NREL
Transforming ENERGY

Power grid planning with higher renewable share

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National Renewable Energy Laboratory

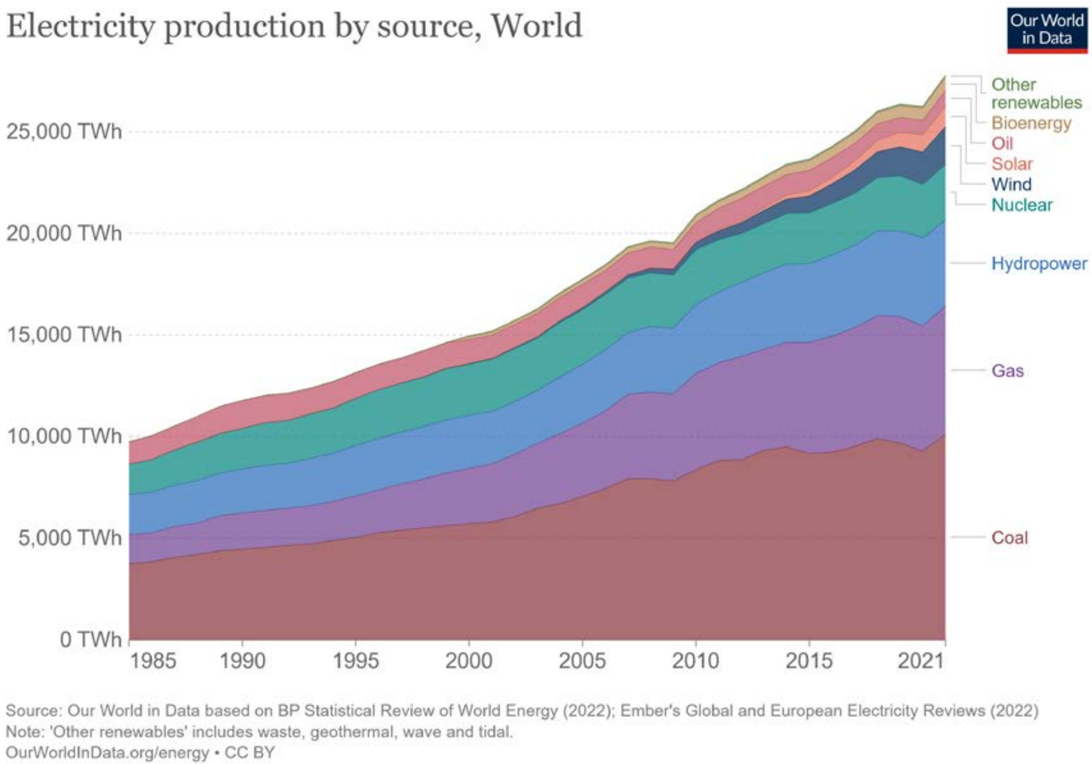
Technical Workshop of the Female Leaders in Energy, United States Energy Association

Jan 31st, 2023

Photo by Dennis Schroeder, NREL 55200

Contents

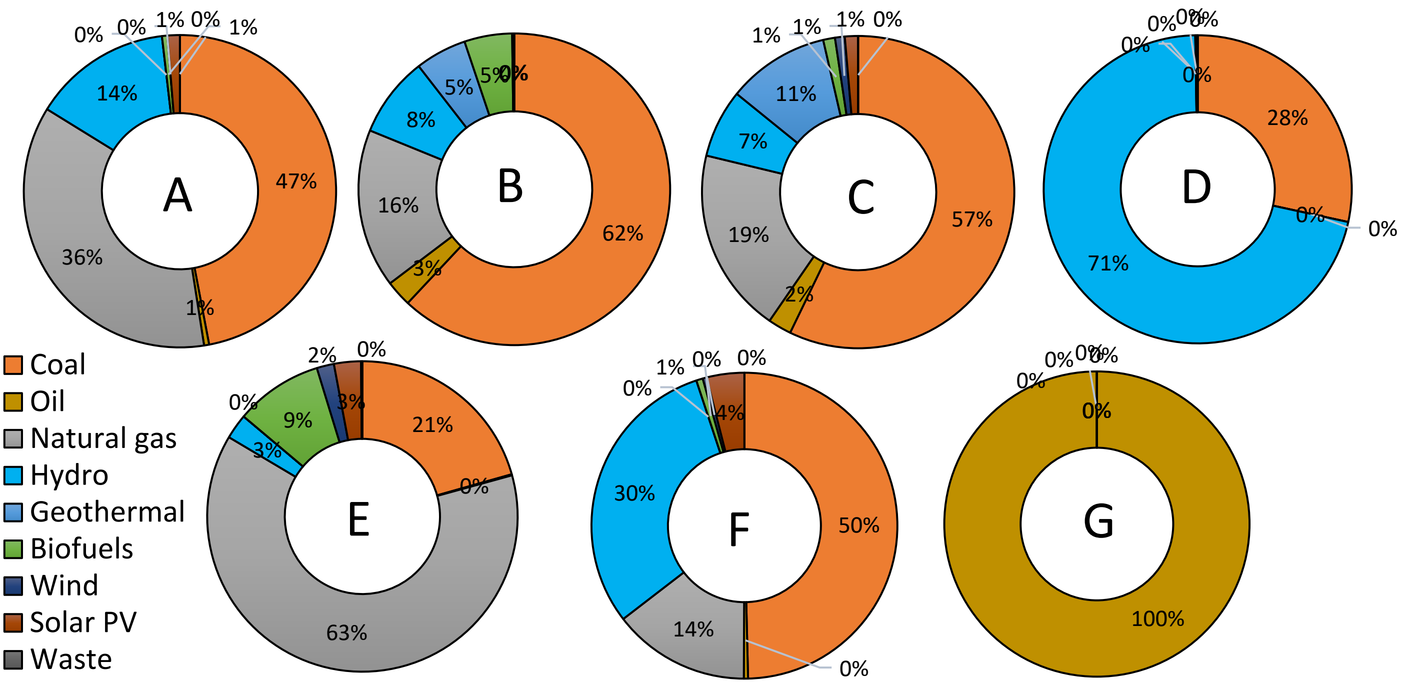
World electricity production trend



Ref: https://ourworldindata.org/electricity-mix

Electricity generation share of some countries

Shall we identify your country



Ref: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser;
https://ourworldindata.org/energy/country/timor#what-sources-does-the-country-get-its-electricity-from

