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Teaching the “Duck” to Fly

Second Edition

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Acronyms

GIWH	Grid-integrated water heating	MW	Megawatt
ISO	Independent system operator	PV	Photovoltaic
ISO-NE	New England Independent System Operator	TOU	Time-of-use
kWh	Kilowatt-hour	UPS	Uninterruptible power supplies

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Foreword to the Second Edition

The First Edition of *Teaching the “Duck” to Fly*, released by The Regulatory Assistance Project (RAP) in January 2014, posed an integrated approach to the way utilities and regulators examine the challenge of adapting to a power system with significant variable renewable resources. Prior to that time, the focus of most analysts was simply on the strained flexibility of the remaining fossil generation fleet, and the need to add flexible generation and electricity storage resources, both of which have high costs. *Teaching the “Duck” to Fly* changed this, by focusing at least equal attention on the flexibility that customer loads, low-cost thermal storage, time-varying pricing, and other simple strategies could provide in adapting to a two-way system, relying equally on supply-side and customer load management.

The First Edition was presented at meetings of US regulators, at the Florence (Italy) School of Regulation, and to utilities and their regulators in China, India, the Middle East, Africa, and Australia. It was the subject of a series of webinars, attracting a global audience. Feedback from these varied audiences was considerable, and the author, RAP as an organization, and indeed the entire industry have learned more in the intervening two years. Here are a few lessons we take away from this experience.

Some of the concepts in the First Edition proved to be of limited value. For example, concentrated solar power has not been well received in the market, mostly because of the dramatic drop in the cost of solar photovoltaic (PV) generation. West-facing solar is important where it is achievable, but the benefits are modest. In this Second Edition, these are consolidated into a strategy for “peak-oriented renewables,” that include wind sites with favorable production characteristics and more disciplined use of existing hydroelectric resources.

However, the First Edition also dramatically understated the potential of **water heating** and **air conditioning** storage technologies. These technologies have evolved quickly in recent years, and the economics are becoming

more favorable. Dozens of pilot programs for grid-integrated water heating have proven this concept and will soon be deployed in many regions. The number of ice storage and chilled-water storage air conditioning systems has grown, but still reaches less than two percent of the potential market. The Second Edition makes greater use of these highly reliable, low-cost resources to further smooth the utility load profile.

A new strategy has been introduced in the Second Edition: control of **water and wastewater pumping**. These uses consume about seven percent of total US electricity. Water is very easy to store in tanks, reservoirs, and aquifers. In many cases, all that is needed to stimulate management of these loads is a restructuring of the electricity pricing to remove demand charges and substitute time-varying energy charges. The potential can be even greater if water and wastewater utility planning is conducted interactively within electricity least-cost planning, so that, for example, increased water storage capacity can become a substitute for increased electricity generation capacity.

As in the original edition, the Second Edition starts with the load shape of an illustrative California utility, before and after addition of significant solar and wind resources. It then incrementally includes each of the strategies to produce a gradual change in the load shape. The “bottom line” of this Second Edition is a package of measures that, conservatively estimated but aggressively deployed, can dramatically reshape the electricity load that must be served by dispatchable resources. The “ending load factor” after the ten strategies is an impressive 86.5 percent, far higher than what exists today. Simply stated, it should be easy to adapt to the “Duck Curve” that emerges as variable renewables are installed on utility grids around the world.

Finally, the author wants to thank a few of the many people and organizations who helped examine, critique, and test the concepts proposed in the First Edition. These people have enhanced those ideas, tested them on real utilities and real utility customers, and helped make the

