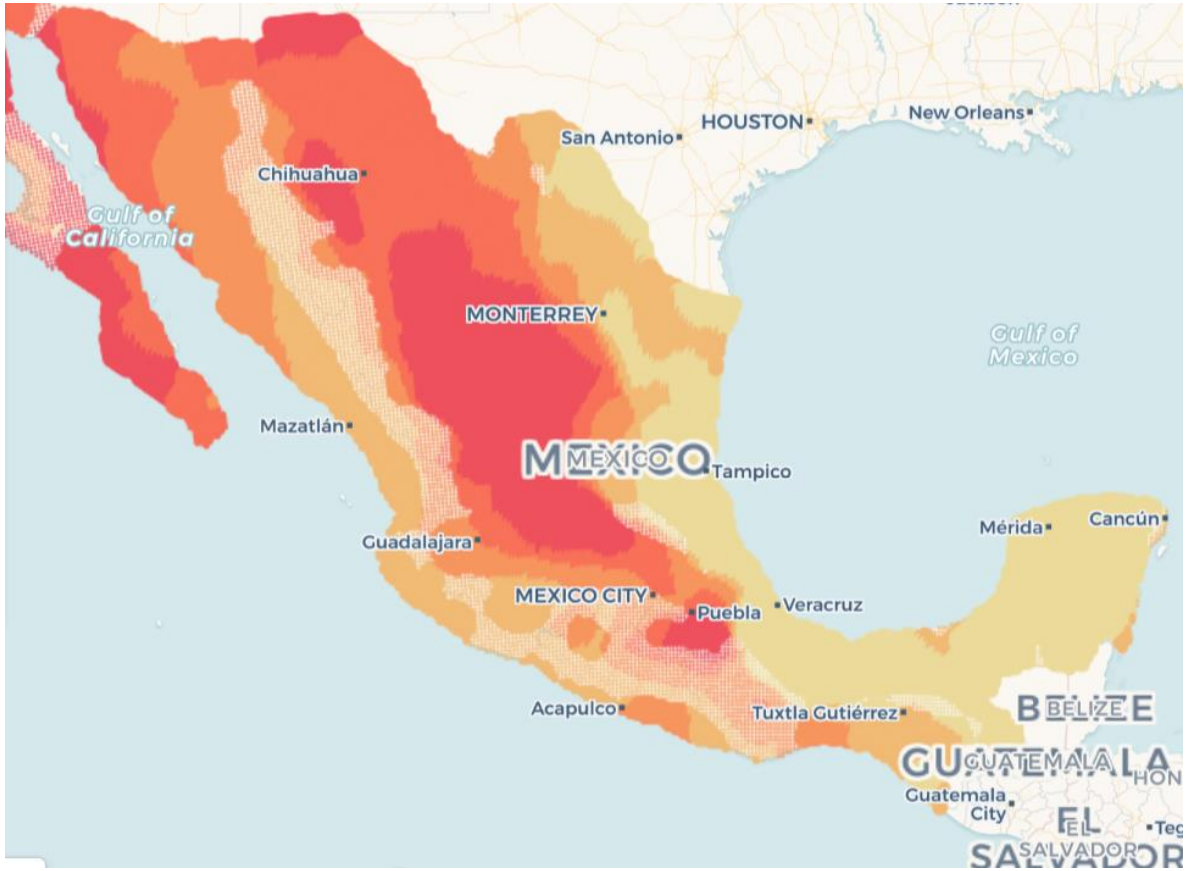
Spatial Variability



WEIGHTED MEAN CAPACITY FACTOR

3.37 — 51

17 AVG



WEIGHTED MEAN CAPACITY FACTOR

17.5 — 25.9

23.1 AVG

