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# The Benefits of Baseload Renewables: A Misunderstood Energy Technology

Misinformation about baseload renewables has distorted the discussion about the least-cost future renewable energy mix. There are renewable baseload power sources with generation profiles that can economically replace other retiring electricity sources megawatt for megawatt, thereby avoiding incurring additional costs from purchasing and then balancing renewable intermittent power sources with storage or new transmission.

Benjamin Matek and Karl Gawell

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## I. Introduction

Today's energy literature appears to be proclaiming that "baseload energy is dead," and sometimes argues that variable energy resources are able to meet all or nearly all of the power needs of future electricity systems.<sup>1,2</sup> On the contrary, it has been a well-established energy industry best practice for decades to value a diverse mix of electricity sources in order to ensure grid stability

and security, and reduce the overall risks of volatility.<sup>3</sup> Energy diversity helps to maintain a sustainable supply of fuels for electricity generation that protects consumers from potential price spikes or shortages. In addition, valuing baseload power is viewed as a key element in meeting demand effectively. Recently, it has been asserted that over-procurement of individual technologies is causing rising electricity prices. This assertion is

indicative of a need to re-evaluate current views on electricity supply diversity and the value of baseload renewables.<sup>4</sup> Already we see a price increase starting to take effect. The government's Energy Information Administration (EIA) speculates that between 2013 and 2014, wholesale electricity prices rose across the country, "driven largely by increases in spot natural gas prices and high energy demand caused by cold weather in the beginning of the year."<sup>5</sup>

Many advocates would have the public believe that baseload power is a relic of the past. As a result, there is an abundance of analysis in the renewable space promoting the view that intermittent power sources can substitute for baseload power using demand-side management, electricity storage, and enhanced coordination or forecasting of power plants. But there is another option often overlooked by policymakers when choosing resources: to further develop renewable baseload sources like geothermal, biomass, or hydro power. Instead of trying to fit the grid to renewables' variability, balancing authorities and energy commissions can also fit renewables to the grid. They can build baseload geothermal, biomass, or hydro power in conjunction with other power sources to meet their power needs through a more diverse supply.

Recognizing that no one-size-fits-all solution is preferable, the

reevaluation of baseload renewables may well provide the best path to address today's power challenges and be the most effective way to combat the threat of climate change. However, to determine the best path forward, a number of system-wide issues need to be addressed. They include:

ffi What combination of technologies has lowest system-wide costs?

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ffi What mix will have the lowest cost considering both replacement costs and operation and maintenance costs over a period of several decades?

ffi What combination of resources provides the best total emissions profile?

ffi Which mix of technologies provides the best system reliability?

ffi What mix of technologies provides the most efficient use of limited capital in achieving long-term climate goals?

These are just some of the questions that need to be asked as power authorities move to

generate greater amounts of renewable power. The fact that there are more questions than answers is in part a reflection of the limitations on available literature. However, this article supports the assertion that baseload renewable resources are an important, undervalued means to make grids more resilient to changing climate, keeping electricity prices low, achieving cost-effective emissions reductions and using existing infrastructure more efficiently.

In the past, baseload power came mostly from coal and nuclear facilities. According to the EIA, coal-fired and nuclear power plants together provided 56 percent of the electricity generated in the United States in 2012. However, EIA estimates nearly one-sixth of U.S. coal capacity is expected to be retired by 2020. Additionally, operators of three nuclear power reactors – San Onofre (California), Kewaunee (Wisconsin), and Crystal River (Florida) – have retired since 2011, representing 3.7 GW of capacity. The 620 MW Vermont Yankee will retire by 2015 and, the Oyster Creek Nuclear Plant in New Jersey is expected to retire in 2019.<sup>6</sup> Several other nuclear facilities face potential closure in the next decade, including California's only remaining nuclear facility, the 2,240 MW Diablo Canyon plant.<sup>7</sup>

Generally, while fluctuations do exist in the demand for power

during peak hours and morning ramps, electricity is required 24 hours a day within all balancing authorities.<sup>8</sup> The power supply being used to meet demand is increasingly based on intermittent or variable power sources and natural gas. EIA found that natural gas-fired power plants accounted for just over half, solar provided nearly one-quarter and wind power one-tenth of the new utility-scale generating capacity added in 2013. The natural gas capacity additions came nearly equally from combustion turbine peaker plants and combined-cycle plants which provide intermediate and baseload power. Additionally, almost half of all capacity added in 2013 was located in California.<sup>9</sup>

**A**s climate goals increasingly press utilities for emission reduction, the U.S. electrical grid will continue to transition to cleaner fuels. In particular, coal is expected to be phased out and replaced by natural gas and renewable power sources. While this process may be important to meet state and federal climate change goals, it is important to think about the consequences of the current transition process. In some places, intermittent power sources will need to be structured to create a baseload resource in order to ensure grid stability. Given the nature of demand, an electricity grid cannot function without substantial baseload power on the system. Most power demand

requires baseload power supplies, and a certain minimum energy must be maintained on every electrical grid to ensure against blackouts or system failures. While the amount of baseload required depends on the region, the best future mix of renewables should recognize the value of having some baseload in addition to intermittent and peaking power sources.

