NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Technology, Policy and Finance for Clean and Renewable Energies

Douglas Arent, Ph.D., Deputy Associate Laboratory Director, Scientific Computing and Energy Analysis

UNU-WIDER; September 2018

NREL at a Glance

1,800

Employees,
plus more than
400
early-career researchers and visiting scientists

World-class
facilities, renowned technology experts

nearly 750

Partnerships
with industry, academia, and government

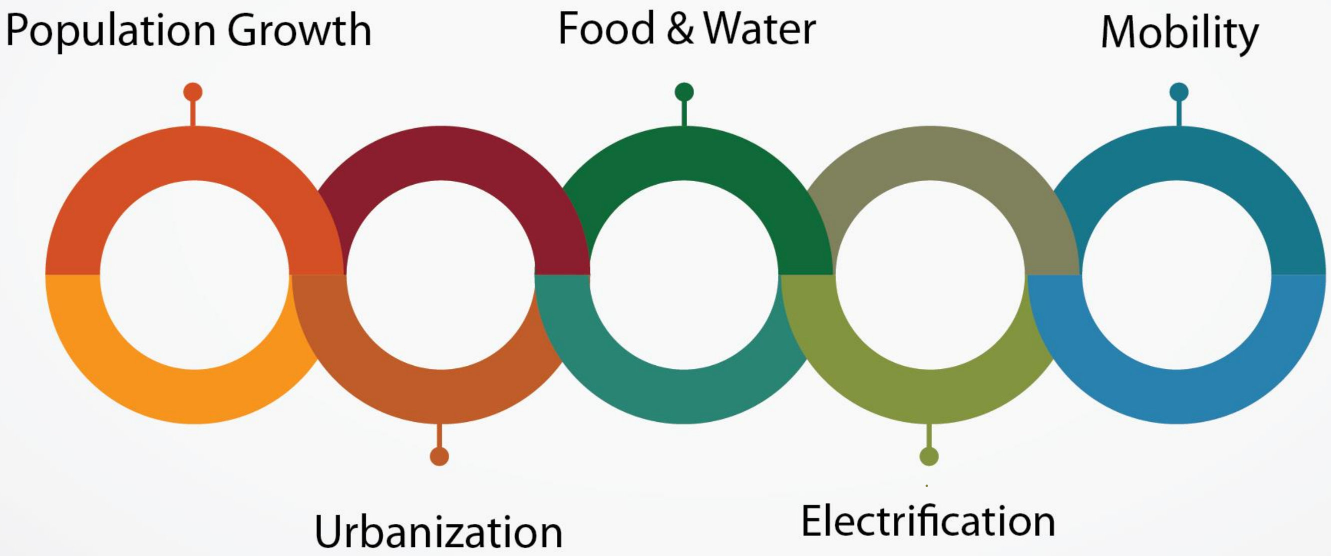
Campus
operates as a living laboratory

$872M annually

National economic impact

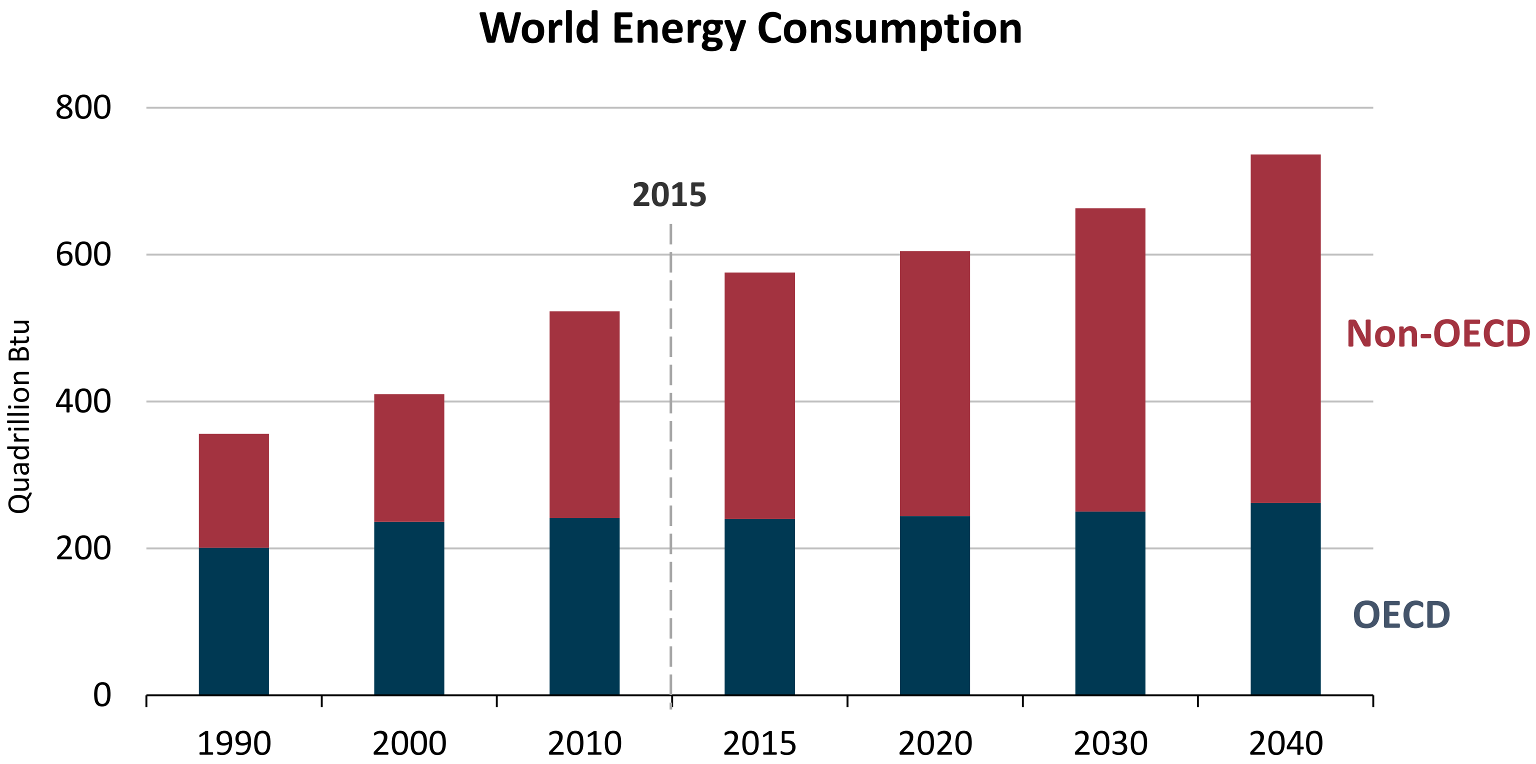
NREL advances the science and engineering of **energy efficiency**, **sustainable transportation**, and **renewable power technologies** and provides the knowledge to **integrate and optimize energy systems**..