Source: NREL, https://tinyurl.com/y86eeh3t

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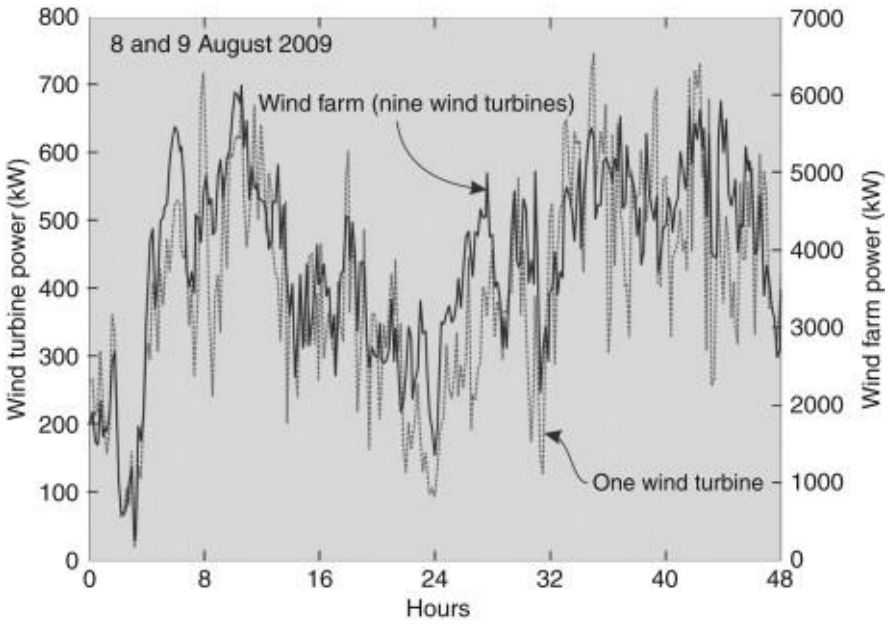
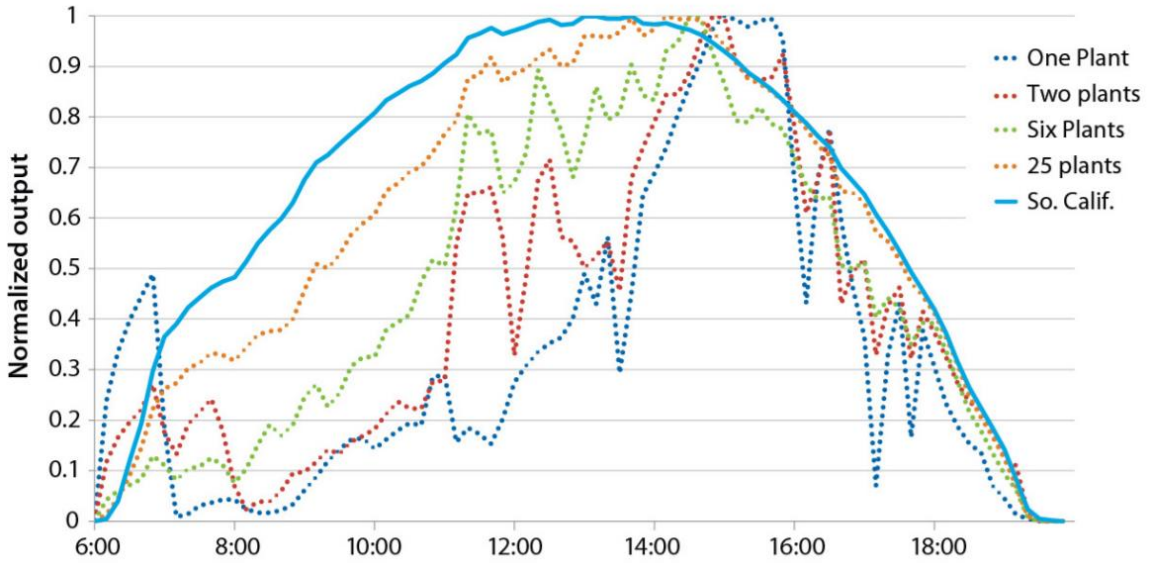
Temporal Variability