## II. Values of Baseload Power to Electricity Grids

Baseload power is the minimum amount of power that a utility or distribution company must generate for its customers, or the amount of power required to meet minimum demands based on reasonable expectations of customer requirements.

In a hypothetical electricity market's supply curve, baseload generating units, which generally

operate 24 hours per day year-round, appear on the cheapest part of the supply curve (Figure 1). The opposite or right side of the supply curve represents peaking generators that operate at hours of high demand. Intermediate generating units (also known as cycling units), operate between baseload and peaking generators, and vary their output to adapt to changes in electricity demand.<sup>10</sup>

Some renewable electricity sources – e.g. bioenergy, hydro, and geothermal power – can easily imitate a traditional coal-fired or nuclear station's generation profile to operate as baseload, and may be integrated without any additional backup. Geothermal power, in particular, operates the most efficiently when it runs continuously without interruption; however, some geothermal plants can load follow and depending on the

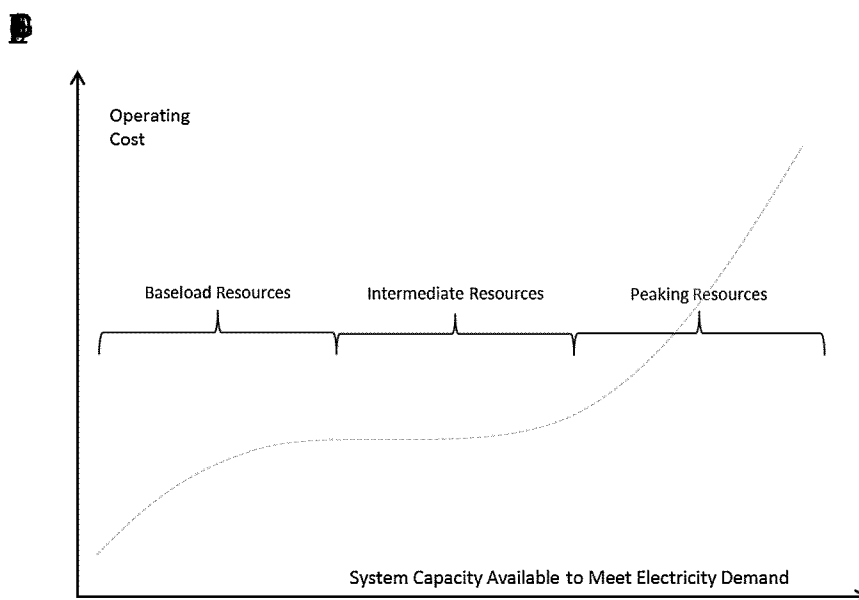


Figure 1: Hypothetical Electricity Market Dispatch Curve

engineering of the plant can provide other flexible system needs.<sup>11</sup>

An example of a diverse portfolio as a renewable electricity best practices case study for California is provided by E3. E3, a consulting firm specializing in North American electricity markets, published a report in January 2014 that modeled different future power mixes for California's renewable portfolio standards (RPS). The study<sup>12</sup> found a future 50 percent RPS in California is likely to be met by these challenges:

- Renewable integration challenges, particularly overgeneration during daylight hours, are likely to be significant at a 50 percent RPS.

- With high penetrations of non-renewable generation, some level of renewable resource curtailment is likely to be necessary to avoid overgeneration and to manage net load ramps.

- A number of promising integration solutions that could help to mitigate overgeneration, including procurement of a diverse portfolio of renewable resources, increased regional coordination, flexible loads, and energy storage.

- The lowest-cost 50 percent RPS portfolio modeled here is one with a diversity of renewable resource technologies. The highest-cost portfolio modeled is one that relies extensively on rooftop solar photovoltaic systems.

An important conclusion from these findings is the value of, first, a diverse portfolio of resources. Intermittent sources alone cannot cost-effectively generate electricity for a balanced grid. The study's diverse portfolio scenario included increased generation from both geothermal and biomass power which both of which traditionally have baseload generation profiles. Second, in the "less-diverse" generation

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### Intermittent sources alone cannot cost-effectively generate electricity for a balanced grid.