MEGA TRENDS

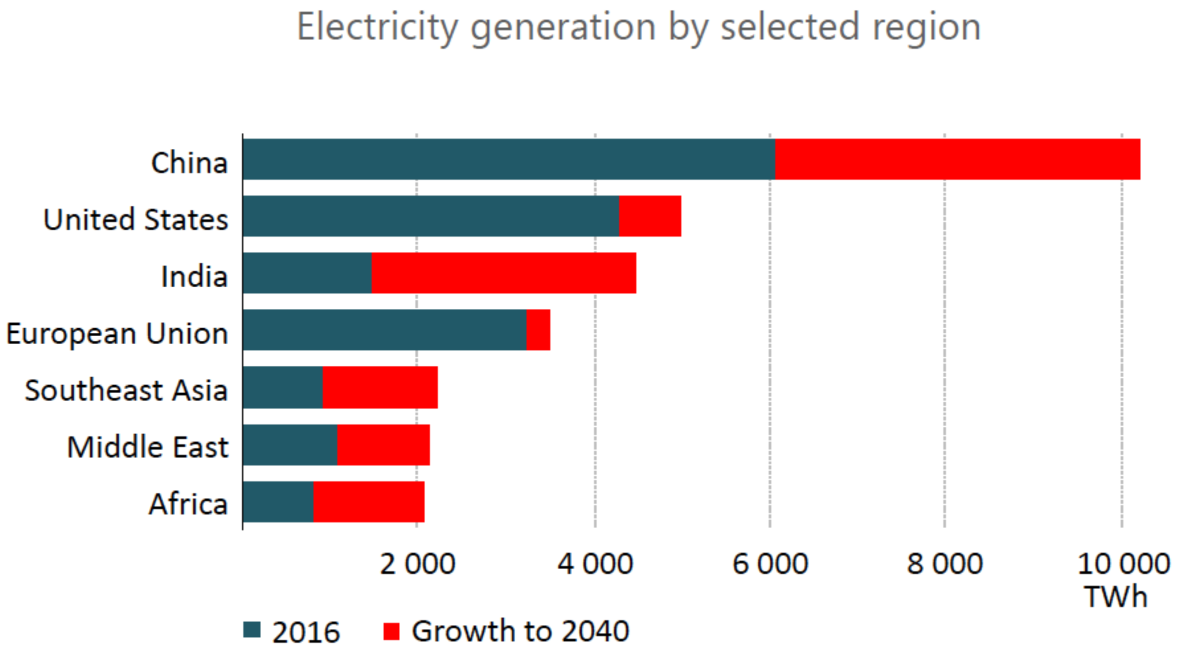


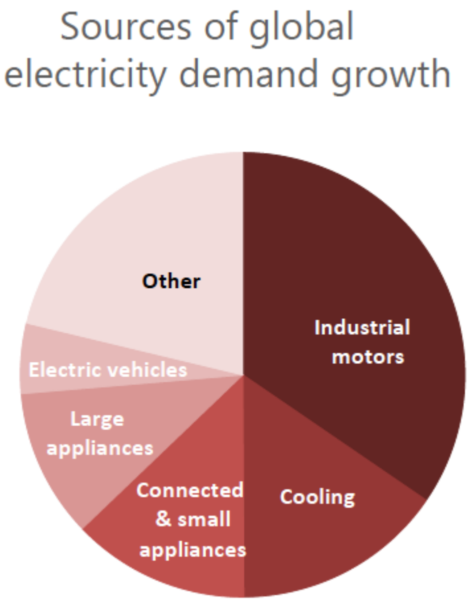
Global Trends in Digitization, Decentralization, Decarbonization