Wind



Source:
https://www.sciencedirect.com/book/9780128045671/renewable-energy

Solar



Source:
https://www.nrel.gov/docs/fy13osti/60451.pdf

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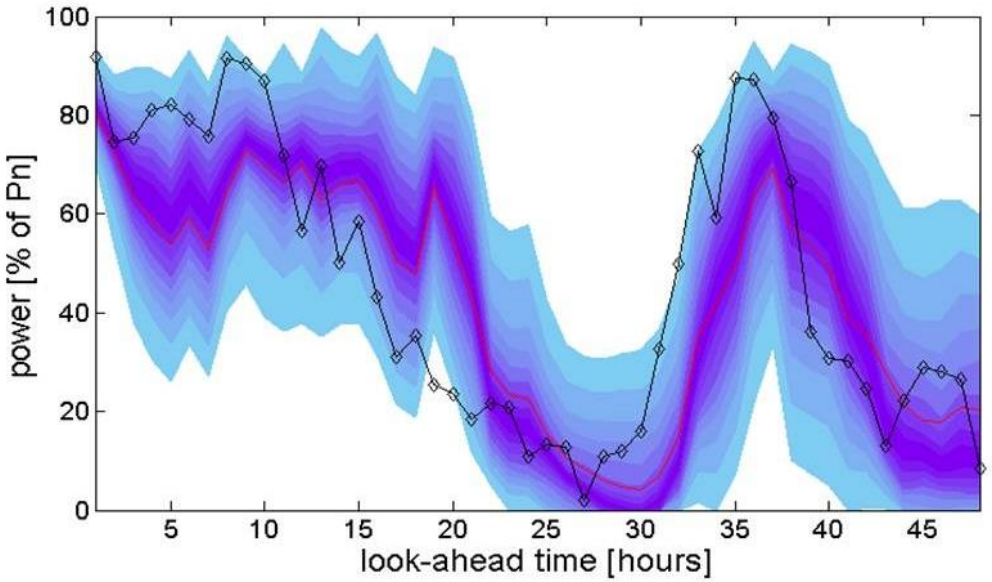
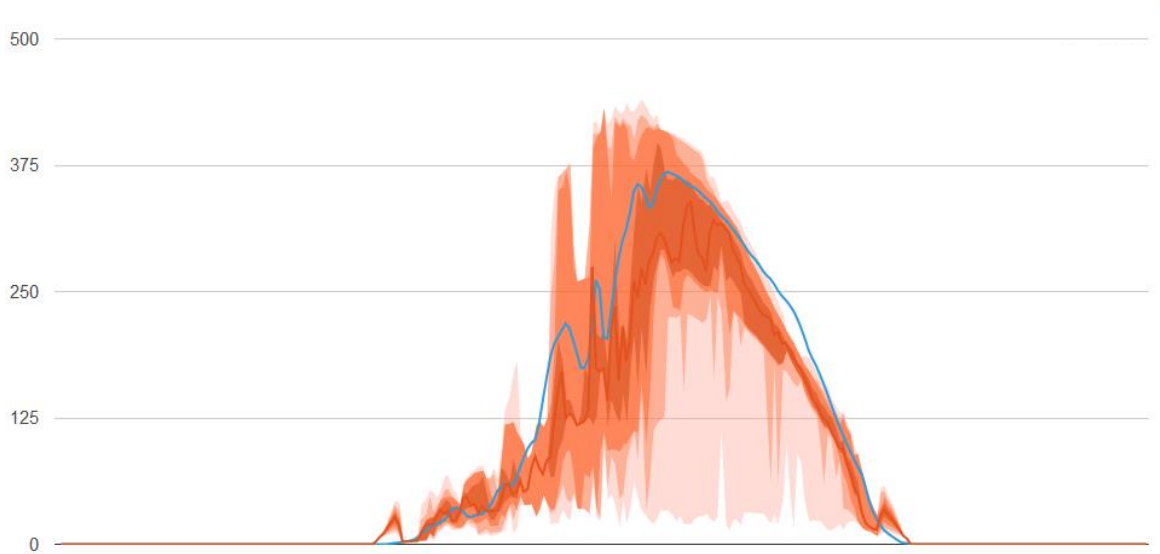
Uncertainty

