EXAMPLES OF ADAPTATION IN THE ENERGY SECTOR

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STRUCTURAL ADAPTATION

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HYDROPOWER IS AN ESSENTIAL PART OF THE ENERGY MIX

- Hydropower is a dominant presence in renewable generation
  - The overall cost of hydropower ($0.047 per kWh) is slightly below wind and solar ($0.053/kWh for onshore wind, $0.115/kWh for offshore wind and $.068/kWh for solar PV)
  - Between 2000 and 2019, hydropower costs went up by 27% due to rising installed costs

Source: IRENA, 2019

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CLIMATE CHANGE IS CHANGING THE VIABILITY OF HYDRO PLANTS

Increasing temperatures

Increasing frequency and intensity of extreme precipitation events

Accelerated snowmelt and glacial retreat (due to rising temperatures)

Decreasing river flows

Flooding can cause damage to levees and the overtopping of dams, create challenges to hydropower storage capacities
outages, damage to equipment and adverse downstream impacts
increasing the risk of power outages

create challenges to hydropower storage capacities, increasing the risk of power outages

Increasing sediment transport leading to reduced storage capacity and water flow, and causing turbine deterioration

Reduced availability of cooling water for thermal power plants

Declining hydropower production and cost-effectiveness

Increased evaporation from the reservoir

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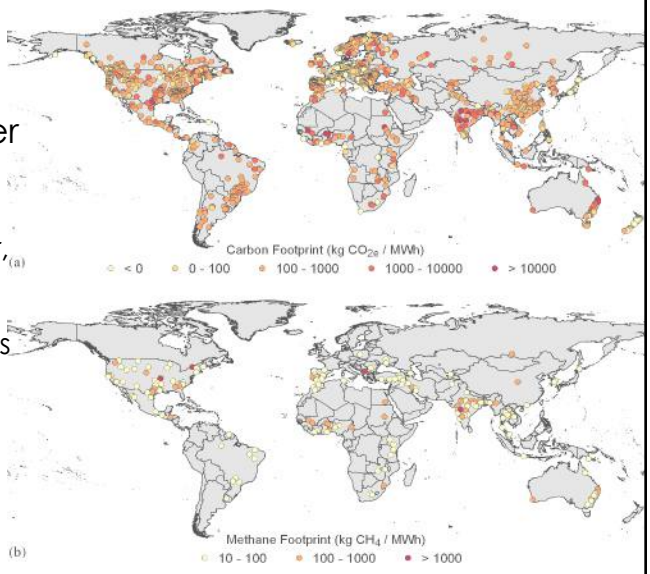
HYDROPOWER DAMS AS A SOURCE OF ENERGY ARE NOT WITHOUT GREENHOUSE GAS COSTS

Hydropower plants generate about 100g of CO_2 equivalent per kWh, and a similar amount of methane

- "Biological activities" in a reservoir, such as decaying vegetation and nutrient runoff from watersheds upstream, are important indicators of GHG emissions
- The rate of soil erosion into a reservoir is a leading predictor of CO_2 emissions



Sources: Deemer et al, 2016; Scherer et al, 2016

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ADAPTATION OPTIONS INCLUDE

- Risk-based engineering / planning
- Improved understanding of cascading impacts
- Changing the operational regimes of reservoirs, including operating procedures for low water conditions
- Climate-proofing engineering interventions
- Changing dam construction
- Changing dyke construction
- Changing management of dam spills (spillways, gated systems and fuse plugs)
- Establishing component-based flood barriers
- Develop integrated water management plan and improve watershed management
- Expansion of plant capacity
- Manage reservoir capacity
- Install monitoring systems on rivers
- Improve forecasts of extreme events and snowmelt timing
- Relocation of hydropower plants, and sometimes communities

Requires high resolution climatic and hydro-meteorological scenarios for each site and for the river basin they belong to