World Energy Consumption Rises 28% between 2015 and 2040



Electrification Will Dominate Energy Growth

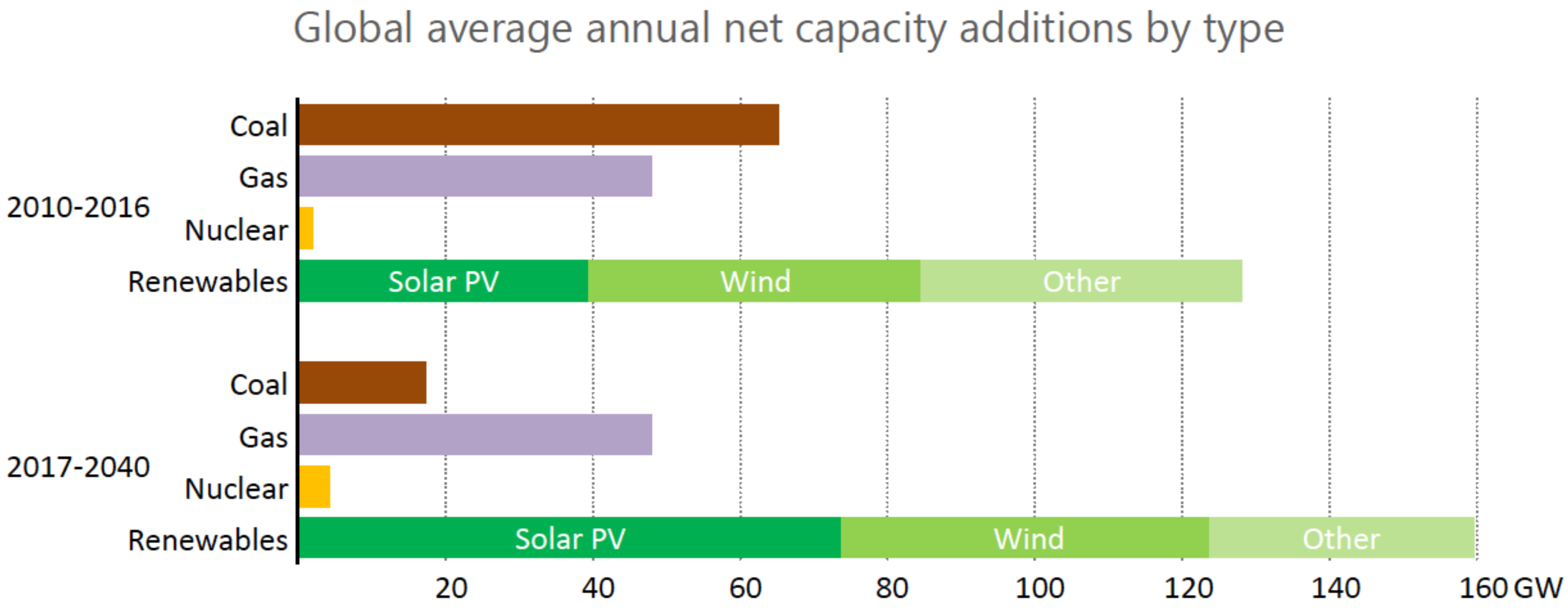




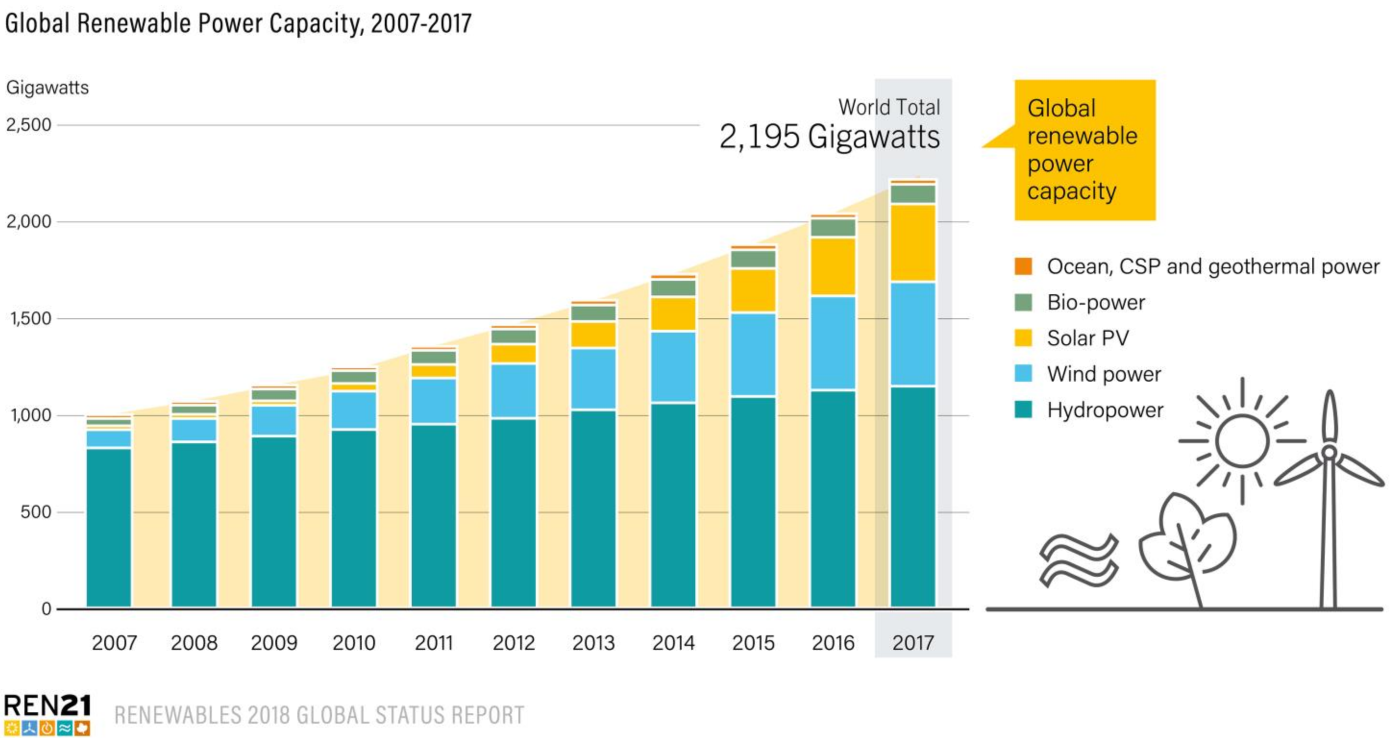
India adds the equivalent of today's European Union to its electricity generation by 2040, while China adds the equivalent of today's United States

International Energy Outlook 2017

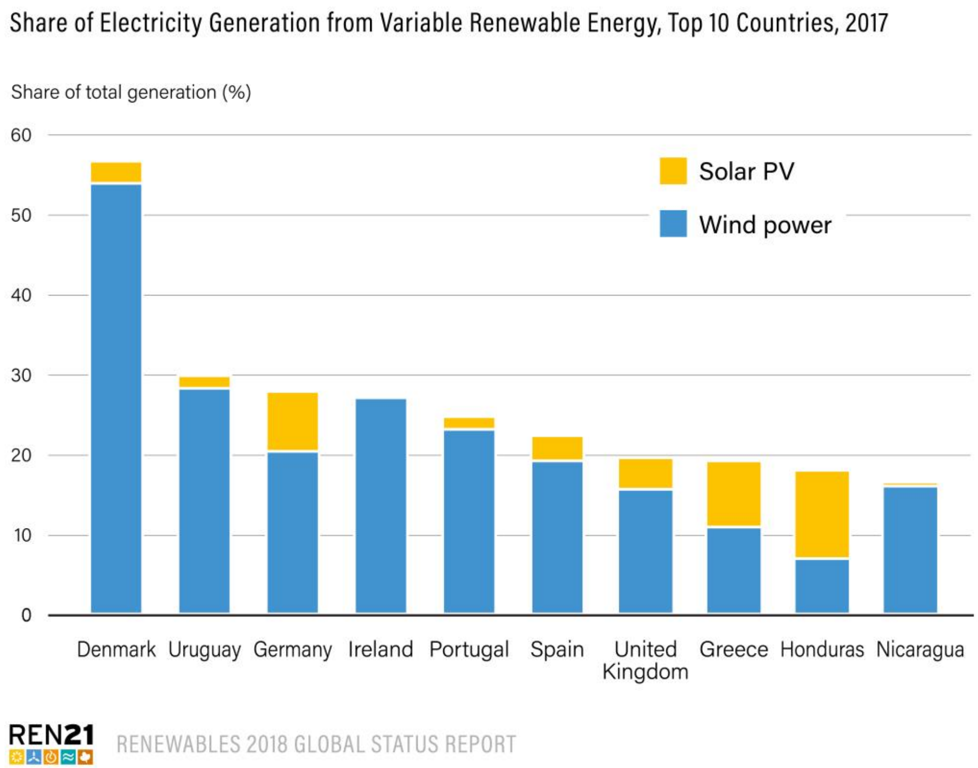
Renewables Dominate Power Capacity Growth



Global Renewable Power Capacity



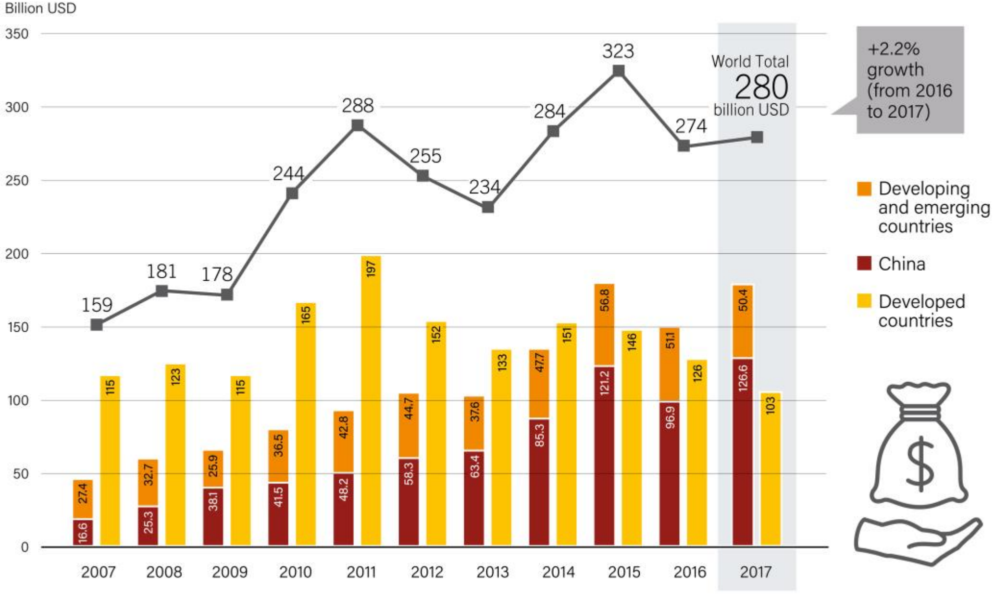
High Shares of Variable Renewable Power on the Grid