Wind



Source: https://www.ewea.org/

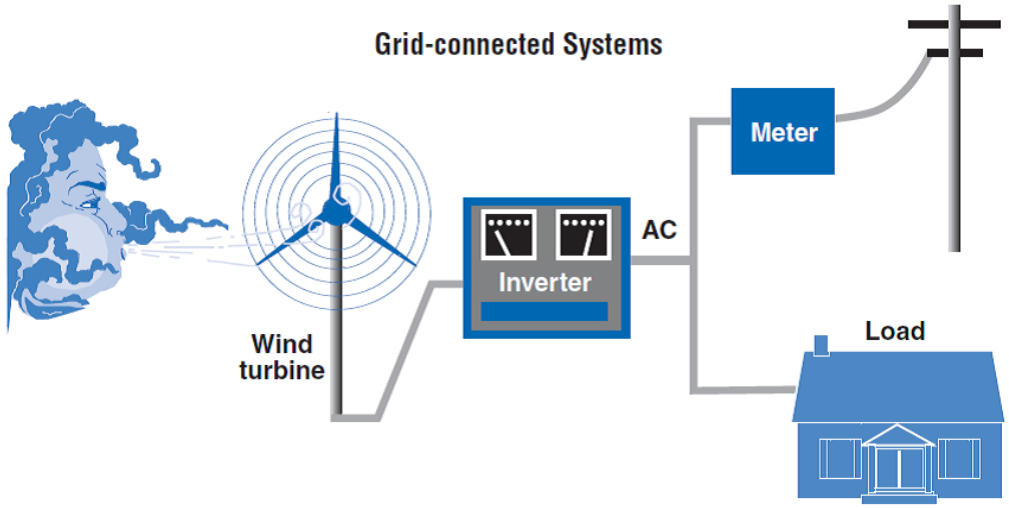
Solar



Source: https://steady-sun.com

Asynchronous Generation

Wind



Source: https://windexchange.energy.gov/

Solar