Electricity generation share of some countries

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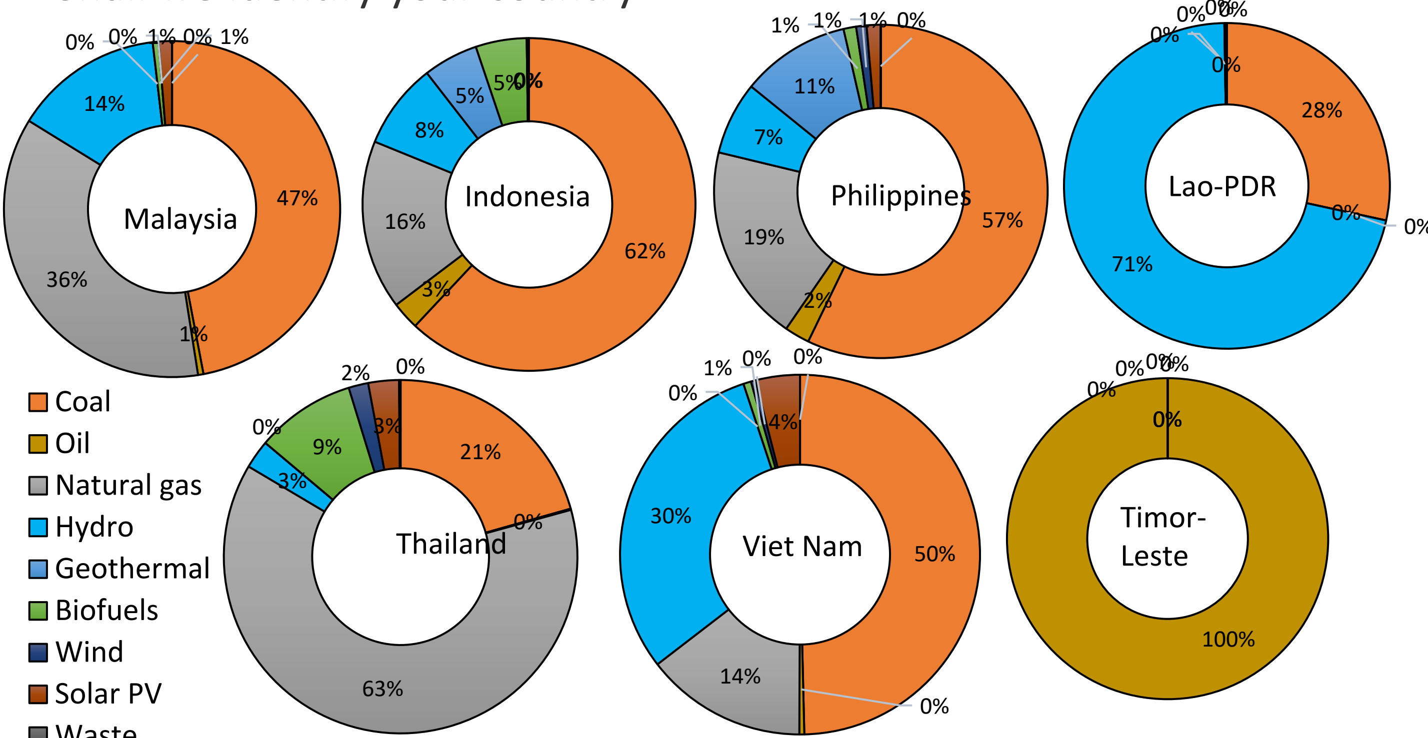

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National Renewable Energy Laboratory at-a-Glance

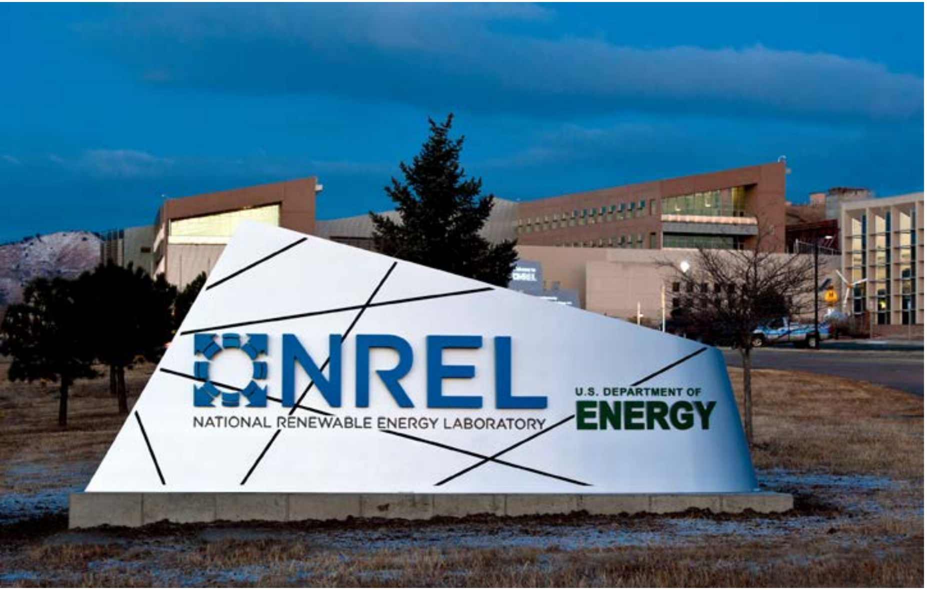
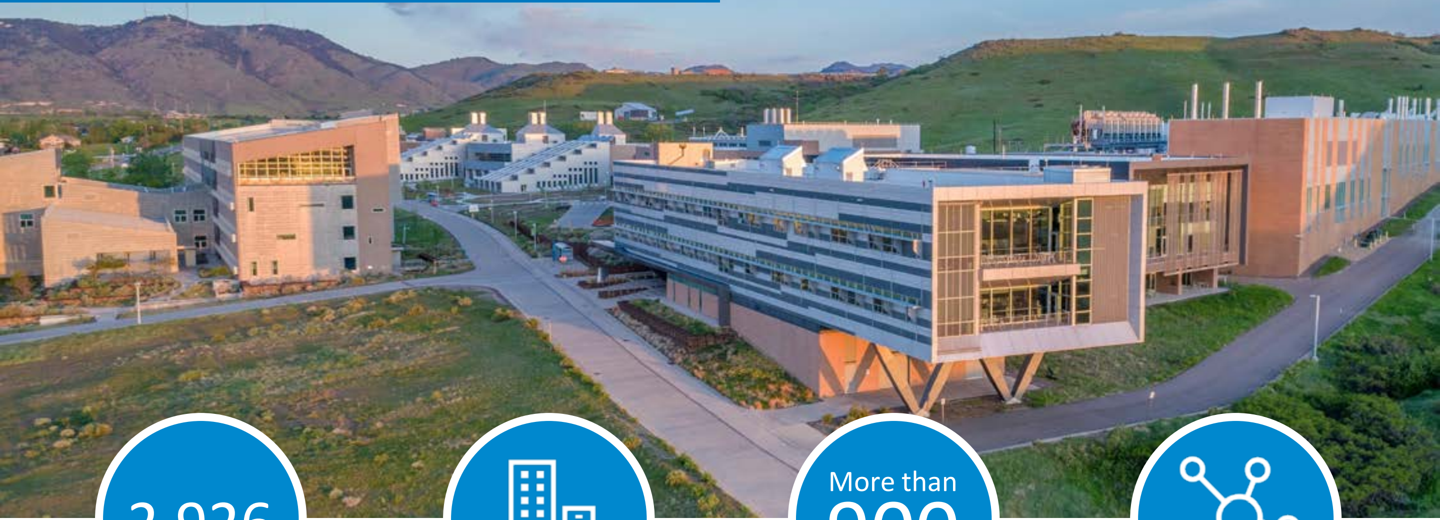