Global Investment in Renewable Energy

- → Global **new investment** in renewable power and fuels in 2017: **USD 279.8 billion (+2.2%)** (USD 319.8 billion incl. large hydropower)
- → **Investment in new renewable power** capacity roughly **three times that in new fossil fuel** capacity
- → **Renewable energy: 68%** of the total amount committed to new power-generating capacity in 2017
- → **USD 310 billion (est.)** committed to constructing new renewable power plants, compared to:
  - Fossil fuel-fired generating capacity: USD 103 billion
  - Nuclear power capacity: USD 42 billion

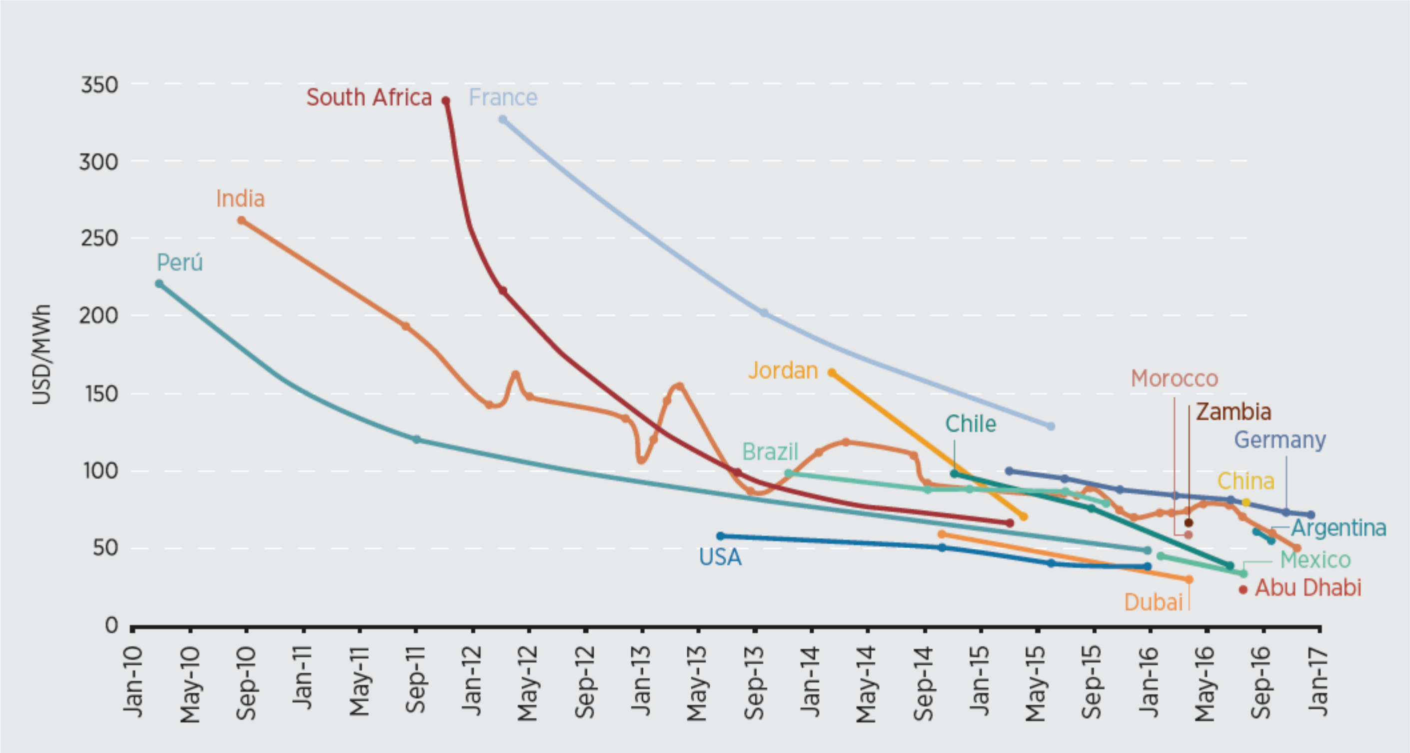
Global New Investment in Renewable Power and Fuels in Developed, Emerging and Developing Countries, 2007-2017



Source: BNEF

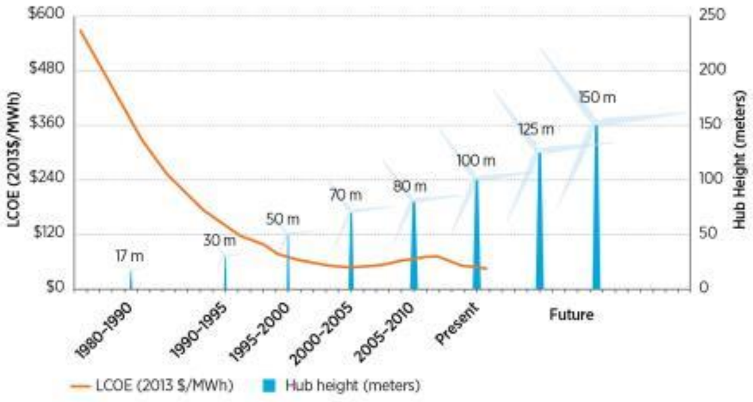
REN21 RENEWABLES 2018 GLOBAL STATUS REPORT

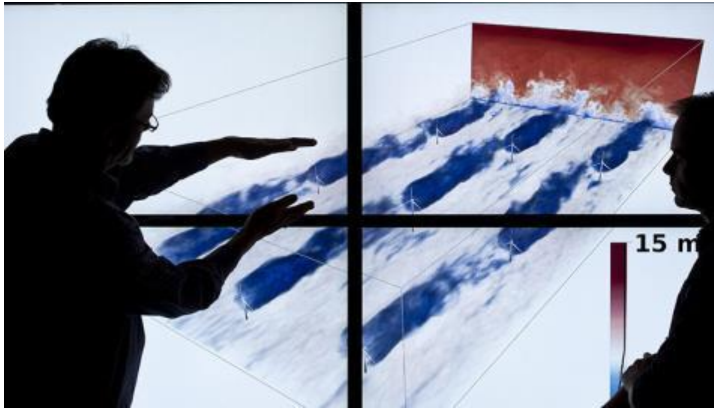
Costs and Performance of PV exemplifies decadal advancements