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portfolio, higher ratepayer costs will occur because of the need for additional ancillary services to curtail overgeneration.

E3's conclusions demonstrate that, in California, resources that are flexible, able to ramp, and reliable are absolutely essential for a minimum cost grid. Today's baseload renewable resources such as geothermal power and biomass are perfect firming resources for a future 50 percent renewable grid. E3 continues:

The largest integration challenge that emerges from the [E3's model] is "overgeneration." Overgeneration occurs when "must-run"

generation—non-dispatchable renewables, combined-heat-and-power (CHP), nuclear generation, run-of-river hydro and thermal generation that is needed for grid stability—is greater than loads plus exports. This study finds that overgeneration is pervasive at RPS levels above 33 percent, particularly when the renewable portfolio is dominated by solar resources. This occurs even after thermal generation is reduced to the minimum levels necessary to maintain reliable operations.<sup>13</sup>

Overall, E3 mentions that a combination of an oversaturation of baseload resources like nuclear and overgeneration from solar resources will cause problems for California's future electricity grid, which raises costs. Geothermal power and other renewable baseload sources are capable of acting flexibly to adjust to the electrical grid's needs and should provide advantages not yet recognized in the regulatory system.

For example, some geothermal binary power plants can ramp up and down very quickly. These plants can be ramped up and down multiple times per day from 10 percent to 100 percent of nominal output power. The normal ramp rate for dispatch (by heat source valve) is 15 percent of nominal power per minute. The ramp rate for dispatch in Flexible Operation Mode is 30 percent of nominal power per minute.<sup>14</sup> For comparison, gas turbines are usually kept warm and rotating at minimum power for use as available power resources for the

grid. A new type of “flexible” gas turbines, GE LM2500 or GE LMS100, can be ignited and raised to full power within 10 minutes (as claimed in GE Power – Aero-derivative Gas Turbines publications).<sup>15</sup>

In fact overgeneration is already a growing concern in California. From February to April 2014, the California Integrated System Operator (CAISO) had to curtail wind and solar generation four times for a total of six hours to balance supply and demand on the system. Overgeneration and subsequent curtailments reached 485 MW of wind and 657 MW of solar during one of period. To balance supply and demand power systems must curtail renewable power generators or find others to take extra electricity. Either way, California is raising system costs.<sup>16</sup> These curtailments can be expected to become a larger issue as intermittent power sources increase in use throughout the United States.

Germany another early adopter of renewable technologies faced similar problems. To combat climate change, Germany rapidly built up wind and solar resources but did not adequately plan for the problems posed by their intermittency. As a result, to ensure its grid stability it compensated by building coal plants, especially after their commitment to retire its nuclear facilities following the Fukushima disaster in Japan. Despite notable

accomplishments in renewable energy technology, Germany is fighting to keep its electricity grid balanced. As a result, between 2011 and 2015 Germany will open 10.7 GW of new coal-fired power stations.<sup>17</sup>

In 2013, just under half of Germany’s electricity generation came from coal resources, including lignite and other types of hard coal.<sup>18</sup> As Germany has increased its renewable

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generation from 20.2 percent to 24 percent between 2011 and 2013, its generation profile of baseload coal has increased as well. Over the same period coal generation increased from 42.8 percent to 44.8 percent.<sup>19</sup>

### III. The Costs of Fitting Intermittent Power Source to Be Baseload

In general renewable energy literature there are three main ways to generate multisource baseload power from intermittent power sources. The first is to

coordinate intermittent power sources over vast distances to act a “single unit,” such as interconnecting widely separated wind farms with transmission. The second is to couple an intermittent power source with a storage system, such as a PV farm with a compressed air energy storage facility or a pumped hydro facility. The third is to couple variable resources with active demand response strategies that will trigger automatically, as needed, to balance the power system. Each of these approaches has its drawbacks and limitations.