Photo by Dennis Schroeder / NREL

The National Renewable Energy Laboratory (NREL) is transforming energy through research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.

https://www.youtube.com/watch?v=WiHBC8gog7s&list=PL3GM1pjrYAcgHAXp5MfRUYgmMu8hC_tNq&index=3

NREL at-a-Glance



2,926

Workforce, including

219 postdoctoral researchers

60 graduate students

81 undergraduate students

World-class

facilities, renowned technology experts

More than 900

Partnerships

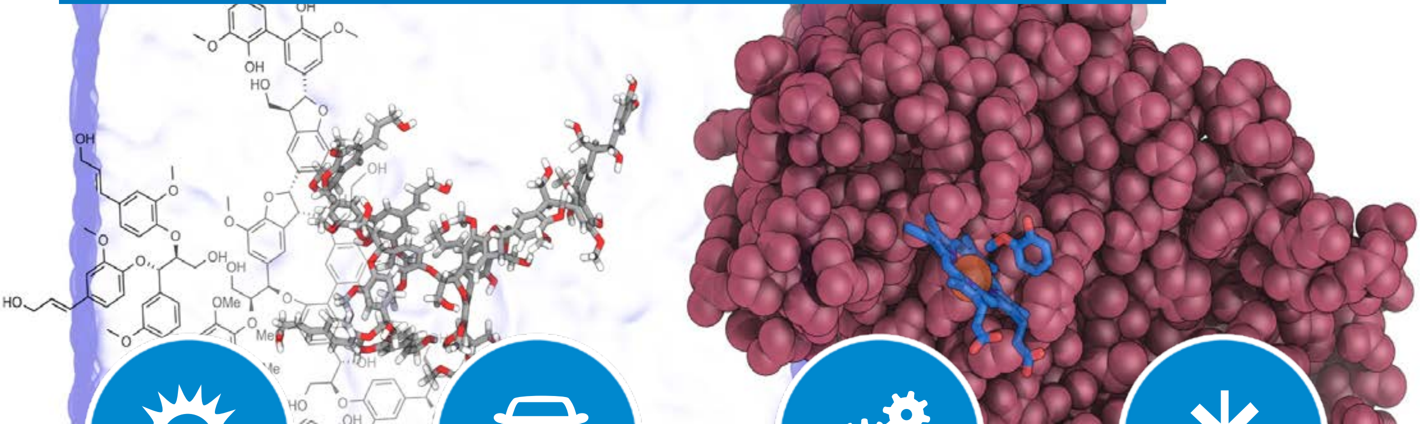
with industry, academia, and government

Campus

operates as a living laboratory

Photo by Joshua Bauer / NREL

NREL Science Drives Innovation



Renewable Power

Solar

Wind

Water

Geothermal

Sustainable Transportation

Bioenergy

Vehicle Technologies

Hydrogen

Energy Efficiency

Buildings

Advanced Manufacturing

Government Energy Management

Energy Systems Integration

Grid Integration

Hybrid Systems

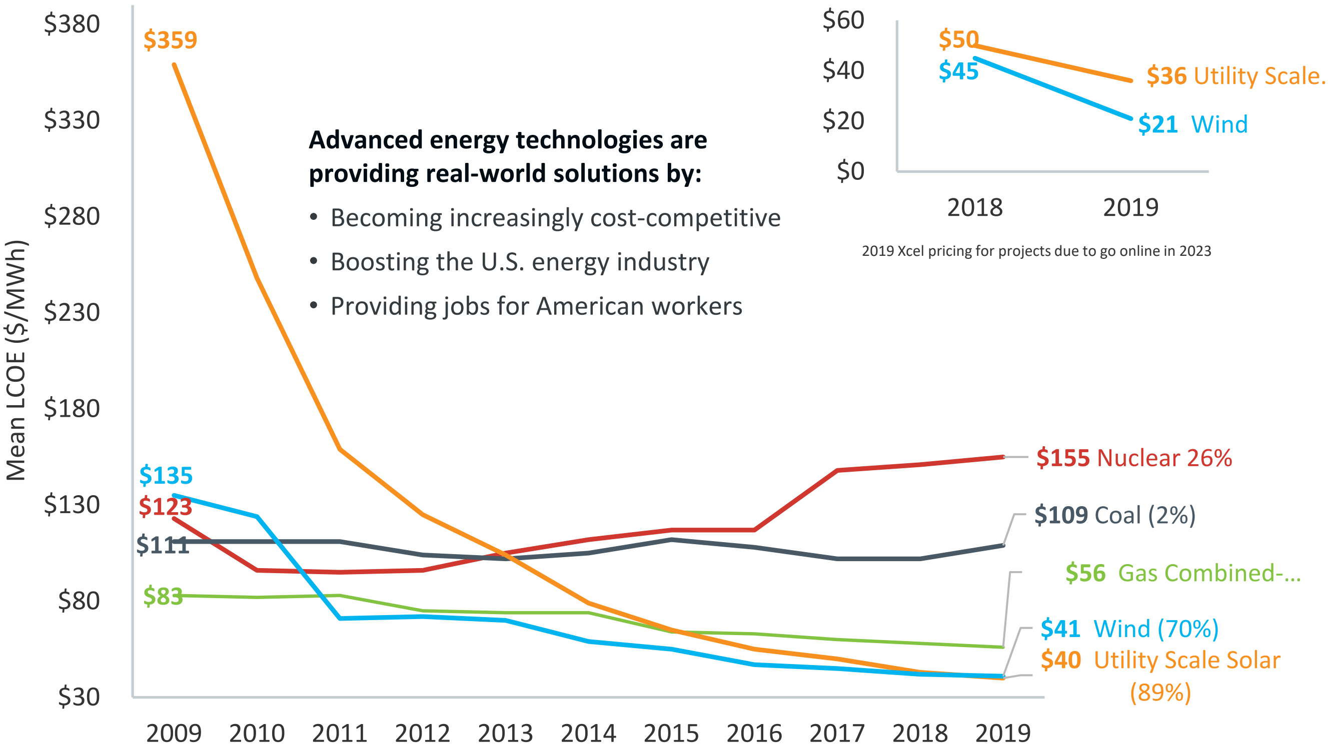
Security and Resilience

Picture by Josh Vermass / Brandon Knott/ NREL

Renewable Power

Photo by Dennis Schroeder / NREL

Cost for Renewables are Falling



Advanced energy technologies are providing real-world solutions by:

- Becoming increasingly cost-competitive
- Boosting the U.S. energy industry
- Providing jobs for American workers

2019 Xcel pricing for projects due to go online in 2023

Ref: Lazard’s 2019 Levelized Cost of Energy Analysis

Solar Research

Areas of research include concentrating solar power, photovoltaics, grid integration, and market analysis.

