Challenges and Solutions of an Energy Transformation

What a Transition to a Renewable-Based Energy Supply Means for Policymakers

Prepared by the California Foundation on the Environment and the Economy

EXECUTIVE SUMMARY

In recent decades, governments have pursued policies to increase the amount of wind and solar power in the energy grid. These policies have resulted in environmental and energy security benefits. However, this transition has also produced challenges to the grid, requiring intense management to properly integrate renewables. The ongoing integration of renewables requires an understanding of energy system dynamics and the mechanisms that can help manage both the real time and ongoing energy grid transformation. To this end, an Organization for Economic Co-operation and Development (OECD)[1] report recommends that policymakers improve energy storage technologies, improve wind and solar forecasting, enhance energy demand management, pursue regional expansion of energy grids, and clarify the ways in which power plants and grid management activities impact energy system costs as a whole. While energy grids vary between state and country, policymakers can utilize these tools to achieve ambitious renewable integration goals without sacrificing the reliability and affordability of grid operation.

BACKGROUND

Society relies on a stable electrical system whereby electricity is produced and delivered to people and businesses that need it to accomplish daily routines. The energy system, also called the grid, is comprised of four basic activities: energy production, transmission, distribution, and energy consumption (see Figure 1). In general terms, energy is generated and then processed through transformers that convert it into a form that can be transported over long distances. Once within a regional network, a grid operator (also known as a "balancing authority") manages and transmits this energy to various utilities that then distribute it to the end user.

Figure 1. *Basics of the Energy System (commonly called the grid)*

Image Courtesy of the U.S. Department of Energy

In larger energy systems, the grid operator is the organization responsible for matching energy supply and demand. They are constantly performing a balancing act to ensure that there is always enough energy to

[1] The Organization for Economic Cooperation and Development (OECD) is a forum comprised of 34 democratic governments with market economies that collaborate with each other and the 70+ non-member economies to "promote economic growth, prosperity, and sustainable development."

meet demand but not so much that the grid infrastructure is overloaded. Too little or too much energy can cause brown outs, black outs, and/or extensive system damage that can take months to repair.[2]

A fundamental constraint of balancing energy supply and demand is the limited capacity to store large amounts of energy.[3] [4] This means that as energy is being produced, it must be distributed in real-time for immediate consumption. The main methods of balancing energy grids has been to ramp up and down production of energy plants ("ramping") that can be rapidly dispatched to meet demand, curtail renewable energy production to reduce the energy supply ("curtailment"), or have customers cut energy demand ("demand response").

THE NUANCES OF WIND AND SOLAR ENERGY

The balancing of demand and supply has implications for the production and distribution of renewable energy sources like wind and solar. Traditional grids relied on energy that could be generated to meet demand as it changed throughout the day.[5] For example, as more people came home from work and started turning on appliances and lights, power plants would gradually ramp up their energy production to meet that demand. Wind and solar power plants, however, only generate energy when the wind is blowing or the sun is shining. For this reason, wind and solar power are often called "variable" or "intermittent" renewables.

This intermittency complicates the process of energy grid balancing. For instance, the variability of renewables causes too much energy at times. If the grid operator anticipates that energy production will exceed consumer needs, then power plants will be asked to curtail energy production. This excess energy may even result in the negative price of energy in which power producers must *pay* grid operators in other systems to take excess energy. [6]

Additionally, instead of being able to meet demand by making adjustments to energy production, a grid relying primarily on wind and solar requires that other energy sources fill in the gaps left by variable renewables. Such energy sources—commonly called "dispatchable" for their ability to be dispatched to meet changing demand—are many of the same energy supplies that already support the majority of the grid. As more wind and solar projects come online, dispatchable energy represents a shrinking yet still critically important source of power that ensures grid reliability.

Five Key Characteristics of Wind and Solar Energy

The output is carbon free
Unlike coal, natural gas, and other fossil fuel-based energy resources, wind and solar do not emit a carbon dioxide byproduct.

The cost of providing another kilowatt-hour (kWh) unit of wind or solar is nearly zero
The costs of harnessing this energy are nearly nothing (although project developers must still pay expensive installation costs).

They are not "dispatchable"
Only when the wind is blowing and the sun is shining can they be dispatched to meet demand.

They vary throughout the day
Their energy fluctuates at different times of day. Generally, wind is blowing strongest at very early morning and solar is strongest during mid-afternoon (though this profile varies by location).