Source: https://www.cleanenergyreviews.info

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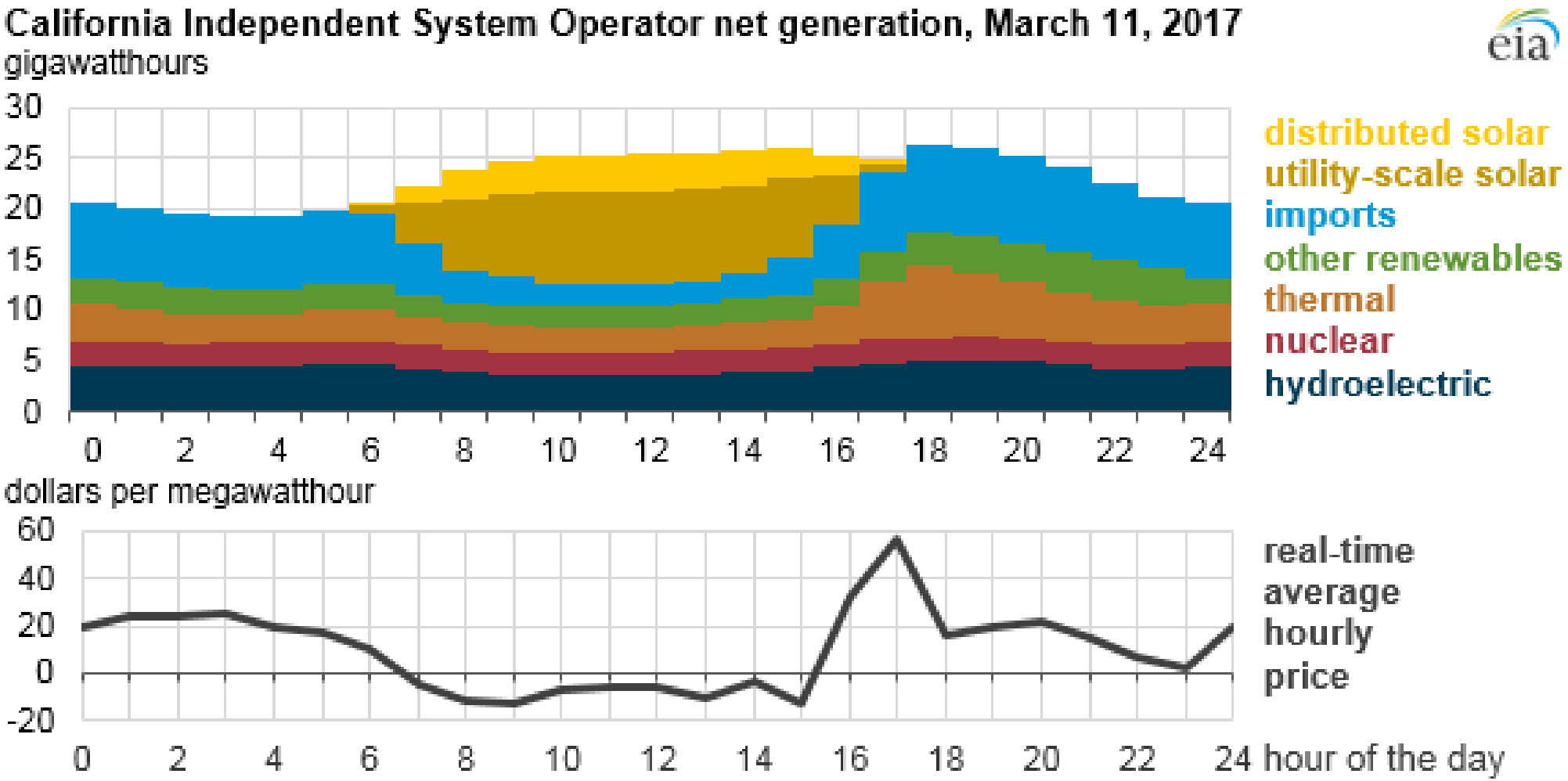
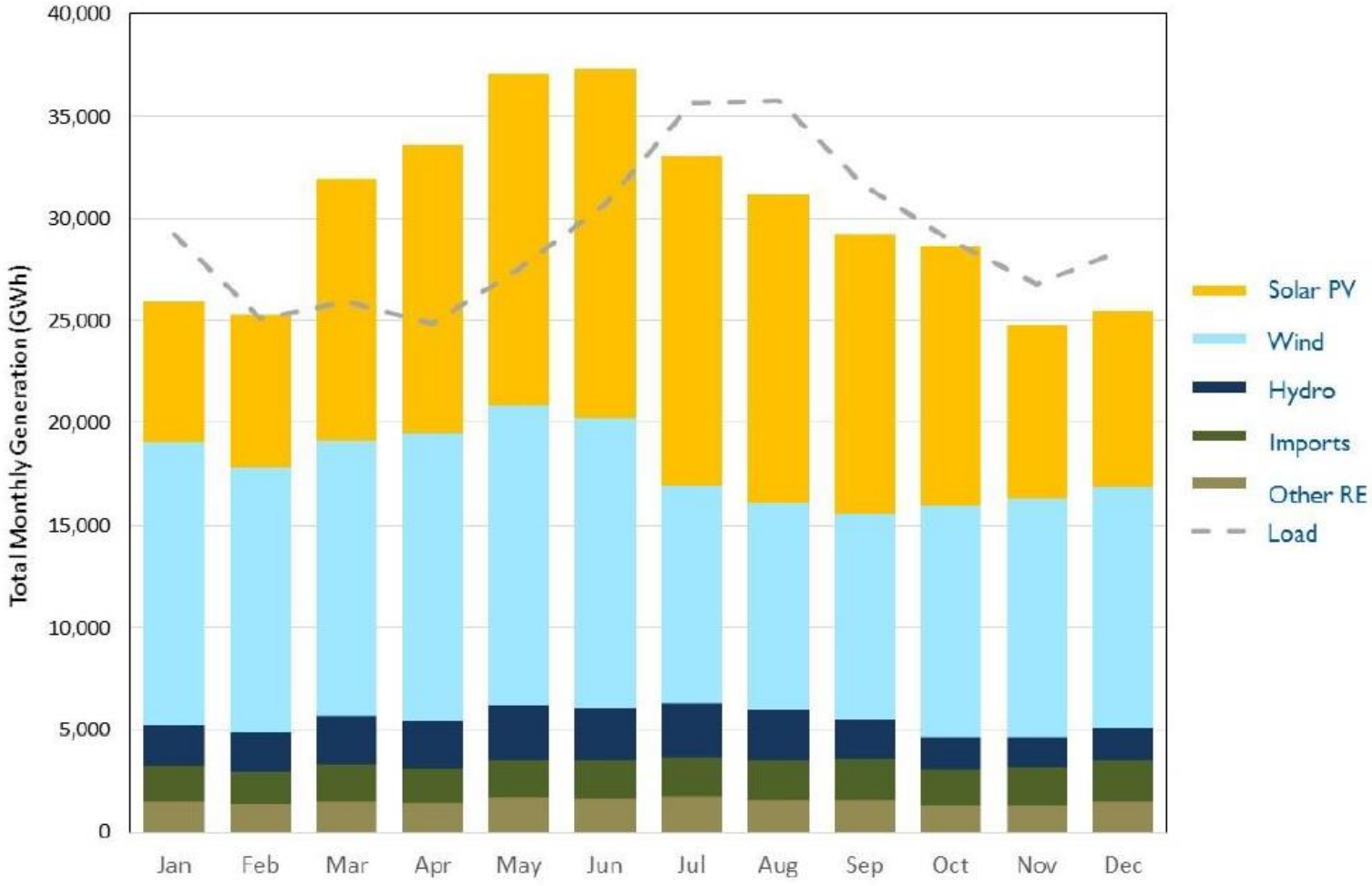
Impact on Electricity Prices