Together, these areas will enable reliable, low-cost solar energy at scale—on the grid and beyond the grid.

https://www.nrel.gov/solar/; https://www.nrel.gov/csp/

Research Challenges

- Integrate large amounts of solar energy into the power grid while maintaining security and reliability, and enhancing resilience
- Improve the efficiency, lifetimes, and manufacturability of photovoltaic materials
- Develop technologies for a third generation of concentrating solar power plants to further reduce costs and improve thermal storage capabilities
- Capture surplus solar energy to provide heat and produce fuels and clean water
- Create flexible, highly efficient solar cells that can make low-cost power available without wires anywhere the sun shines
- Make solar an even better investment through work on bankability,
reliability, and recyclability



Wind Energy

Enabling low-cost and grid-supporting wind energy by joining forces with DOE, industry, and interagency and state partners to advance scientific knowledge and technological innovation.

Research Challenge

- Validate multiple wind technologies at scale to achieve an integrated energy system that can meet the complex energy challenges of the future.
- Develop taller wind turbines with larger rotors to capture greater wind resources at higher elevations and lower the levelized cost of wind energy.
- Develop innovations for offshore wind such as floating platforms, scaling solutions for larger offshore designs, advanced turbine controls, and lightweight drivetrains.
- Optimize total power output across the entirety of a wind plant instead of at the individual-turbine level.
- Enable sustainable manufacturing through new materials and new manufacturing processes.

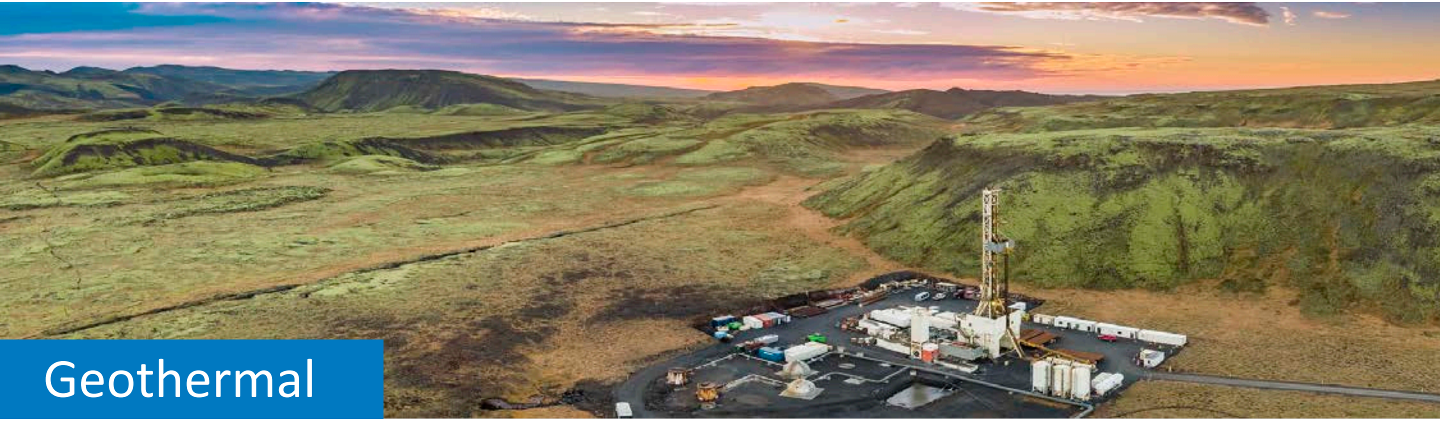
https://www.nrel.gov/wind/

Water-Power Research

Driving innovation in the design and utilization of next generation marine energy and hydropower/pumped storage systems through foundational research, tool development, and laboratory and in-water optimization.

Research Challenges

- Advancing scientific understanding to enable the full potential of hydropower/pumped storage hydropower to contribute to reliability, resilience, and renewables integration in our rapidly evolving power systems
- Developing technology to enable wave, tidal, ocean, and river current energy systems to provide reliable power to utility scale and blue economy markets (e.g., ocean observing)
- Transforming technology to drastically improve performance and reduce marine energy and hydropower generation costs.



Geothermal

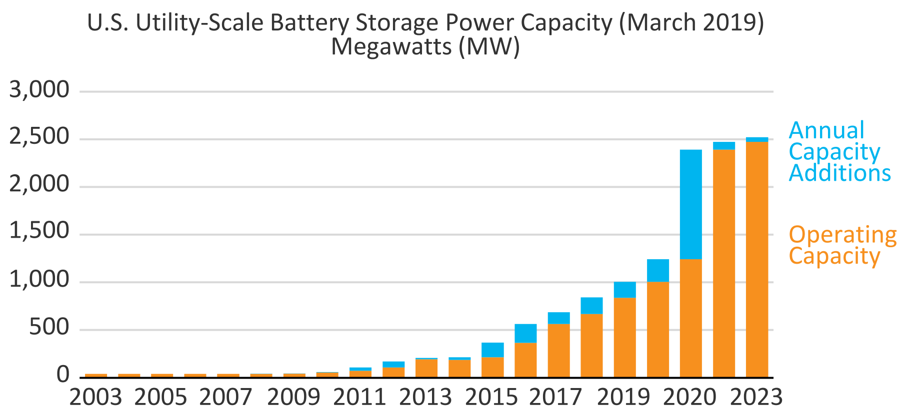
Geothermal provides both heat and power—24 hours a day, 7-days a week—increasing grid reliability and security, with the smallest footprint of any renewable. Reducing costs and enabling geothermal anywhere can increase deployment nearly 26-fold by 2050.

Research Challenge

- Reduce well field development costs through increased drilling efficiency and drilling rates and reduced material construction costs.
- Enable development of geothermal anywhere through new technologies such as Enhanced Geothermal Systems (EGS) or Advanced Geothermal Systems (AGS).
- Economically recover lithium and other critical minerals from geothermal brines to meet U.S. and global demands.
- Identify the feasibility of hybrid geothermal-solar systems and subsurface thermal energy storage.

Utility-Scale Battery Storage Power Capacity

Operating utility-scale battery storage power capacity has more than quadrupled from the end of 2014 (214 MW) through March 2019 (899 MW).