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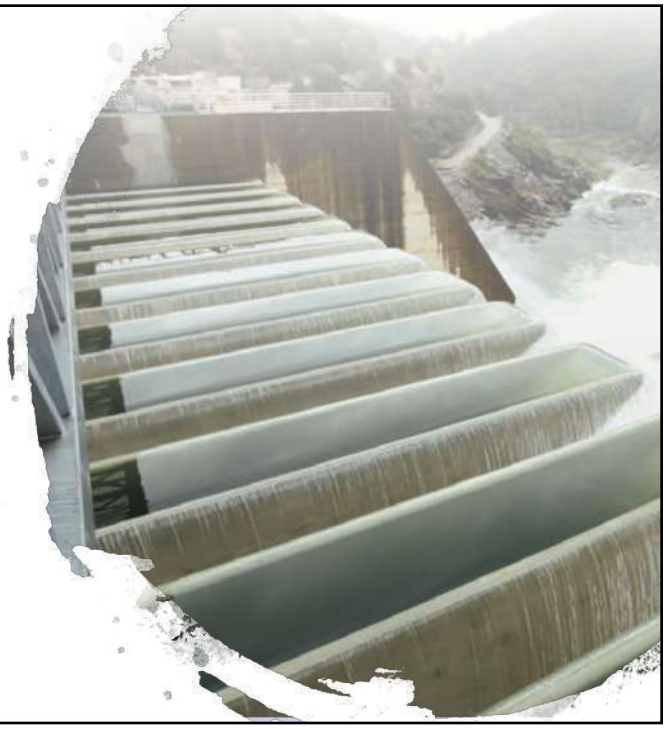
PIANO KEY WEIR SYSTEM

- The Hydro Engineering Centre (CIH) at Electricité de France (EDF) developed the Piano Key Weir (PKW) system
- Improved flood discharge system that helps to release water safely from dams during heavy precipitation events
  - The increased "crenelated" surface area of the PKW system provides an additional spillway to manage increased water flow
  - Particularly relevant in the narrow gorges
- 10 dams in France equipped with PKW technology and around 30 globally



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TRANSMISSION NETWORKS

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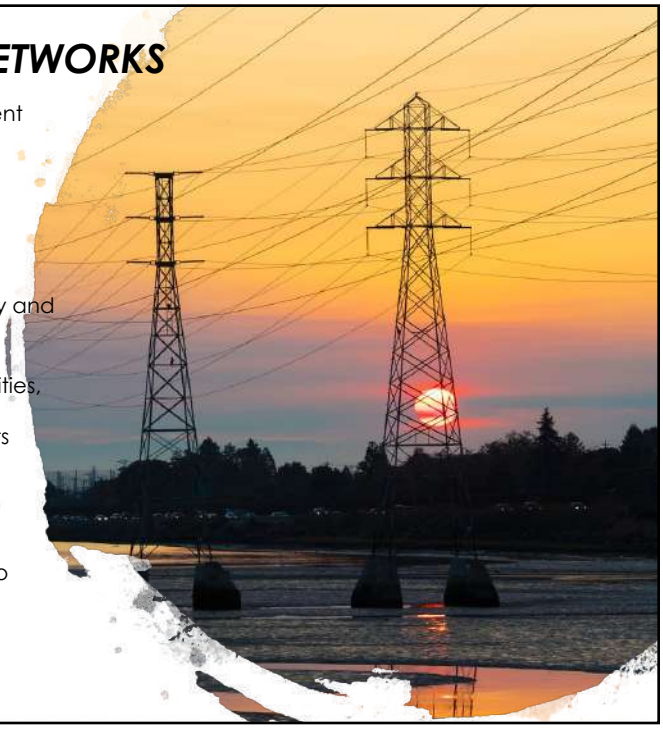
ADAPTING TRANSMISSION NETWORKS

- **Hardening** refers to measures that protect equipment from weather-related damage
  - Trimming trees near high-voltage cables
  - Underground cabling
  - Installing higher power lines poles
  - Implementing the use of 'low-sag' conductors
- **Smartening** by increasing energy network's flexibility and responsiveness ("smart grid" technologies)
  - Flexibility of energy source
  - Switches that can assign priority to critical facilities, such as hospitals and cooling stations
  - Installing conductors with hotter operating limits
  - Increasing the minimum and maximum design temperature of new overhead line routes
  - Software to optimize overhead line ratings
- **Micro-generation and renewable energy sources** to reduce single source failure
- **Energy-efficiency** programs that reduce electricity demand
  - Lighten the load on the grid



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REDUCING SAG IN TRANSMISSION LINES

- Traditionally, overhead high voltage transmission lines have used the "aluminum conductor steel reinforced" (ACSR) design, and line losses (the loss of power during transmission) can be more than 20% of the electricity being transmitted as a function of line and weather conditions
  - Have a high coefficient of thermal expansion, which causes the cables to expand and sag and generate more resistance with increasing load, causing the lines to overheat
- Reconductoring with ACCC cables can increase the transmission capacity of the power grid
  - Carbon fiber composite core is up to 25% stronger than steel core, which significantly reduces the sag at high temperature. Additionally, ACCC cables are up to 60% lighter which allows ACCC cables to have longer spans and fewer and shorter supporting structures