Source: U.S. Energy Information Administration

Seasonality

Projected Renewable Generation vs. Electric Load in California



Source: The INGAA Foundation, Inc., The Role of Natural Gas in the Transition to a Lower-Carbon Economy

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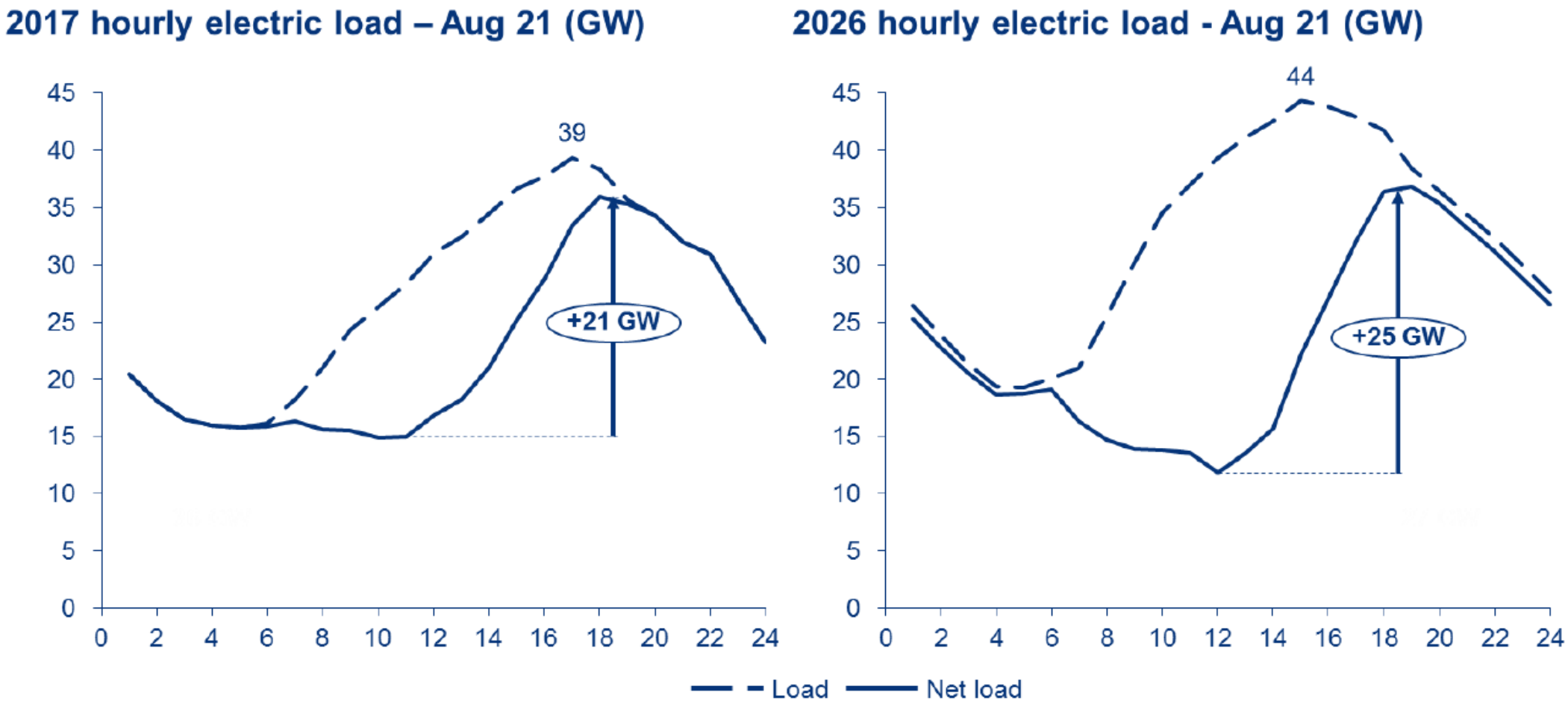
Diurnal Pattern

Hourlv Electric Load in California



Source: Wood Mackenzie, Western Interconnection Gas – Electric Interface Study

How can we study the potential impacts of higher penetrations of wind and solar energy on power system planning and operations?