Source: United States Energy Information Agency, Today in Energy, July 10, 2019

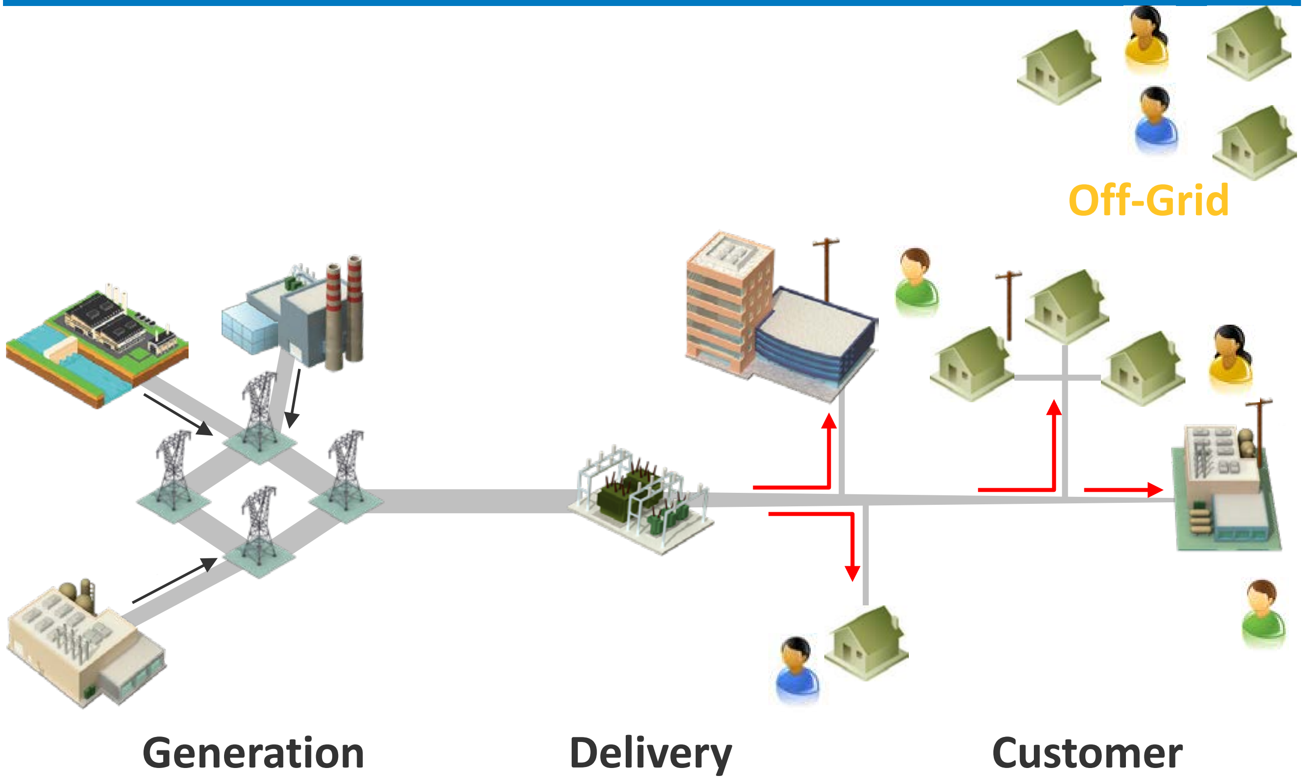
Photo by Werner Slocum / NREL

Power grid planning with high renewable power share

- Power grids were designed to operate by large conventional power plants with fossil fuel, nuclear and hydropower
- How to make it work with variable renewables like wind and solar?
- Big model, big data, lots of efforts are required to redefine the power grid

https://www.youtube.com/watch?v=mbQtidp1HCQ&list=PLmIn8Hncs7bE5I8iPLfqN4tbgc0o2FTkR&index=1

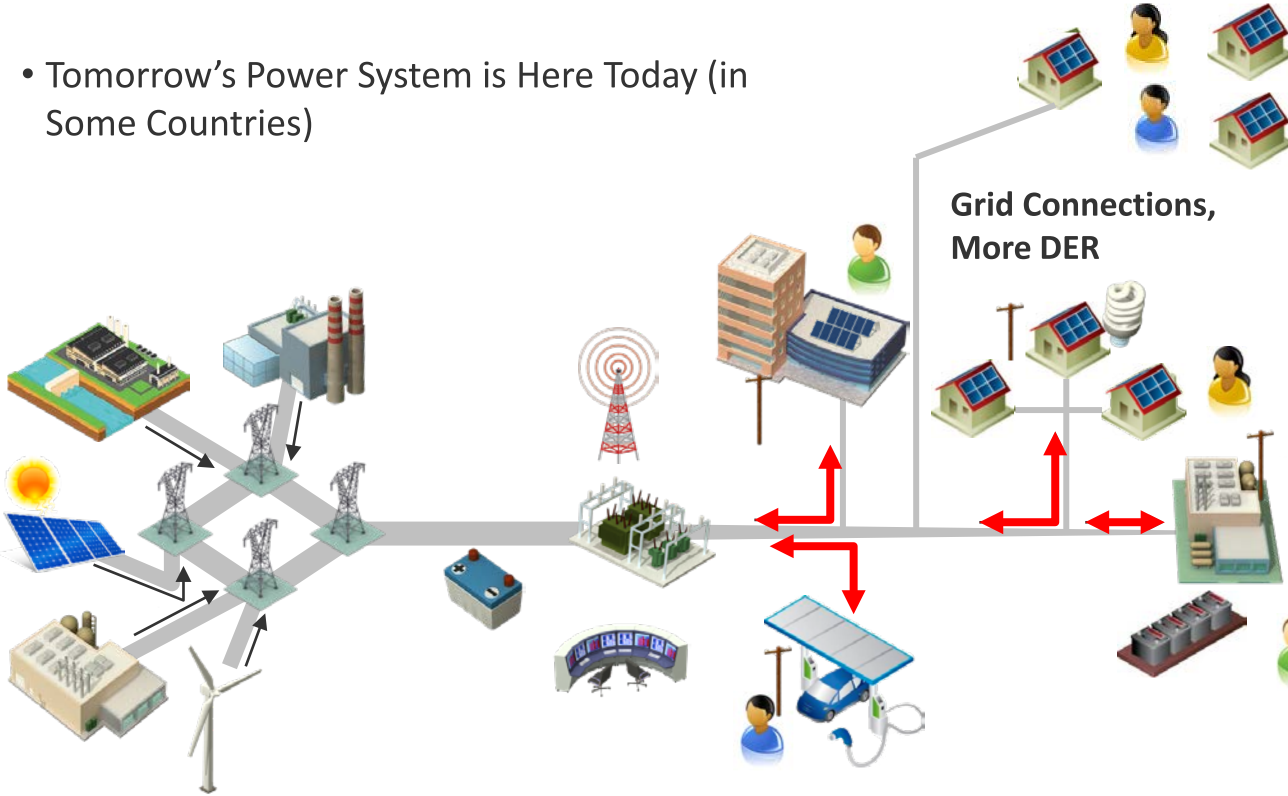
Today's Power System



Ref: Bryan Hannegan,EPRI https://eea.epri.com/pdf/epri-energy-and-climate-change-research-seminar/2013/2013_07.pdf