IRENA, 2016; PV Auction Prices

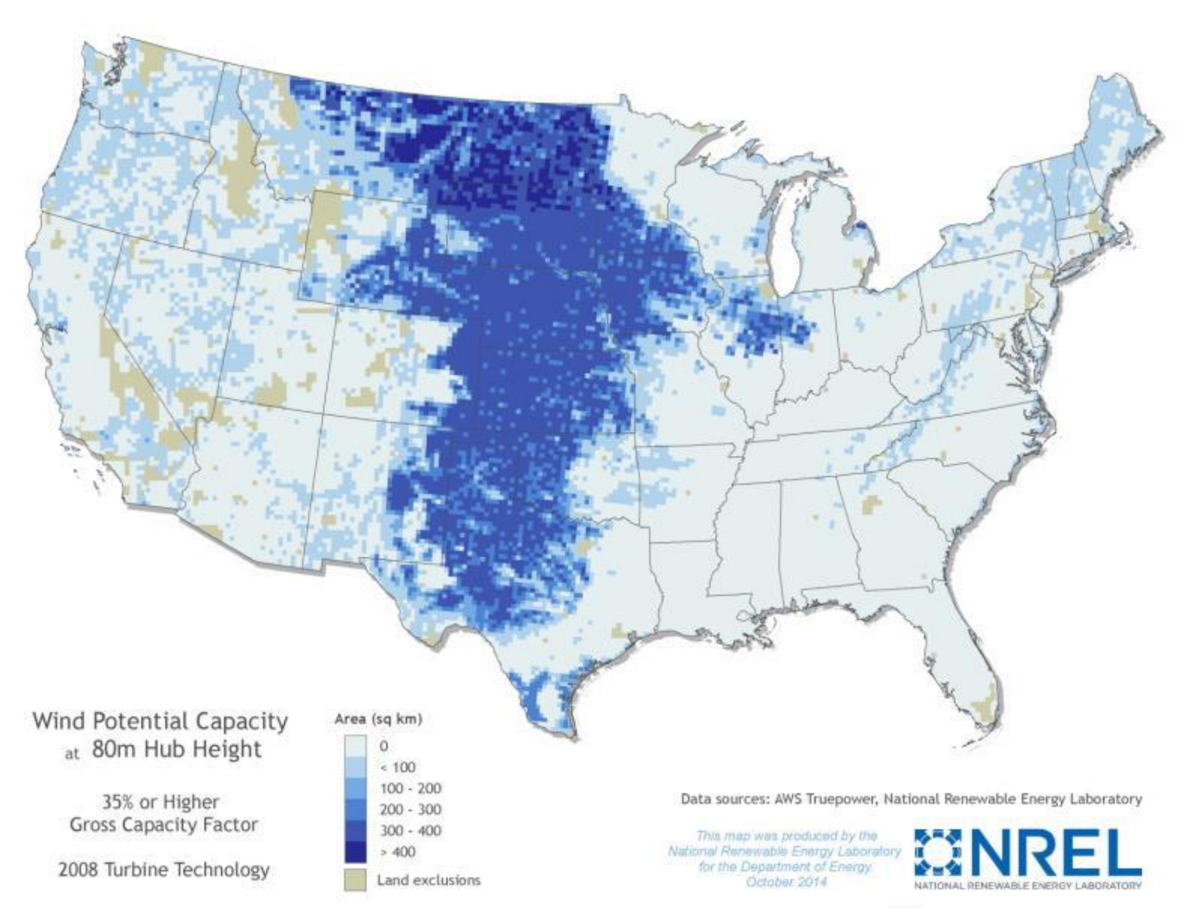
Potential of Wind: More Generation as Turbines Grow