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DISTRIBUTED ENERGY GRID

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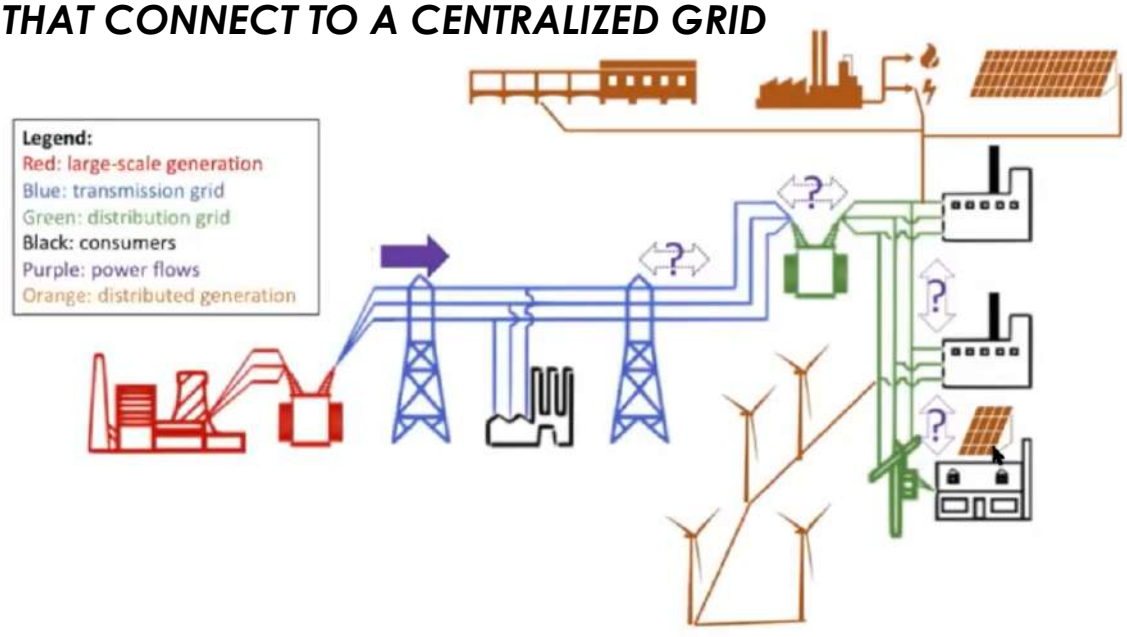
DISTRIBUTED GENERATION UNITS ARE SMALL POWER PLANTS THAT CONNECT TO A CENTRALIZED GRID



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NEW YORK STATE'S REFORMING THE ENERGY VISION (REV)

- Came about in direct response to the reality of climate change and the devastating impact of Hurricane Sandy
  - 3 key objectives: 50% energy generation from renewables; 90% reduction in GHG from 1990 level; and 23% decrease in energy consumption from 2012 level
- Key challenge: The electricity utility business model is not aligned with societal goals and with the rapidly evolving electric grid that they oversee
  - Creates incentive for utilities to help customers use less energy
  - Renewable and other distributed energy resources at the edge of the grid to help resolve the loss of power during extended outages
  - Meeting peak power demands on critical days

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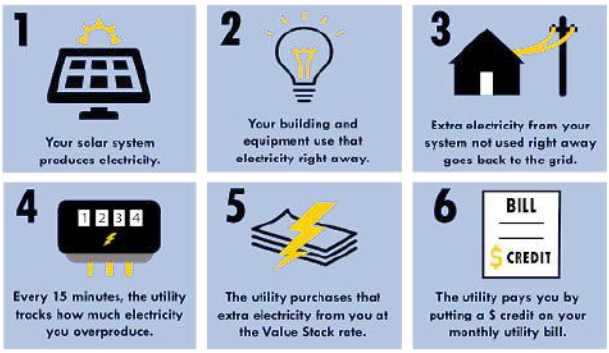
VALUE OF DISTRIBUTED ENERGY RESOURCES (VDER) TARIFF

- Unlike net metering, which is a simple kWh-for-kWh exchange, the VDER evaluates solar's benefits as a "value stack." This collection of values includes locational, environmental, and temporal factors of solar energy.