Tomorrow’s Power System

- Tomorrow’s Power System is Here Today (in Some Countries)



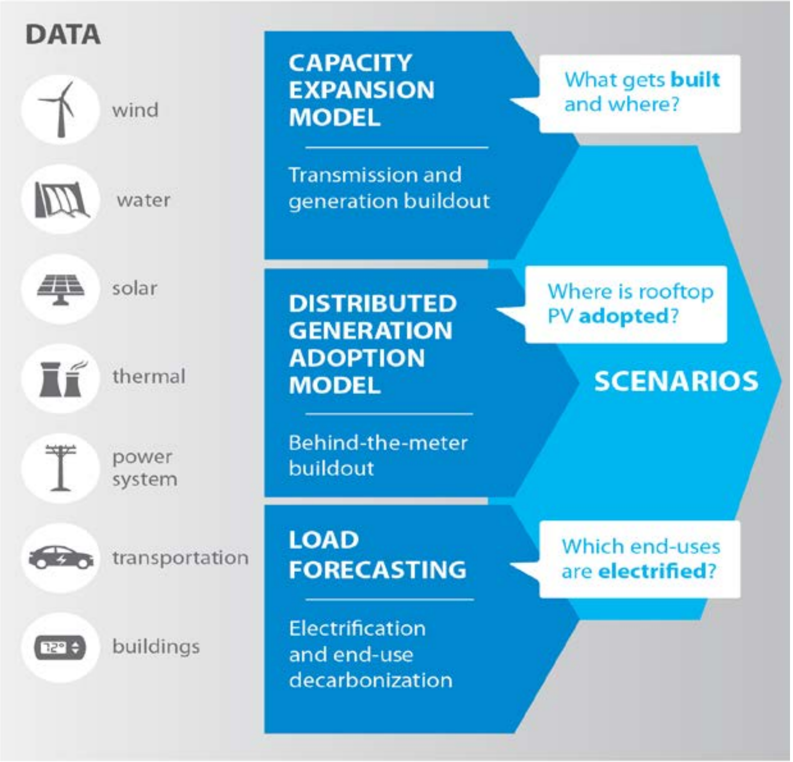
Bryan Hannegan,EPRI https://eea.epri.com/pdf/epri-energy-and-climate-change-research-seminar/2013/2013_07.pdf

Capacity Expansion

BUILD
What do we build
Where and when

Power grid: 10-20 years out

- Generation and transmission capacity expansion looking forward to 10-20 years of future
- Capacity expansion models co-optimize generation and transmission buildouts

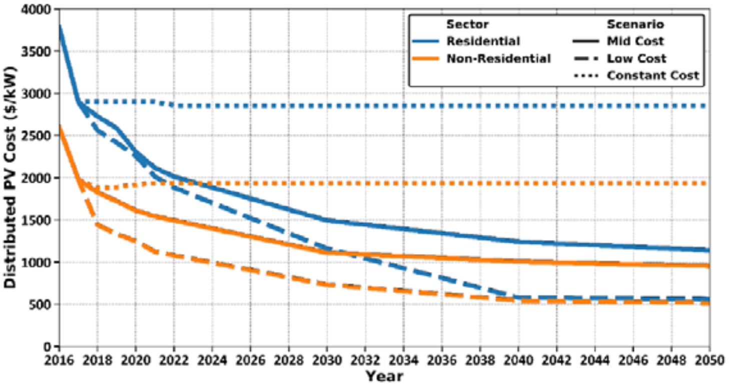


Ref: NARIS, NREL https://www.nrel.gov/docs/fy21osti/79224.pdf

Distributed Generation adoption

- Develop rooftop PV projections for the residential, commercial, and industrial sectors

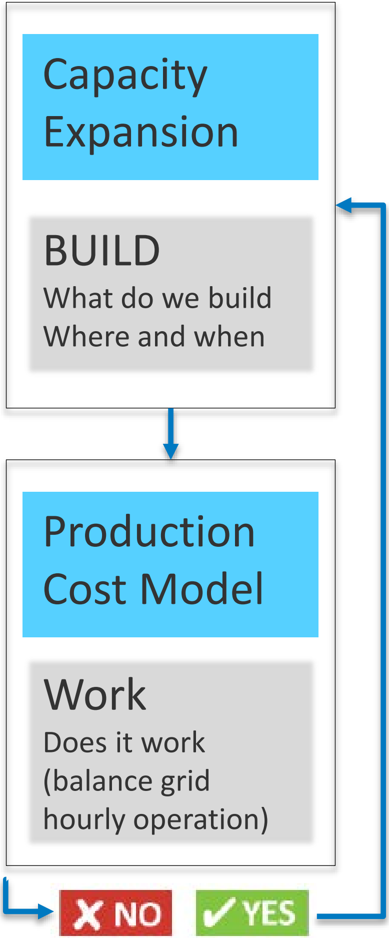
- Customers are statistically sampled based on representative features such as electricity consumption and rooftop size
- Technical potential calculation considering developable roofs and unshaded areas



Cost trajectories for distributed PV

Ref: NARIS, NREL https://www.nrel.gov/docs/fy21osti/79224.pdf

Power Grid operation: Daily, hourly



PCM also known as Unit Commitment and Economic Dispatch Modeling

Simulate operation of electric power system

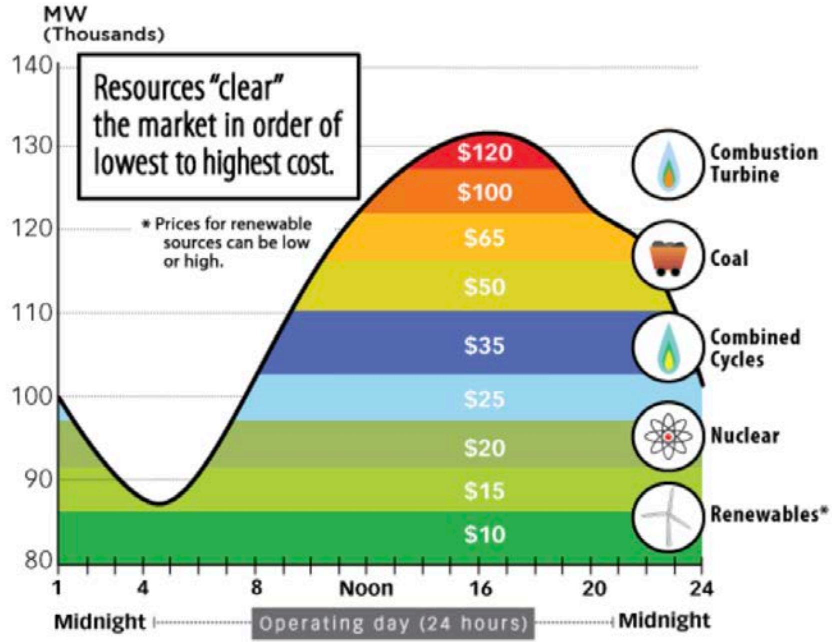
Hourly or sub-hourly chronological commits and dispatches generating units based on:

- Electricity demand
- Operating parameters of generators
- Transmission grid parameters
- Timeseries profiles of wind, solar, water
- Ensures provision of operating reserves

Ref: LA100, NREL https://www.nrel.gov/docs/fy21osti/79444-6.pdf

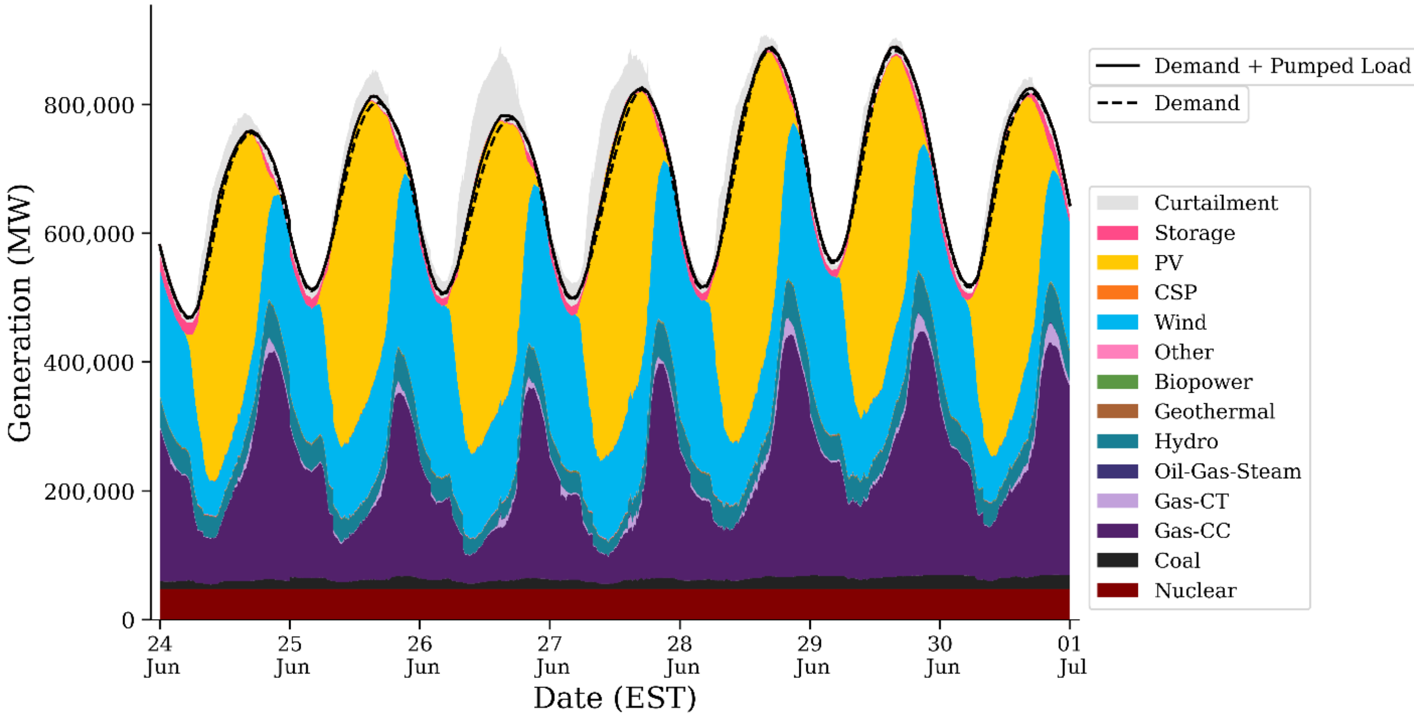
Power Grid operation: Daily, hourly

- Power generation cost
  - fuel cost, variable operation and maintenance cost (*which technology has the highest value, and which is the lowest*)
- Power plant operating parameters
- Start-up and stop time and cost (which technologies have better flexibility)
- Renewable resources and load time series data



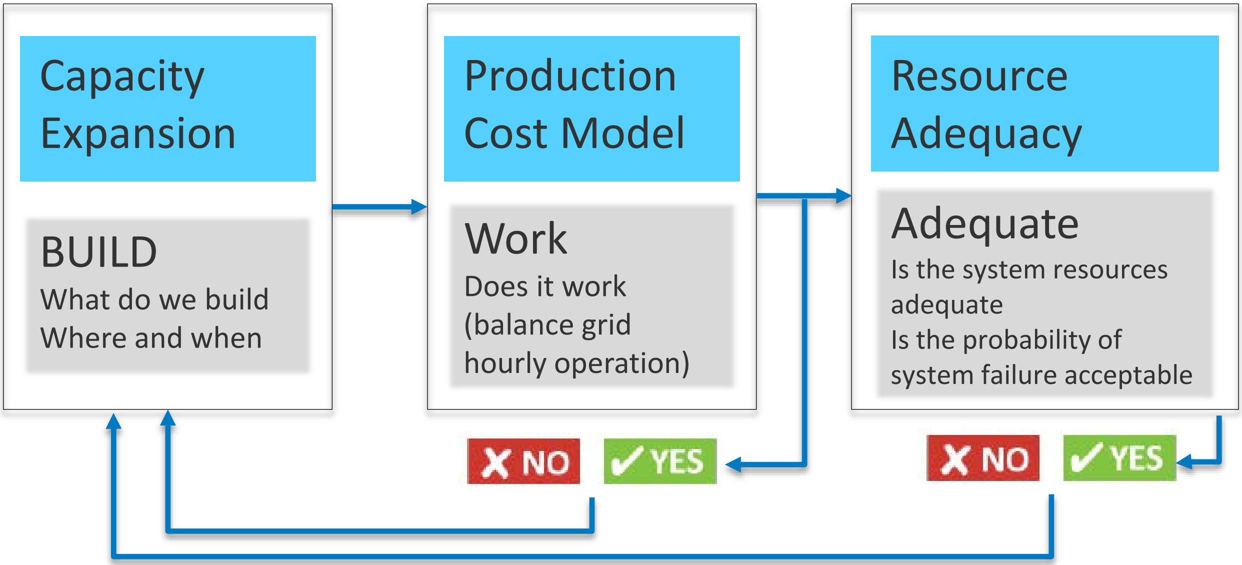
Ref: PJM (https://learn.pjm.com/three-priorities/keeping-the-lights-on/how-pjm-schedules-generation-to-meet-demand