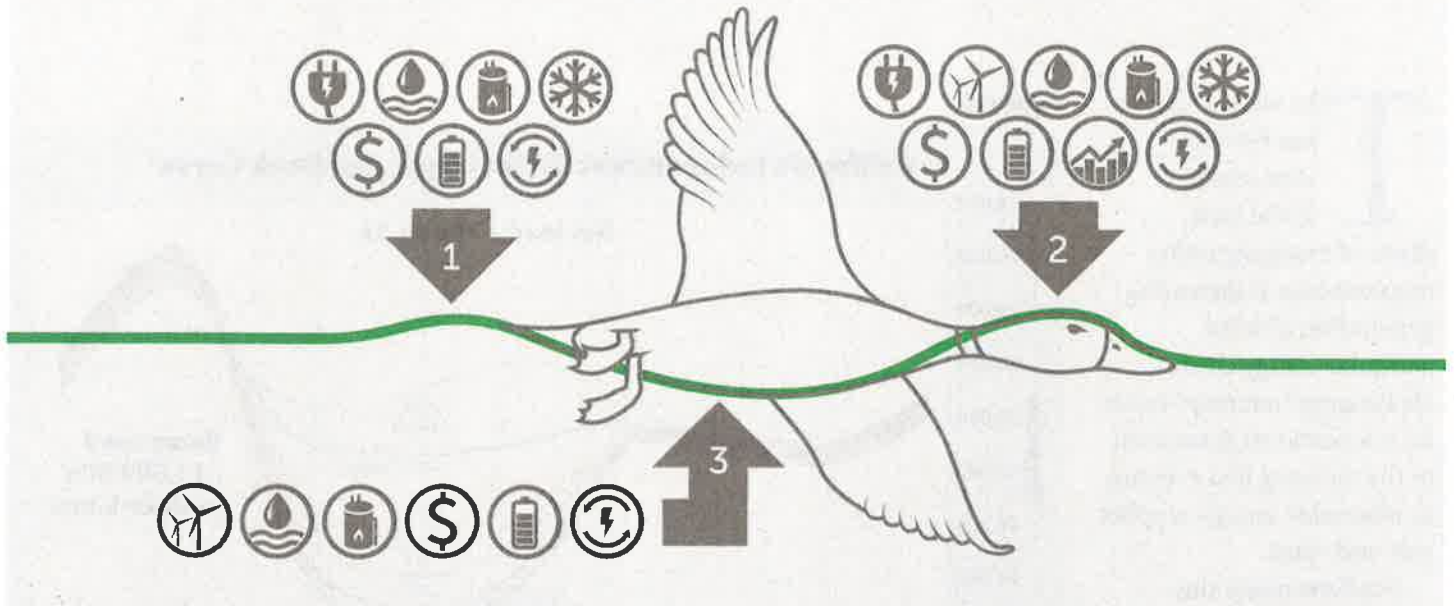
Second Edition a much better product. These include:

- Burbank Water and Power, and its General Manager Ron Davis, for quickly putting some of the concepts from the First Edition to a reality test in California as that utility expands from less than five percent renewables in 2010 to 50 percent renewables by 2030, including the strategies relating to water pumping, west-facing solar, air conditioning storage, rate design reform, inter-region power trading, and time-varying pricing for electric vehicle charging loads;
- The Hawaii Public Utilities Commission, Hawaiian Electric Company, Kauai Island Utility Cooperative, and Hawaii Energy, for embracing the concepts of *Teaching the “Duck” to Fly* and quickly expanding the state of the science in a very dynamic and challenging electricity market;
- Steffes Corporation, Great River Energy, and the Peak Load Management Association, for advancing the state of the science for water heater controls, one of the two most important emerging strategies in this paper;
- Calmac Corporation and Ice Energy, for assistance understanding the technology and economics of air conditioning storage, the other of the two most important emerging strategies;
- The Northwest Power and Conservation Council, for a 30-year disciplined approach to evaluating energy efficiency options, including the peak load value of different energy efficiency measures that makes Strategy 1 a well-recognized option; and
- Finally, my many RAP colleagues who contributed to the original concept, and have helped expand my own knowledge to make this Second Edition possible. Stimulated by our founder, David Moskowitz, to continually challenge skepticism and to hatch and promote “Big Ideas” that can change the world, RAP is an incredible group of smart, creative people. It is a joy to work with them. Visit *About RAP* on the RAP website to meet all of these amazing people.

Jim Lazar
Olympia, Washington
January 2016

Teaching the "Duck" to Fly:

10 strategies to control generation, manage demand, & flatten the Duck Curve



Targeted Efficiency

Focus energy efficiency measures to provide savings in key hours of system stress. ↓↓



Peak-Oriented Renewables

Add renewables with favorable hourly production. Modify the dispatch protocol for existing hydro with multi-hour "pondage." ↓↑



Manage Water Pumping

Run pumps during periods of low load or high solar output, curtailing during ramping hours. ↓↓↑



Control Electric Water Heaters

Increase usage during night & mid-day hours, & decrease during peak demand periods. ↓↓↑