Solar energy system produces electricity. This electricity is then used by your building and equipment right away. If your solar system produces more than your building uses, the extra power goes to the utility grid. The utility tracks how much extra electricity is uploaded to the grid by your system every 15 minutes. Then, the utility purchases this extra electricity from you at the Value Stack rate by giving you a credit on your monthly electric bill.



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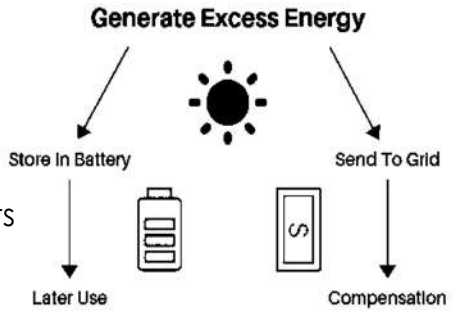
VALUE OF DISTRIBUTED ENERGY RESOURCES (VDER) TARIFF

- VDER tariff applies to batteries with up to 5 megawatts discharge capacity, and pays the battery owner for the energy, capacity value and relief on the distribution system over 25 years
  - In 2018, there were less than 100 megawatts' worth of distributed energy storage projects
  - In 2020, there were more than 1,000 megawatts
  - And the New York Independent System Operator's bulk storage queue jumped from 1,400 megawatts to 8,000 megawatts



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CUSTOMER INCENTIVES

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SOME ADAPTATION OPTIONS

- Hardening measures
  - physical barriers, protective casing, or other upgrades to protect assets from damage
- Deployment of new technologies
- Accurate load forecasting and generation planning
- Climate proofing infrastructure
- Addressing potential changes to fuel and water supplies
- Multi-institutional and public–private partnerships for coordinated action

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PROGRAMS TO ADDRESS SPECIFIC CLIMATE IMPACTS

- Increasing average and extreme temperatures; longer, more severe heat waves
  - CUSTOMER INCENTIVES — **Florida Power and Light (FPL):** Offers monthly credits for participation in the On Call program, which allows FPL to switch certain appliances off during periods of peak demand. Rebates offered for efficient air conditioners and A/C duct repair, and free in-home assessments
  - OPERATIONAL CHANGE & INCENTIVES — **Entergy:** Adding capacity in response to increasing temperatures, in addition to investing in energy efficiency and demand side management, and providing weatherization incentives to low-income customers
- Decreasing water availability; shifting streamflow timing
  - CRVA & OPERATING PARAMTERES — **Seattle City Light:** Working to assess climate change impacts on hydropower generation by characterizing present and future glacier contribution to summer stream-flows, and by updating streamflow projections with multiple climate scenarios
  - TECHNOLOGY CHANGE — **Arizona Public Service:** Long-term agreement to treat and use municipal wastewater from Glendale, Mesa, Phoenix, Scottsdale and Tempe, AZ for cooling at Palo Verde Nuclear Generating Station
  - TECHNOLOGY CHANGE — **NRG Energy's** solar thermal power plant using using dry cooling technology to provide power to PG&E and Southern California Edison

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PROGRAMS TO ADDRESS SPECIFIC CLIMATE IMPACTS

- Increasing size and frequency of wildfires
  - OPERATIONAL CHANGE — **California Public Utilities Commission**: Adopted regulations to reduce fire hazards resulting from overhead power lines and target important transmission lines. Requirements include development of fire prevention plans, fire-threat maps, more frequent inspections
  - OPERATIONAL CHANGE — **San Diego Gas & Electric (SDG&E):** Implemented greater minimum clearances for vegetation, hardened critical portions of its lines, and installed advanced line closers to protect lines in case of emergency. Expanded transmission capacity (e.g., activating the Sunrise Powerlink, connecting San Diego to the Imperial Valley to improve reliability).
- Rising sea levels and more intense hurricanes
  - TECHNOLOGY CHANGE — **Consolidated Edison (ConEd):** Addressed immediate impacts of Superstorm Sandy and the increased risks of coastal flooding in New York City by upgrading substations and hundreds of submersible transformers and network protectors across its network.
  - TECHNOLOGY CHANGE — **DOE, NJ Board of Public Utilities, City of Hoboken and Public Service Electric & Gas Company (PSE&G)** developing first-ever transit system microgrid spanning rail lines and critical stations and maintenance facilities across New Jersey Transit's busy northeastern corridor (serving nearly 900,000 passengers daily) between Newark and New York City, to ensure trains keep running even if the centralized grid goes down.
  - TECHNOLOGY CHANGE — **AEP:** Equipped the town of Presidio, Texas with a large-scale energy storage system and Fault Location, Isolation, and Service Restoration (FLISR) system in order to allow uninterrupted service if the town's single 69 kV transmission line is knocked out.