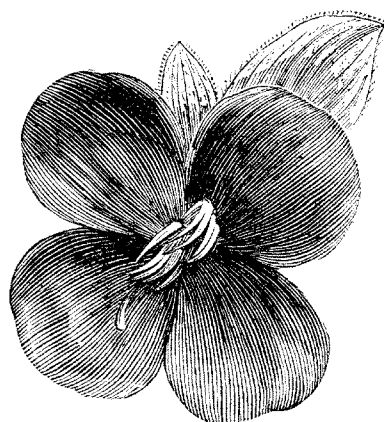
The first method involves balancing power over wide areas by means of expanding transmission and coordinating intermittent sources, such as wind. Studies found doing so improves reliability but with cost. For example, one study from Stanford in 2007<sup>20</sup> showed the more sites that are interconnected; the more the array resembles a single farm with steady winds. However, this model is based on the assumption that a vast transmission network exist to interconnect these wind farms which in reality may not be possible. Of the 50,388 combinations of 19 connected wind farms modeled the authors found “an average of 33 percent and a maximum of 47 percent of yearly averaged wind power from interconnected farms can be used as reliable, baseload electric power.”<sup>21</sup> This result

indicates that this method would require not only building more transmission to provide the same amount of power, but would also require installation of additional generating capacity.

Coordinating intermittent resources raises the total cost of meeting a specific power need when factoring in additional transmission or ancillary costs. While expanding variable resource input to allow averaging of resources improves reliability, it will also increase the minimum capacity of the transmission system needed to meet a specific power need. This expansion could expose the power system to additional bottleneck problems since more transmission capacity will be necessary to produce the same amount of power. For example, instead of building one 50 MW renewable baseload facility that will use a transmission line 60–70 percent of the time, two or three interconnected wind farms would be required to meet the same load. As a result, additional transmission infrastructure is needed, raising ancillary and transmission costs.

**R**enewable baseload electricity sources use existing transmission capacity efficiently because of their high capacity factors. A 50 MW intermittent power source needs to consume 50 MW of transmission even though the intermittent source may seldom use the full capacity of

that line. For congested transmission lines, the integration of intermittent resources can raise costs as more transmission infrastructure is built to accommodate the same amount of power. Often, high-quality intermittent resources are distant from areas of high electric power demand. Therefore, they require investment in additional



transmission infrastructure to accommodate new intermittent power sources into the grid, raising costs.

The models that forecast interconnected resources are based on the assumption of the further development of transmission infrastructure to accommodate storage or baseload wind. In another model example, Mason and Archer 2012 considered two situations where wind can be used as a baseload resource. They write:

In the Wind-NGCC model, only wind electricity is transported long-distance via HVDC since the NGCC plant is located within the terminal local electricity

transmission network. This means that the variable supply of wind power results in less than maximum capacity utilization of the long-distance HVDC electricity transmission lines. This increases transmission cost.

**D**espite the increase in transmission costs, their model did find a few scenarios where operating wind power in a baseload mode would be economical but, in general, it depended heavily on future natural gas prices.<sup>22</sup>

The second example, which considers intermittent power coupled with energy storage, is technologically feasible in the right circumstances, but generating baseload power from coupled storage and intermittent sources comes with higher costs. These cost increases arise from both upsizing the renewable power needed and adding the costs of storage.

Most large-scale energy storage technologies are still untested, with the exception of pumped storage (hydro power), compressed air storage, and a few battery technologies. There is only about 200 MW of compressed air and battery storage technology operating in the U.S.<sup>23</sup> The remaining 22 GW of storage capacity is hydroelectric pumped storage, which has generated electricity in the U.S. for several decades and is a proven technology. While pumped storage technologies are commercial, they come with disadvantages such as limited

suitable sites, low energy density, and dependency upon water availability.<sup>24</sup> Meanwhile, battery technologies made with heavy metals can pose an environmental hazard from their waste. As noted by the Environmental Protection Agency (EPA), batteries contain heavy metals such as mercury, lead, cadmium, and nickel. These materials can contaminate the environment if not discarded or maintained properly.<sup>25</sup>

In 2010, California's legislature passed Assembly Bill (AB) 2514 which was designed to encourage California's public utilities to incorporate energy storage into the electricity grid to help reduce dependence on fossil fuel generation to meet peak loads. Regulatory filings from the public utilities show only three set specific targets after finding energy storage was cost-effective or appropriate for their balancing authority. In total, most of the 30-plus public utilities which commented on the adoption of AB 2514 found setting storage targets as "not appropriate" or "not cost-effective at this time." Only three commissions set targets totaling roughly 30 MW of storage by 2016 and roughly 160 MW by 2021. They are Glendale Water and Power, Los Angeles Department of Water and Power, and Redding Electric Utility.<sup>26</sup> The only utilities that seem capable of affording the storage technology are investor-owned utilities, which have begun the procurement of storage technologies. It is worth noting

the appearance that, under the framework established for procurement of storage technology in California, a "cost-effectiveness" criterion is used – that seems to include a range of values – instead of the "least cost-best fit" standard applied to other technologies (although some argue whether "best-fit" is really included).<sup>27,28</sup>



Another study from 2008 used a nonlinear mathematical optimization program for investigating the economic and environmental implications of wind penetration. The study found that electrical grids which were more dependent on intermediate hydro power handled the integration of intermittent wind and that the cost effectiveness of intermittent sources is related to the share of hydro power in the grid which acted as to balance out the intermittency of wind power.<sup>29</sup>

Lastly, an unseen cost is the excess capacity necessary to generate the same amount of load.