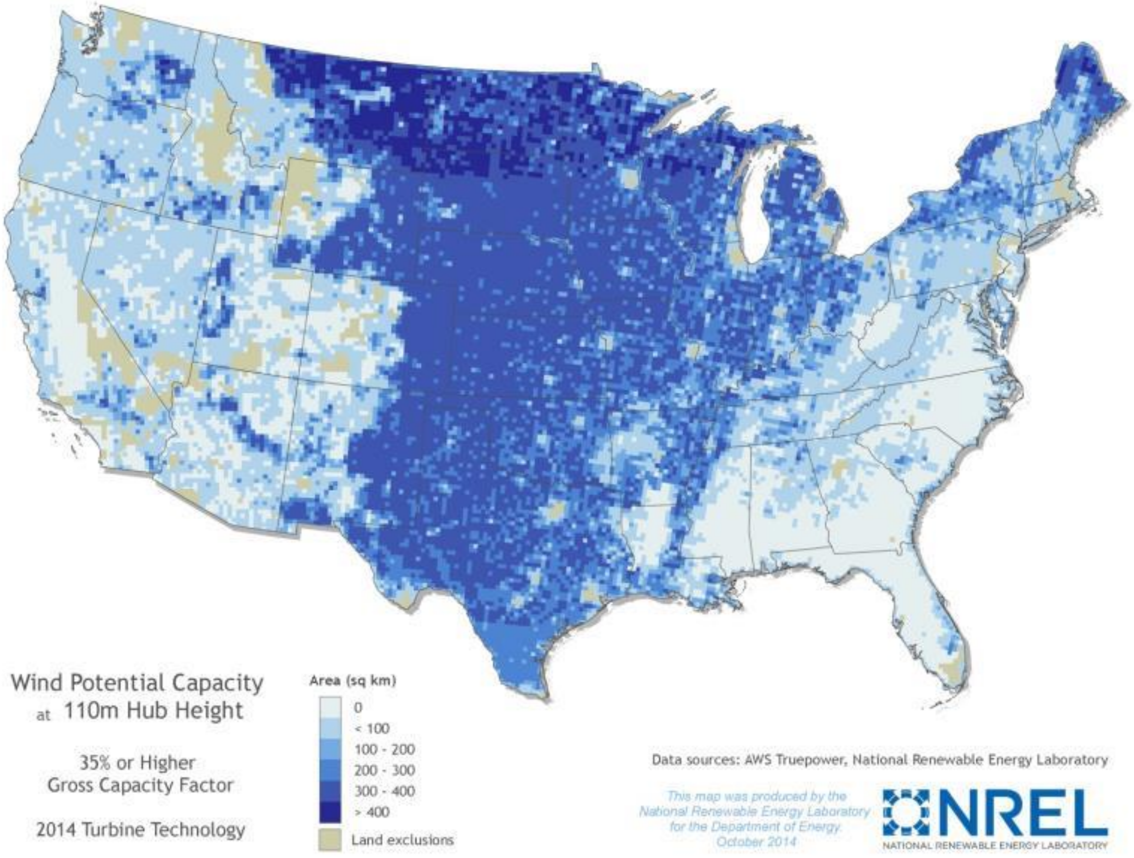


Wind Energy Potential Capacity at 80m Hub Height

2008 Turbine Technology

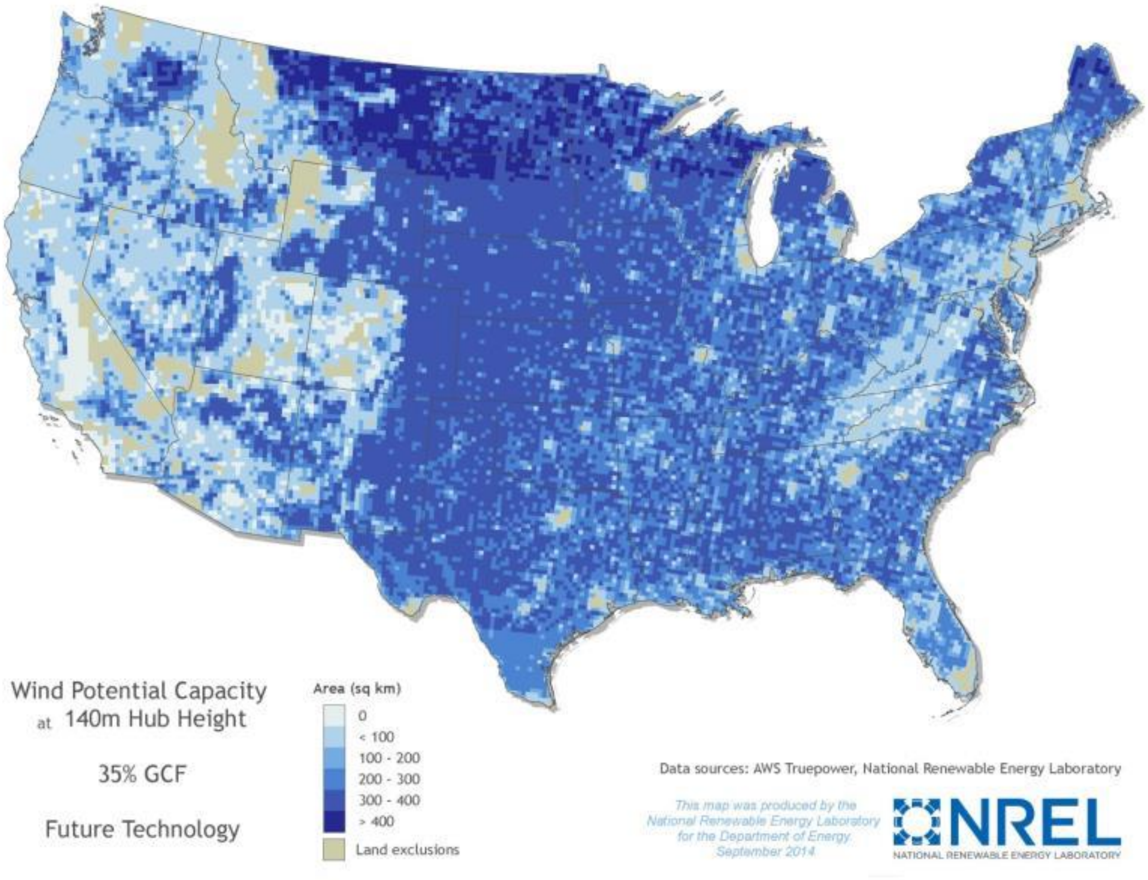


Wind Energy Potential Capacity at 110m Hub Height
2014 Turbine Technology

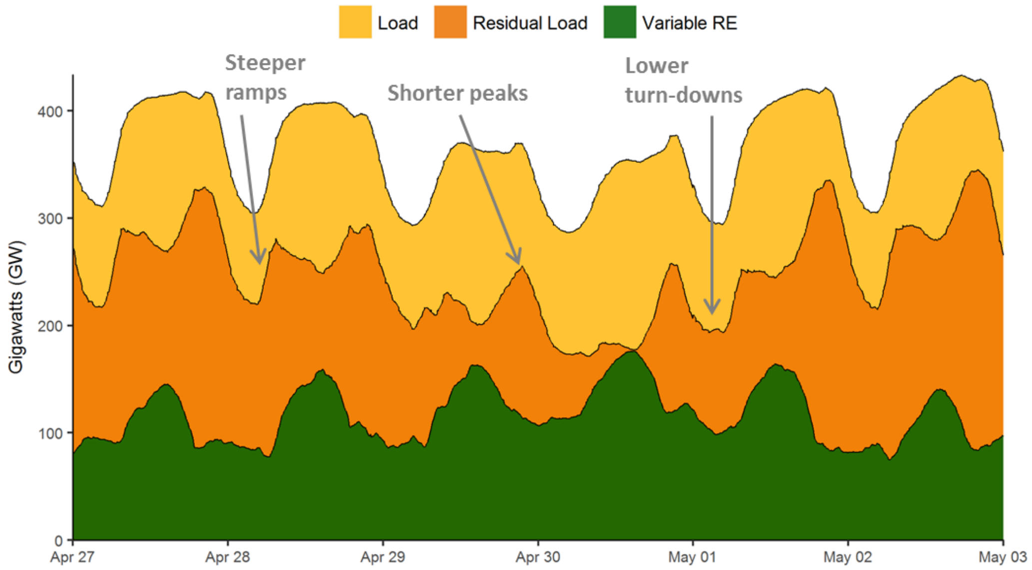


Wind Energy Potential Capacity at 140m Hub Height

'Near Future' Turbine Technology ($150 W/m^2$)