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OPOWER & CUSTOMER PERCEPTION

- "Green nudge" (aka, the grass is greener on the other side of the fence…)
- Motivation for energy saving

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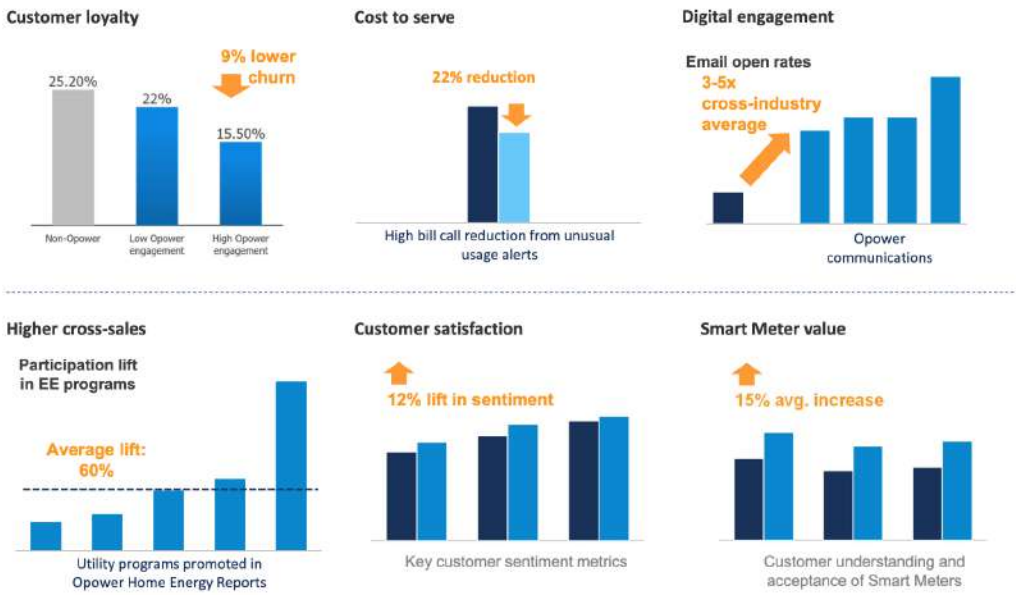
OPOWER & CUSTOMER PERCEPTION



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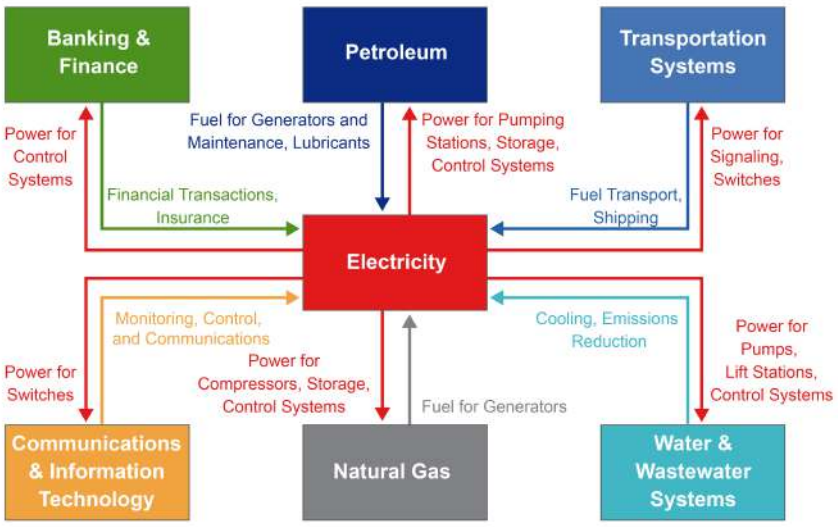
INTERCONNECTIVITY WITH ADDITIONAL SECTORS

The interdependence of critical infrastructure systems increases the importance of electricity resilience, as disruptions to energy services will also affect other sectors



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