Power System Models

Capacity Expansion Model

Optimization of the expansion of the power system generation and transmission to meet future goals and forecasts, while considering system constraints.

Production Cost Model

Optimization of the variable electricity generation costs, while considering system constraints.

Reliability Model

Power flow simulations and dynamic simulations of the power system to evaluate its stability and response to a contingency.

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What is a Production Cost Model

It is an optimization mathematical model that simulates the operation of a power system by defining the commitment and dispatch of generators, storage, and flexible demand, while considering system constraints and minimizing variable operational costs

$$\min \sum_{t=1}^{t=T} \sum_{g=1}^{g=G} (P_{g,t} * C_g)$$

subject to:

$$\sum_{g=1}^{g=G} P_{g,t} = D_t \qquad \forall\, t \in T$$

t: time period

g: generator

$P_{g,t}$: electricity generation of generator ***g*** during period ***t*** (MWh)

C_g: variable generation costs of generator ***g*** ($/MWh), these include variable operation & maintenance costs, fuel costs, as well as startup and shutdown costs

D_t: electricity demand during period ***t*** (MWh)

and many other generation, transmission, storage, demand, and operational reserve constraints

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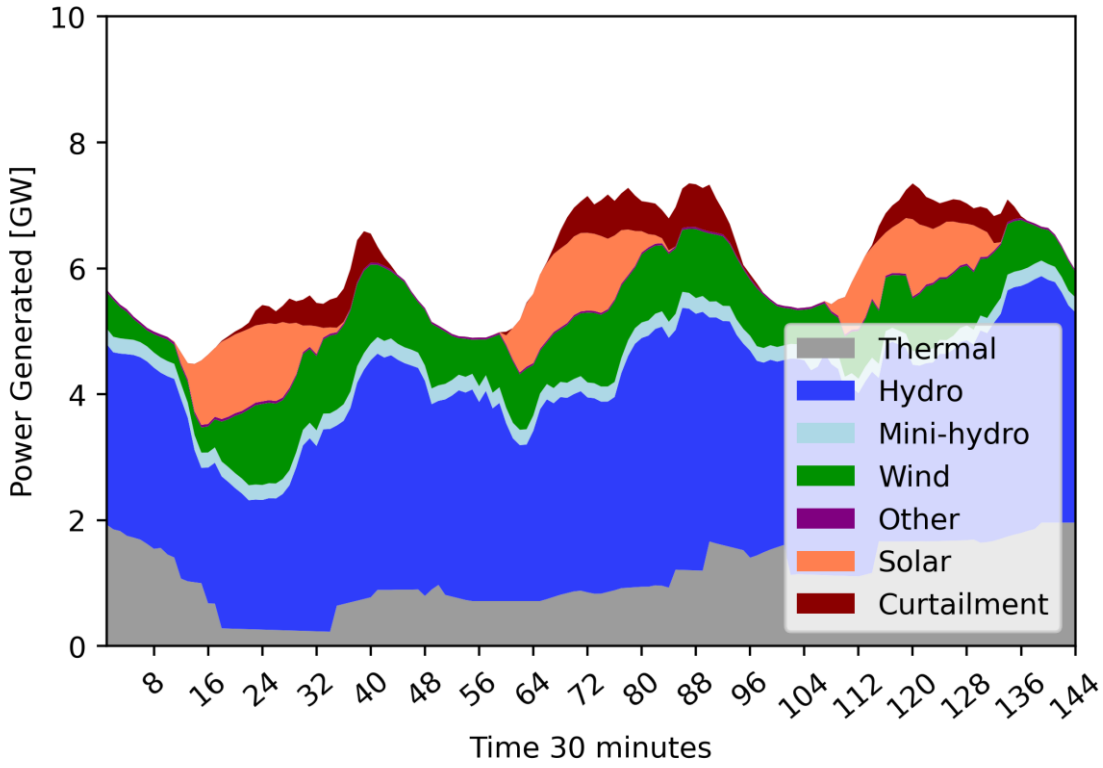
Inputs of a Production Cost Model