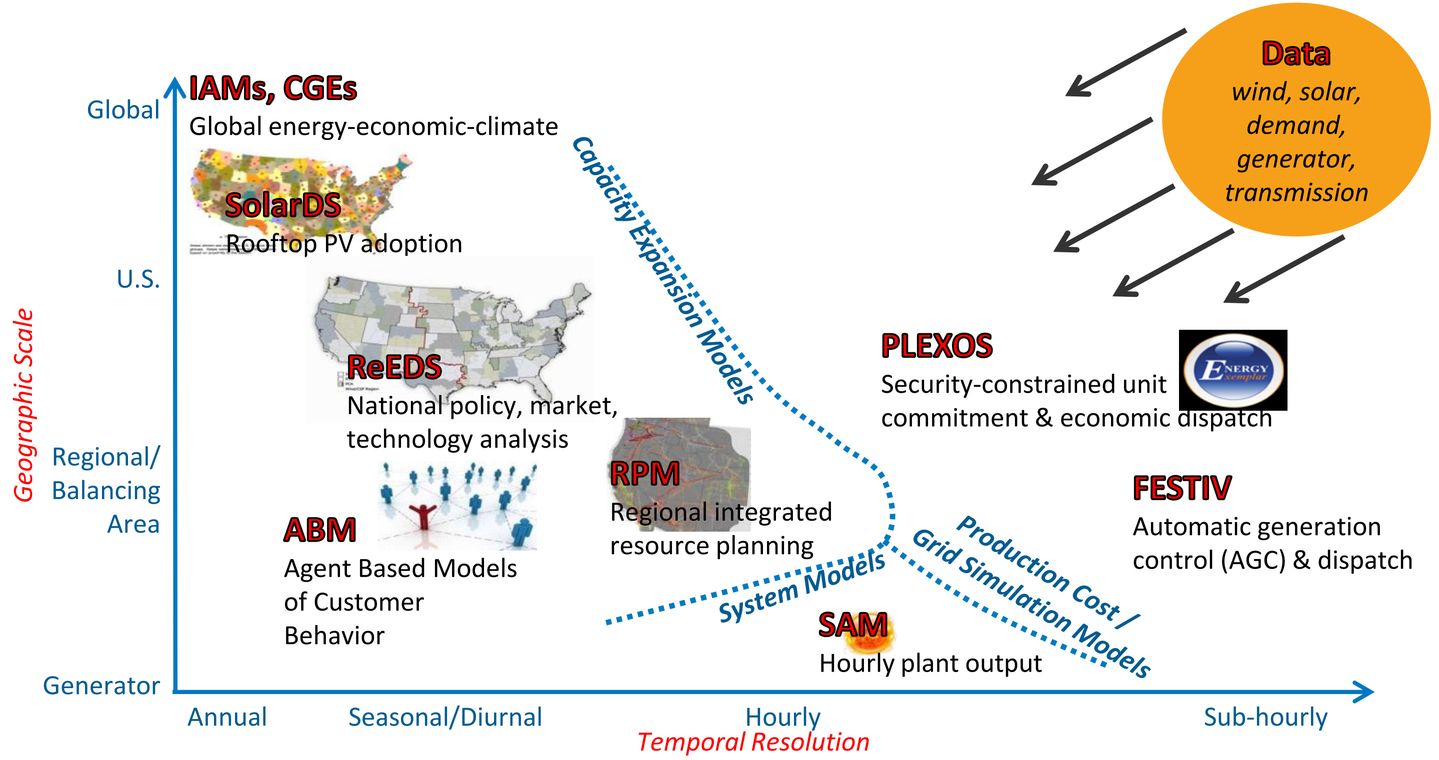


Wind and Solar Add Variability to Supply Side

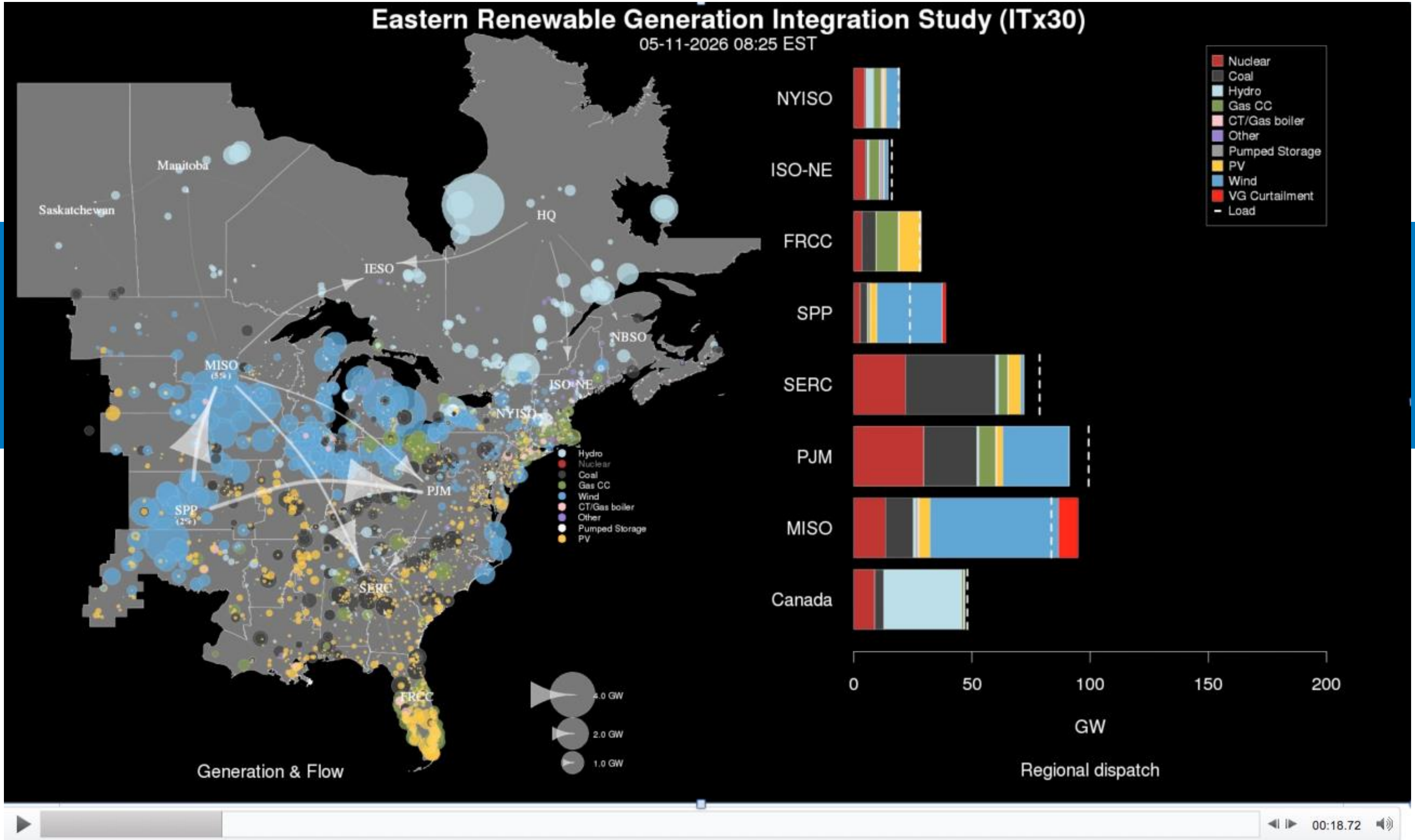


Wind and solar add variability and uncertainty to the generation supply, increasing the need for grid flexibility.

Electricity Modeling at Multiple Scales



Gaining insights from Advanced Visualization



ERGIS Visualization

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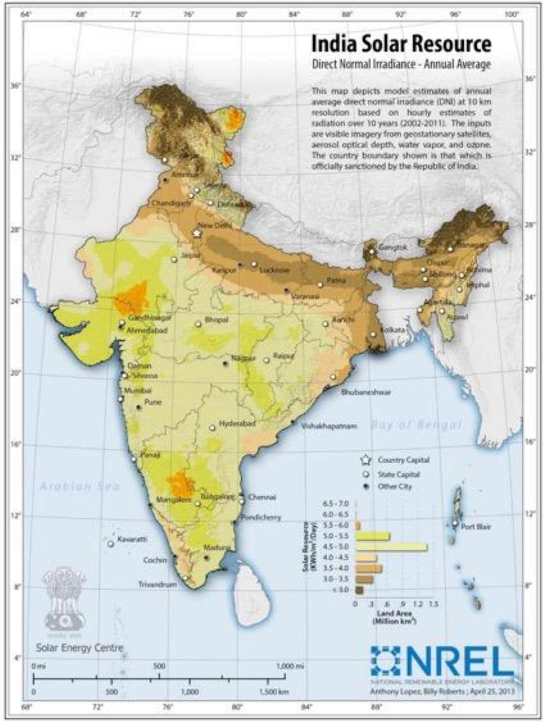
Eastern Renewable Generation Integration Study

Generation, Regional Flows, & Dispatch
ITx30

May 11 - May 13, 2026
High Variable Generation

India's 2022 100 GW Solar Goal Requires an Evolution in Power System Planning



Solar (and wind) generation is variable, uncertain, and location-constrained…

…raising new considerations for grid planning and operations

1. More flexibility is needed to balance supply and demand
2. More transmission might be necessary
3. Grid services (e.g. inertial response) from wind/solar or other equipment come at additional cost
4. Existing conventional generators are needed, but run less, affecting cost recovery

GOVERNMENT OF INDIA MINISTRY OF POWER

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21st Century POWER PARTNERSHIP Accelerating the transformation of power systems

ESMAP Energy Sector Management Assistance Program

India's power system with 160 GW wind and solar—Achieving system balance every 15 minutes