Their production changes on a minute-to-minute basis
Changing weather conditions (i.e. fluctuating winds, increase in cloud cover) means that predicting wind and solar generation in advance is difficult.

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[2] OECD Nuclear Energy Agency. (2012). Nuclear Energy and Renewables System Effects in Low-carbon Electricity Systems. Retrieved from https://www.oecd-nea.org/ndd/pubs/2012/7056-system-effects.pd

[3] Energy can be stored by retaining water behind dams or pumping water uphill. It can then be released at times of increased demand to generate energy.

[4] OECD op cit.

[5] Ibid.

[6] Council of Economic Advisors (June 2016). *Incorporating renewables into the electric grid: expanding opportunities for smart markets and energy storage*. Executive Office of the President of the United States. Retrieved from https://www.whitehouse.gov/sites/default/files/page/files/20160616_cea_renewables_electricgrid.pdf

How Wind and Solar Outcompete Dispatchable Energy and Why It Matters

While it may seem straightforward to provide standby power to fill energy gaps as needed, there are market forces that confound energy balancing.

First of all, the shift to a renewable-based energy grid has not occurred by happenstance. It's the result of a strategic move by governments to address energy security and carbon emissions concerns. Policymakers adopted laws and policies that promoted homegrown, green energy projects. Programs have ranged from the taxation of carbon-intensive energies to explicit and implicit subsidies for installation and generation of renewable energy. These policies have had the twofold effect of discouraging investment in dispatchable energies that emit carbon dioxide while alleviating the upfront costs associated with renewable power plant installation. Equally important, technological advances have led to drastic declines in the cost of renewables relative to other sources of energy. The result has been a worldwide renewable energy boom that has seen increasing capacity and generation of wind and solar while traditional carbon intensive power plants are beginning to be phased out.[7]

Second, wind and solar are incredibly cheap to produce after installation costs have been paid. Their marginal cost—or the cost of producing another kilowatt of energy—is nearly zero. Accordingly, grid operators will generally opt to meet demand using the cheaper energy supply.[8] This transaction is one reason that renewables now routinely out-compete energy supplied by traditional power plants. Consequently, it's not surprising that investments in renewable power plants were twice that of fossil fuels in 2015.[9]

The third major pressure relates to changes in something called "system costs" (see right).[10] As renewable production has increased, some system stakeholders have voiced concerns that wind and solar generators are not adequately paying for the grid challenges they impose on other power providers and that dispatchable

Understanding System Costs and How it Relates to Renewable Integration

System costs (excluding environmental costs) are the aggregate monetary costs that energy production of any kind causes on all energy system stakeholders, from power plants to consumers. These costs are sometimes called "hidden" because they have neither been systemically monetized nor paid for by the firm causing the cost.[1] Instead, these costs are absorbed into the wider system of energy costs that are ultimately passed on to consumers of electricity.

It's critical to note that system costs exist *with or without* wind and solar power. However, increases in wind and solar power have led to concerns about the changing nature of system costs. Examples of system costs in the context of renewable energy are detailed below:

Congestion Costs

This results from too much energy on the same transmission line. This has been associated with solar production when very sunny days result in high levels of solar energy flooding transmission lines.

Ramp up Costs

When the sun goes down or wind gusts decrease, it requires that dispatchable energies have to ramp up their production dramatically to make up for the subsiding renewable availability. Ramp up costs increase over time as renewables further penetrate the energy market.

Grid Servicing Costs

Costs associated with ancillary services related to grid stability and reliability services. One example is the spinning (i.e. the plant is up and running but not producing energy) of dispatchable power plants to be capable of actually generating energy within 15 minutes.

Long Run Costs

While the costs specified above occur in the short term, there are long-term costs resulting from the need to install reserve power plants that support intermittent renewable energy. Long-term costs may also include additional congestion costs.

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[7] CEA op. cit.

[8] Ibid.

[9] Randall, T. (2016, April 6). Wind and Solar Are Crushing Fossil Fuels. Retrieved from http://www.bloomberg.com/news/articles/2016-04-06/wind-and-solar-are-crushing-fossil-fuels

[10] Although systems costs could be broadly interpreted to include environmental costs of energy production, in this context we utilize the more narrow definition that focuses only on grid operation costs.

energy providers are not being adequately compensated for the grid services they provide. On the other hand, there are those that point out that system costs have always existed in one form or another, and thus, it's unfair to blame wind and solar for changing market dynamics. These individuals also assert that focusing solely on a narrow definition of system costs that excludes environmental and energy security is misrepresenting the true impact of renewable integration.