- Transmission network topology (substations, lines, transformers)
- Thermal capacity, resistance, and reactance of transmission elements
- Technical constraints, availability, and efficiency of generators
- Variable operation & maintenance, fuel, and startup & shutdown costs of generators
- Operational reserve requirements & ability of generators to contribute to them
- Electricity demand time series
- Hydro, wind, and solar resource time series
- Generation & transmission operational limits to maintain system reliability & stability

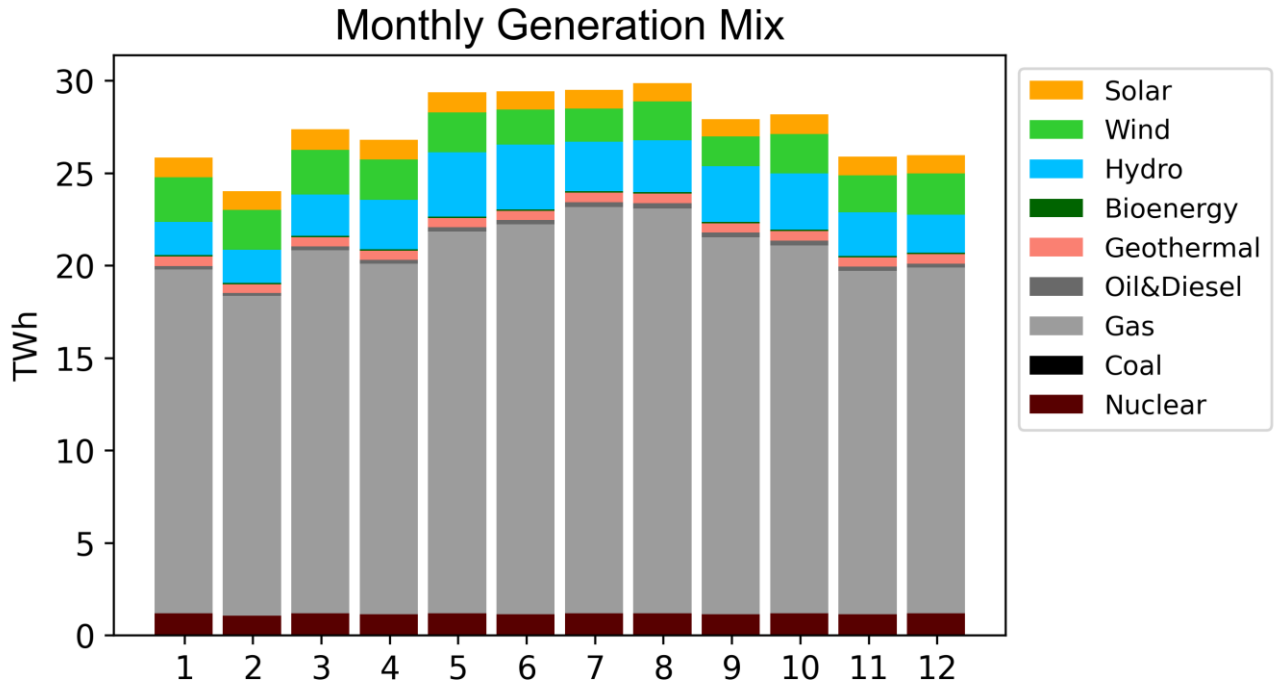
Outputs of a Production Cost Model

- Ability of the system to meet demand and operational reserve requirements
- Commitment and dispatch of generators
- Transmission flows & congestion
- Renewable curtailment
- Energy storage utilization
- Flexible demand behavior
- Fuel consumption
- Greenhouse gas emission
- Electricity Prices



Applications of a Production Cost Model

- Simulation of power system operations under potential future scenarios and conditions
- Analysis of potential power system operational challenges
- Analysis of the impact of different investments:
  - Energy storage
  - Flexible demand
  - Transmission capacity
  - Flexible generation
  - Etc.
- Analysis of electric sector regulations



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Thank you for your attention!

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