http://www.nrel.gov/india-grid-integration

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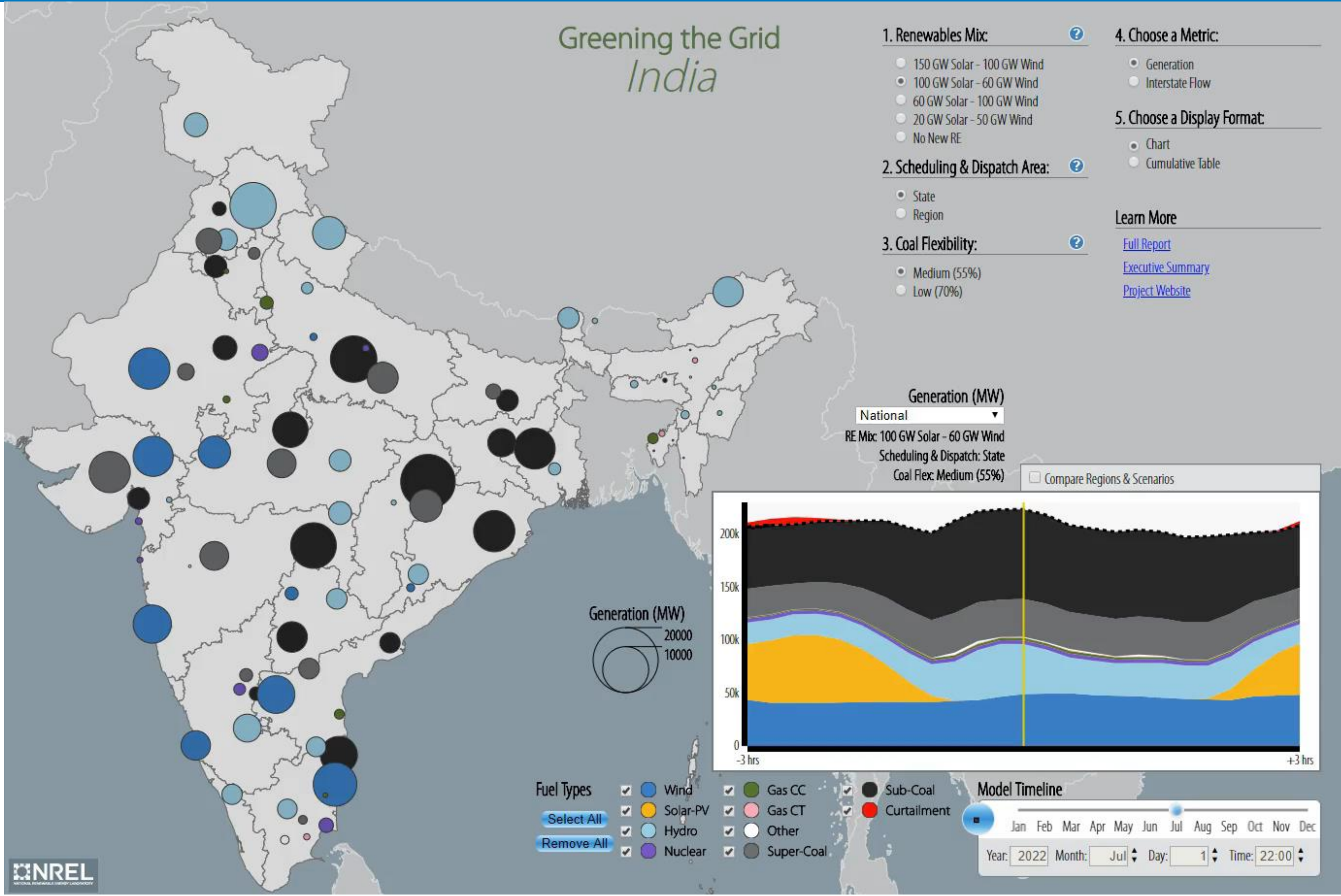
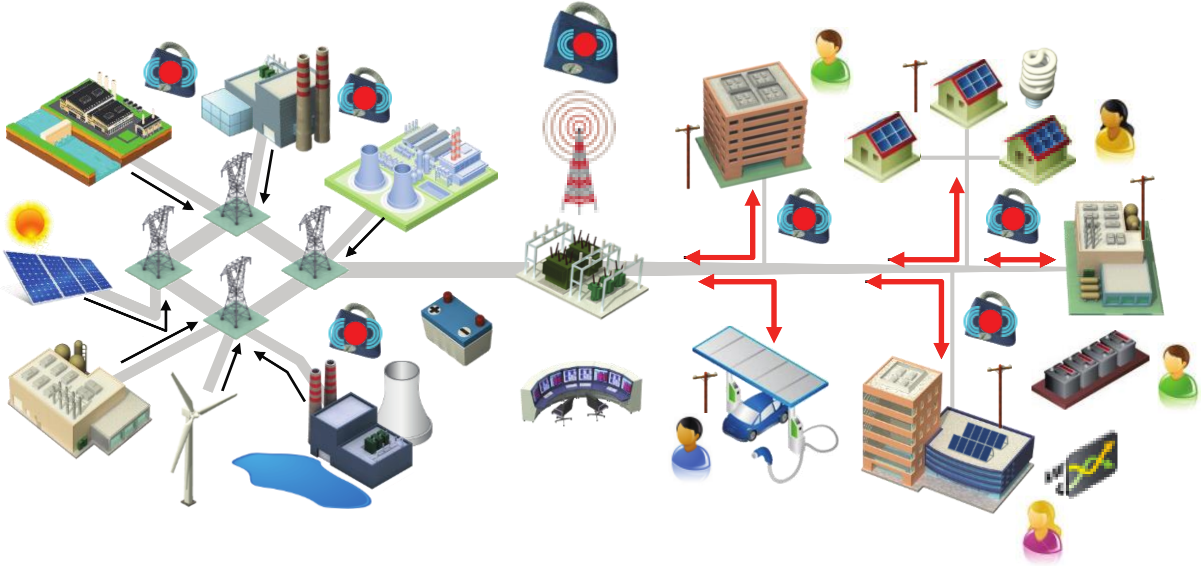


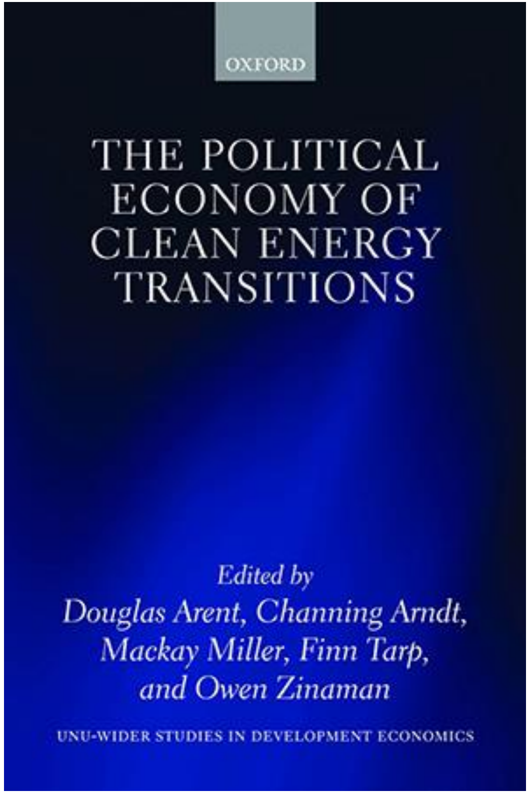
The Evolving Power System



Transitioning today: Restructuring,
New Business Models, New Technologies

A Few Takeaways

- Technology advances are changing the landscape
  - IT & ET & Business model Innovations…
  - Renewables offer domestic advantages with potential economy wide benefits:
    - Price certainty, trade, water/food, health…
- Policy, Finance/business models enable or hinder change
- Power Sector Structural reforms underway across the globe
- Innovation in Financing and Financial reforms continue to evolve to support creative business solutions



Human-Centered Innovation

It is not the essential nature of a technology that matters but its capacity to fit into the social, political, and economic conditions of the day.

–The Economist, March 12, 2012 “The Dream that Failed”

References and Resources

www.nrel.gov

www.21stcenturypower.org

www.cleanenergysolutions.org