A study by Budischak et al.<sup>30</sup> modeled inland wind, offshore wind, and photovoltaics coupled with electrochemical storage. This study found that to cover 90 percent of load from wind, solar, and battery storage 180 percent of the electrical energy capacity is needed. To cover 99.9 percent of the load requires almost 290 percent of the electrical energy capacity. This result was the most cost-effective scenario for the regional transmission organization PJM.

Lost in the baseload discussion is the issue of environmental emissions. As is becoming common practices in places like California, and fueled by low natural gas prices, gas turbines are rapidly being commissioned to balance out intermittent generation. However, building straight baseload renewable plants, such as geothermal, biomass, or hydro power, in many circumstances produces fewer net emissions than coupling intermittent sources with gas turbines or energy storage. The data presented in Figure 2 is amalgamated from California Air Resources Board, EIA, EPA, Intergovernmental Panel on Climate Change, and estimates of carbon emissions from coupling storage and intermittent sources published in academic sources.

An example of rising emissions resulting from coupling storage and intermittent sources is provided by Budischak et al.<sup>31</sup> For a scenario where solar, wind and

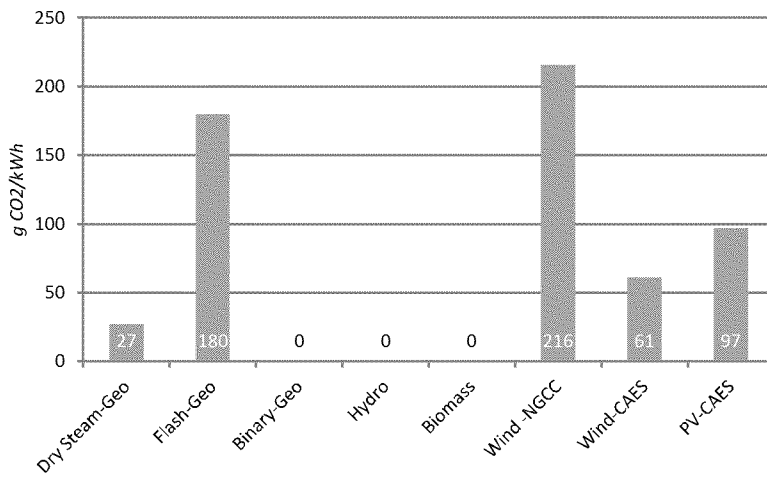


Figure 2: Estimated Direct Emission from Renewable Baseload Technologies vs. Wind/PV Coupled with Storage or Natural Gas.

Note: NGCC Stands for Natural Gas Combined Cycle and CAES Stands for Compressed Air Energy Storage. Direct Emissions from Biomass Combustion at the Power Plant are Positive and Significant, But Should be Seen in Connection with the CO<sub>2</sub> Absorbed by Growing Plants and Therefore Zero for the Purposes of this Chart (Schlömer, S., et al., 2014. Annex III: Technology-specific Cost and Performance Parameters. Intergovernmental Panel on Climate Change (IPCC), Cambridge/New York. [http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc\\_wg3\\_ar5\\_annex-iii.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-iii.pdf) (accessed 22.01.15)). Binary Geothermal Plants have No Carbon Emissions Because They are a Closed Loop System Since no Gasses are Released in the Atmosphere During Power Generation (Matek, B., Schmidt, B., 2013. The Values of Geothermal Energy: A Discussion of the Benefits Geothermal Power Provides to the Future U.S. Power System. Geothermal Energy Association, Washington, DC. <http://geo-energy.org/reports/Values%20of%20Geothermal%20Energy%20Draft%20Final.pdf> (accessed 22.01.15).)