This debate about system costs is emblematic of the uncertainty that surrounds a transition to a grid based on renewable energy. For those that are concerned about increasing system costs, they fear that dispatchable energy firms are placed at a further disadvantage in the market place by making the financing and operation of non-renewable dispatchable energy increasingly less viable.[11] This occurs despite the fact that the energy system still needs dispatchable energy to meet changing demand in ways intermittent renewables do not. It's a paradox in which the integration of renewables threatens the viability of dispatchable energy—one of the things needed to make renewable integration successful.

POLICY IMPLICATIONS

For renewable integration policies to be successfully implemented, policymakers must help the energy grid adapt to the growing pains of the energy transition. A 2012 Organization for Economic Co-operation and Development (OECD) report analyzed some of the challenges renewables present to the energy grid. Their analysis, along with insights from other reports, provide a set of tools that can help manage the effects of increasing amounts of intermittent renewables in the grid. The OECD's observations for policy makers are outlined below:

- **Continue improving energy storage technology:** Energy storage can smooth the variability of renewables by storing energy during times of low demand and then distribute it later when it has a higher value. As energy storage prices continue to drop, it becomes an increasingly viable mechanism to manage intermittent wind and solar resources.
- **Improve forecasting:** Knowing how windy or cloudy it will be in the coming days, hours, and minutes reduces energy supply unpredictability. By making the supply more predictable, system costs can be reduced.
- **Emphasize demand side management:** Traditionally, grid operators have focused their efforts on managing the energy supply. A grid of the future—called a smart grid—would integrate the actions of energy producers, system operators, and energy users such that demand can also be adjusted, which would result in improved matching of supply and demand.
- **Improve the transparency of system costs and establish regulatory frameworks such that system costs can be properly attributed to the firm that creates the costs:** Without an understanding of these costs, they will be indiscriminately embedded into system costs that then become the responsibility of other energy firms. Instead of costs being passed on to other energy firms that are then ultimately paid for by electricity consumers, the OECD states that an approach that internalizes system costs (i.e. the firm that generates the costs is also responsible for paying them) benefits stakeholders as a whole by increasing market efficiency.
- **Recognize the current and future role of "dispatchable" energies that produce relatively little carbon emissions:** Energy sources like natural gas, geothermal, and biomass currently represent the most cost effective solution to renewable variability. Considering that their production generates a more modest carbon emission byproduct when compared with coal and oil, policymakers should find ways to support these dispatchable energy sources now and in the future.

[11] CEA op. cit.

- Improve geographic diversity of a given energy grid: Different weather conditions in different regions of a country and/or continent can benefit the grid by having access to different energy demand and supply conditions that can ultimately be matched to each other. This helps manage renewable variability.
- Create a larger, more interconnected energy grid: This alleviates unpredictable energy production by allowing grid operators to utilize a wider pool of available resources that can help meet supply. A spike in consumer demand places less stress on the grid if system operators have a greater variety of energy supplies that can be dispatched.

LOOKING TO CALIFORNIA

While these recommendations can be a useful guide for addressing renewable integration challenges, they only become practical solutions when customized to a given country or state. California has unique environmental, business, and labor commitments that render some policy options more feasible than others. By thoughtfully considering how potential solutions will interact with each other as well as California's specific policy context, policymakers can begin to craft a multifaceted approach that is tailored to the state of California. Outlined below are discussion points that aim to stimulate a California-focused renewable integration conversation.

DISCUSSION POINTS

- When there is an excess of renewable generation in California (or Germany), how does the grid operator act today? What does it mean to sell power at negative prices?
- How would this situation change under an expanded California grid?
- How would California consumers and businesses benefit from an expanded grid? What are the downsides?
- Why are there concerns about changing system costs? Why do some definitions of system costs exclude environmental and energy security cost/benefits?
- As a Renewable Portfolios Standard (RPS) increases, do greenhouse gases decrease the same percentage incrementally?
- Under an RPS, fossil power plants role in supplying energy is diminished. But is their value to the grid, and overall reliability diminished?
- If fossil resources are compensated less and less over time—due to increasing levels of renewables—do we risk driving them out of the state? If so, how will that impact reliability?
- If California is to meet the Governor's electric transportation goal (1.5 million electric vehicles by 2025), what impact will that have on the grid? What investments in the grid need to be made to accommodate all that new electric load? Can that load be satisfied with all renewable energy?
- How much will retail Time of Use (TOU) rates impact grid conditions? Will it help or hurt the CAISO's ability to maintain reliability?