Power Grid operation: Daily, hourly



Sample power generation dispatch for the week of June 24 from NREL high renewable power grid study (PCM result)

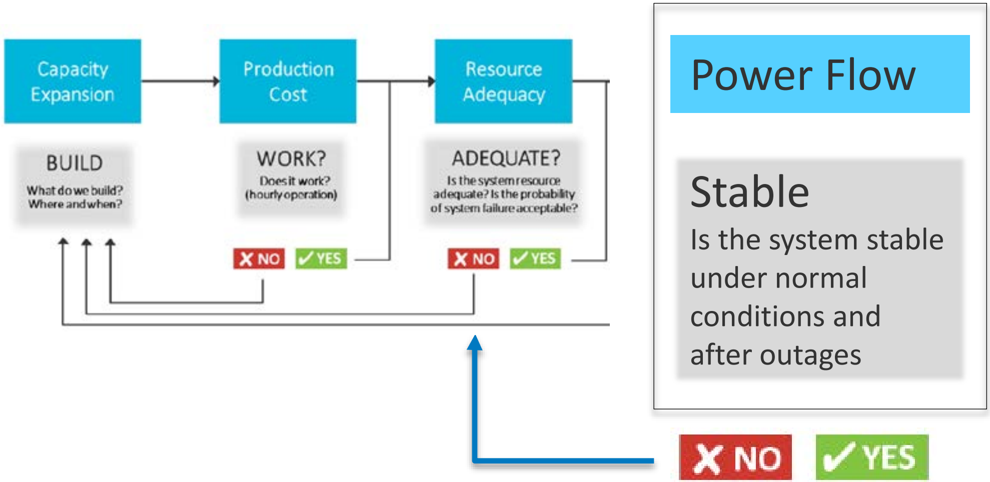
Power Grid Reliability



Power grid operation model for every hour for different meteorological conditions (affecting wind, solar, and load profiles) and random outages of thermal generators

Ref: LA100, NREL https://www.nrel.gov/docs/fy21osti/79444-6.pdf

Power Grid operation: minutes, seconds

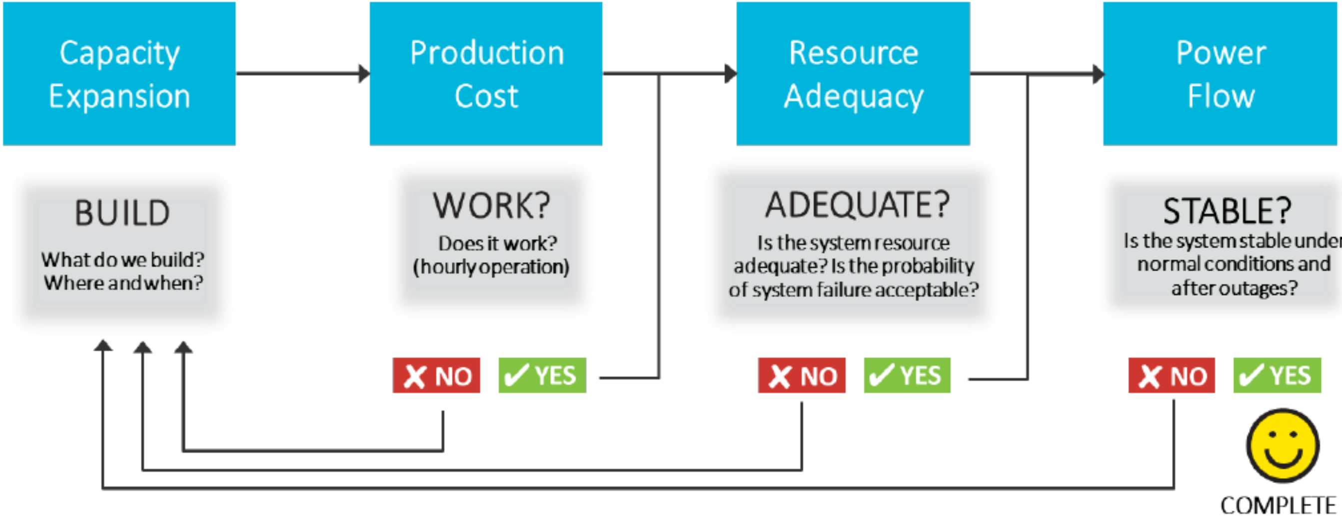


Power system physics models to understand in-depth power system stability of the future system under stress:

- Steady state operation
- Following major disturbances

Ref: LA100, NREL https://www.nrel.gov/docs/fy21osti/79444-6.pdf

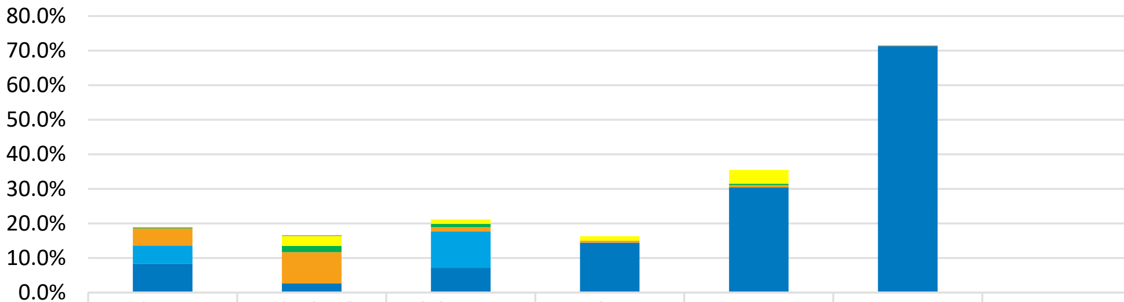
Power system modeling



- Is the projected power system sufficient to meet load, and reserve requirements, below an acceptable reliability threshold,
- Capacity expansion input parameters are adjusted, and models are re-run to produce a new solution, re-validated iteratively until a viable solution is found

Ref: LA100, NREL https://www.nrel.gov/docs/fy21osti/79444-6.pdf

Renewable energy targets



	Indonesia	Thailand	Philippines	Malaysia	VietNam	LaoPDR	TimorLeste
Waste	0.0%	0.1%	0.0%	0.0%	0.0%	0%	0%
Solar PV	0.1%	2.8%	1.3%	1.3%	4.0%	0%	0%
Wind	0.2%	1.8%	1.0%	0.0%	0.4%	0%	0%
Biofuels	5.0%	9.1%	1.2%	0.6%	0.7%	0%	0%
Geothermal	5.3%	0.0%	10.6%	0.0%	0.0%	0%	0%
Hydro	8.3%	2.6%	7.1%	14.4%	30.4%	71%	0%

- What are the renewable energy targets of your country?
- What are the opportunities to achieve the higher renewable power targets?
- What are the challenges to achieving the higher renewable power targets?

Ref: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser

Q&A

www.nrel.gov

NREL/PR-6A40-85164