Source: Schlömer, S., et al., 2014. Annex III: Technology-specific Cost and Performance Parameters. Intergovernmental Panel on Climate Change (IPCC), Cambridge/New York. [http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc\\_wg3\\_ar5\\_annex-iii.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-iii.pdf) (accessed 22.01.15), California Air Resources Board. "Data Reported by Facilities, Suppliers, and Electric Power Entities." Mandatory GHG Reporting – Reported Emissions 2012. 2012. <http://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm> (accessed 14.01.15). Mason, J.E., Archer, C.L., 2012. Baseload electricity from wind via compressed air energy storage (CAES). *Renew. Sustain. Energy Rev.*, 1099–1109. <http://www.sciencedirect.com/science/article/pii/S1364032111005454> (accessed 22.01.15). Mason, J., Fthenakis, V., Zweibel, K., Hansen, T., Nikolakakis, T., 2008. Coupling PV and CAES power plants to transform intermittent PV electricity into a dispatchable electricity source. *Prog. Photovolt. Res. Appl.*, 649–668. <http://onlinelibrary.wiley.com/doi/10.1002/pip.858/abstract> (accessed 22.01.15). Union of Concerned Scientist. "Environmental Impacts of Biomass for Electricity." Union of Concerned Scientist. 2015. [http://www.ucsusa.org/clean\\_energy/our-energy-choices/renewable-energy/environmental-impacts-biomass-for-electricity.html#.VLbUMiLF9kZ](http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/environmental-impacts-biomass-for-electricity.html#.VLbUMiLF9kZ) (accessed 14.01.15).

storage cover 30 percent of PJM's load, equal amounts of fossil fuels are need to compensate for the introductions of these intermittent power sources.<sup>32</sup>

Additionally, the increased presence of distributed

generation (DG) technologies on the electricity grid will likely exacerbate the intermittency of electricity grid load. For example, EIA expects distributed generation from solar alone to grow to 25 GW by 2040.<sup>33</sup> While

DG is important for combating climate change, future balancing authorities will require new transmission management strategies to manage the increased presence of these intermittent technologies. Increasing penetration of DG systems is likely to increase the operational changes and procurement of greater quantities of demand response services. Without changes in policy, these DG technologies could shift higher costs to non-DG customers who must pay for the ancillary and transmission services of the customers with DG technologies.<sup>34</sup>

Demand response or transmission management strategies may be one of the more cost-effective approaches to tackling intermittency but they have both practical and sociological limitations. In short, demand response services or transmission management consists of a broad range of planning, implementing, and monitoring of activities designed to encourage end users to modify their levels and patterns of electricity consumption or generation in the case of DG. A key difference between demand response and energy efficiency is that the energy reductions for demand response are time-dependent, whereas reductions for energy efficiency are not. In general there are still some policy barriers that prevent the more practical demand response and transmission

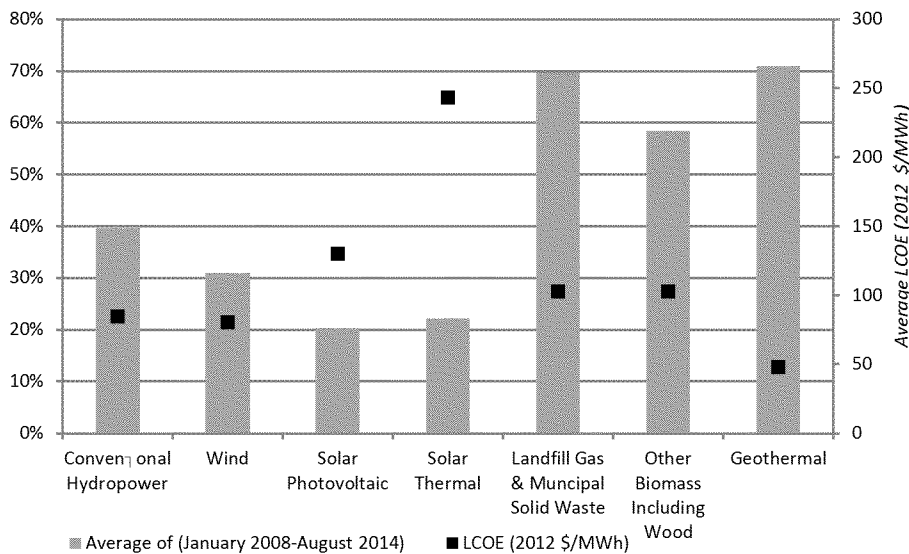


Figure 3: Average Electric Generator Usage for Select Technologies (January 2008–August 2014) versus Average LCOE.

Note: EIA Does Separate Biomass LCOE by Type of Technology in their LCOE Publication so Landfill Gas and Biomass is the Same LCOE. Also These Figures are Estimated Levelized Cost of Electricity (LCOE) for New Generation Resources Commissioning in 2019 Source: Mayes, F., 2014, September 4. Geothermal resources used to produce renewable electricity in western states. Energy Information Administration: Today in Energy. <http://www.eia.gov/todayinenergy/detail>.

management services from being adopted.<sup>35</sup> In addition to recent court decisions that could make certain demand response programs legally more difficult to implement.<sup>36</sup>

#### 4. Using Baseload Renewables Compared to Intermittent Technologies

Figure 3 lists renewable energy technologies by their usage and cost. As this data from EIA shows, geothermal power, landfill gas, and other biomass are often used as baseload power, while conventional hydro power can be used as intermediate power or baseload power, depending on the

resource. Additionally, according to EIA’s data which is national average of levelized cost information, renewable baseload sources are usually cheaper or equivalent in price to intermittent power sources.

Furthermore, a power system that prioritizes least cost per kilowatt-hour without regard to its availability as firm or variable resources undercuts power supplied by more appropriate resources, such as baseload renewable power sources that could displace fossil fuels without higher costs. Procurement of these technologies becomes even more complicated when power systems retain some of the features of past traditional procurement methodologies,

such as peak power pricing. Yet these systems do not adjust pricing to compensate for the gaps created by variable resources – and, correspondingly, penalize power suppliers that offer baseload power.

Figure 4 is an amalgamation of cost estimates for the future use of baseload electricity from intermittent technologies compared with weighted average time-of-delivery (TOD) adjusted contract price paid by utilities in California. The estimates were found by an extensive literature review conducted by the authors. It is important to note, that the estimated prices are from different scenarios as a result of their respected studies and are not meant to prove one technology is more economical or lower cost than another. Ignoring policy constraints and each power system’s unique energy needs, one technology may be more economical in different regions than another. The geothermal, biomass, biogas, and small hydro power numbers are the low and high prices paid by California’s public utilities for renewable baseload electricity. Figure 4 demonstrates the cost advantages of baseload technologies that are already commonly operated, such as biomass, geothermal, or hydro power, and in some cases are extremely economical and available with today’s technology and resources.

Renewable baseload technologies come with their own

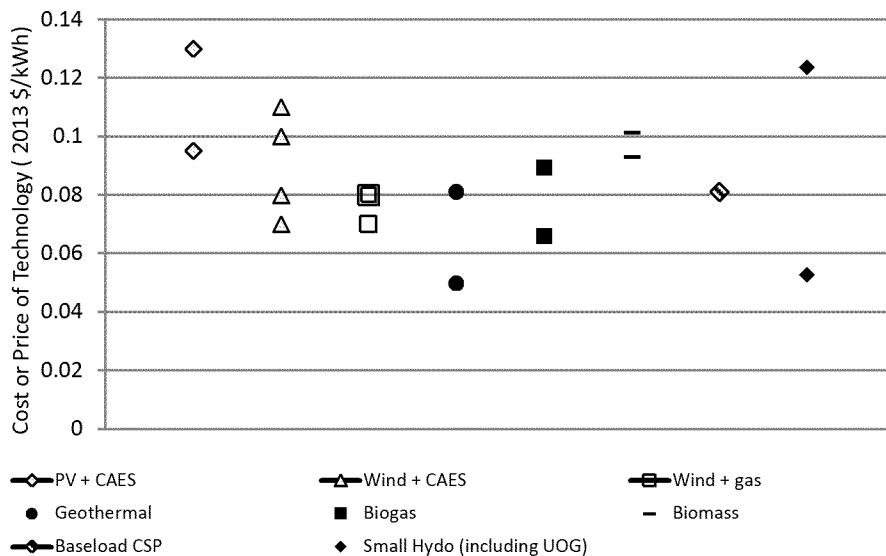


Figure 4: Hypothetical Cost versus Weighted Average TOD Adjusted Contract Price in California of Baseload Renewable Technologies.

Note: The Geothermal, Biomass, Biogas, and Small Hydro Power are the Weighted Average Time-of-Delivery (TOD) Adjusted Contract Price Paid by Utilities Reported by the California Public Utilities Commission in 2013. The Low and High Figures Represent the Range Which Utilities Reported Prices to the CPUC. The Intermittent Power Sources are Costs Estimated by their Respected Authors and Adjusted into 2013 U.S. Dollars using Bureau of Labor Statistics' Inflation Calculator (Bureau of Labor Statistics. CPI Inflation Calculator. 2015. [http://www.bls.gov/data/inflation\\_calculator.htm](http://www.bls.gov/data/inflation_calculator.htm) (accessed 15.01.15)) CSP Abbreviates Concentrated Solar Power, CAES Stands for Compressed Air Storage, PV is an Abbreviation for Photovoltaic, and UOG stands for "Utility-owned generation."

Source: Mason, J., Fthenakis, V., Zweibel, K., Hansen, T., Nikolakakis, T., 2008. Coupling PV and CAES power plants to transform intermittent PV electricity into a dispatchable electricity source. *Prog. Photovolt. Res. Appl.*, 649–668. <http://dx.doi.org/10.1002/pip.858/abstract> (accessed 22.01.15). Greenblatt, J.B., Succarb, S., Denkenberger, D.C., Williams, R.H., Socolow, R., 2007. Baseload wind energy: modeling the competition between gas turbines and compressed air energy storage for supplemental generation. *Energy Policy*, 1474–1492. <http://www.sciencedirect.com/science/article/pii/S0301421506001509> (accessed 22.01.15). Mason, J.E., Archer, C.L., 2012. Baseload electricity from wind via compressed air energy storage (CAES). *Renew. Sustain. Energy Rev.*, 1099–1109. <http://www.sciencedirect.com/science/article/pii/S1364032111005454> (accessed 22.01.15). Denholm, P., 2006. *Renew. Energy*, 1355–1370. <http://www.nrel.gov/docs/fy06osti/38270.pdf> (accessed 23.01.15). Williams, R.H., Succar, S., 2008. *Compressed Air Energy Storage: Theory, Resources, and Applications for Wind Power*. Princeton Environmental Institute. [https://www.princeton.edu/pei/energy/publications/texts/SuccarWilliams\\_PEI\\_CAES\\_2008April8.pdf](https://www.princeton.edu/pei/energy/publications/texts/SuccarWilliams_PEI_CAES_2008April8.pdf) (accessed 23.01.15). Fthenakis, V., Mason, J.E., Zweibe, K., 2008. The technical, geographical, and economic feasibility for solar energy to supply the energy needs of the US. *Energy Policy*, 387–399. <http://www.sciencedirect.com/science/article/pii/S0301421508004072> (accessed 22.01.15). California Public Utilities Commission. *The Padilla Report to the Legislature: Reporting 2013 Renewable Procurement Costs in Compliance with Senate Bill 836* (Padilla, 2011). Sacramento: California Public Utilities Commission, 2014. <http://www.cpuc.ca.gov/NR/rdonlyres/775640F8-38D7-4895-9252-7E17261776FE/0/PadillaReport2014FINAL.pdf> (accessed 22.01.15).

drawbacks, like high upfront costs, a need to secure biomass fuel sources, or limited locations available for geothermal or hydro

power. But when they are available, these sources of electricity can be economical options to balance out

intermittent portfolios at reasonable rates. In doing so, balancing authorities can embrace industry best practice of a diverse mix of resources as the best option for a renewable generation portfolio.

## V. Conclusion: A New Examination of Baseload Renewables Is in Order

Before policymakers decide the nature of future electricity grids, some basic questions about the diversity of an electricity grid should be addressed and a re-examination of the role of baseload technologies appears in order. Instead of assuming one technology is preferred, a range of renewable supply options should be considered. One approach might promote intermittent or variable power sources as a substitute for baseload power using demand-side management, electricity storage, and enhanced coordination or forecasting of power plants. However, there is another option to further develop renewable baseload sources like geothermal, biomass, or hydro power and seek a more diverse supply. There are, of course, points in between as well.

In choosing a path to a new generation mix, the values, performance characteristics and availability of baseload renewable resources should be examined. The value of diversity

should be recognized and integrated into future planning, and the total cost and performance of different mixes of technologies should be examined for each power system or balancing authority, particularly as these systems call upon larger amounts of renewable generation to meet system power needs.

**T**his article seeks to raise a basic questions directed toward the value of a diverse electricity grid while not pointing to a specific solution, in part due to the limitations on available literature and inherent differences in regional power systems and resource availability. Instead, this article raises basic questions about the intermittency-versus-baseload discussion, and points to the values of renewable baseload power, assuming that in the end there will not be a single solution that best fits all of the nation's power needs. &

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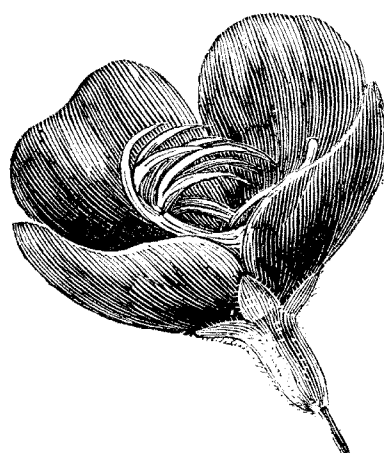
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