Ice Storage for Commercial AC

Convert commercial AC to ice or chilled-water storage operated during non-ramping hours. ↓↓



Rate Design

Focus pricing on crucial hours. Replace flat rates & demand charge rate forms with time-of-use rates. Avoid high fixed charges. ↓↓↑



Targeted Electric Storage

Deploy storage to reduce need for transmission & distribution, & to enable intermittent renewables. ↓↓↑



Demand Response

Deploy demand response programs that shave load during critical hours on severe stress days. ↓



Inter-Regional Power Exchange

Import power from & export power to other regions with different peaking periods. ↓↓↑



Retire Inflexible Generating Plants

Replace older fossil & nuclear plants with a mix of renewables, flexible resources, & storage.

Introduction: Teaching the “Duck” to Fly

The electric sector has become very sensitive to the load shape of emerging utility requirements as increasing penetration of wind and solar energy creates challenging “ramping” issues for conventional generation in the morning and evening, as renewable energy supplies wax and wane.

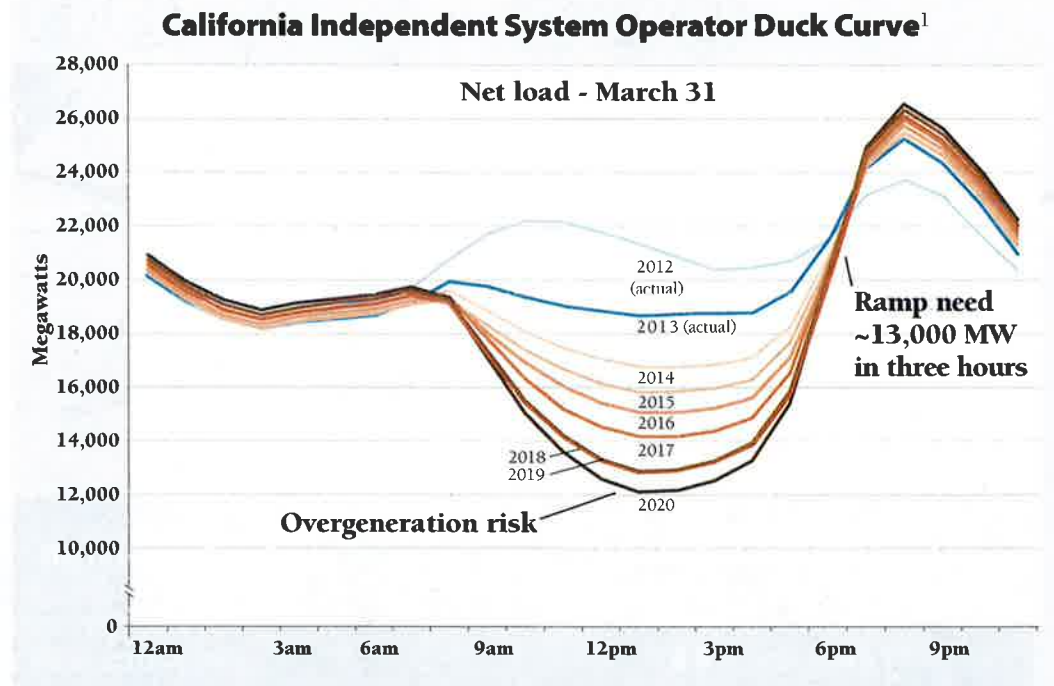
Fundamentally, this issue is no different from the problem utilities have addressed for over a century: adapting the supply of energy to match changing consumer demand. The difference is that daily

and seasonal usage patterns and the resources that have historically served that pattern have evolved gradually over the last 125 years, whereas the renewable energy revolution is creating new challenges in a much shorter period of time.

Addressing this problem will require a change in the way utility power supply portfolios are formulated, but solutions are at hand. Fortunately, we have technologies available to us that our great-grandparents did not.

Previously, the utility’s role was to procure a least-cost mix of baseload, intermediate, and peaking power plants to serve a predictable load shape. Today, utilities have to balance a combination of variable generation power sources, both central and distributed, together with dispatchable power sources, to meet a load that will be subject to influence and control through a combination of policies, pricing options, and programmatic offerings. This now includes the capability to dispatch customer loads, including water heating, air conditioning, and water pumping, strategies at the heart of this paper.

Figure 1

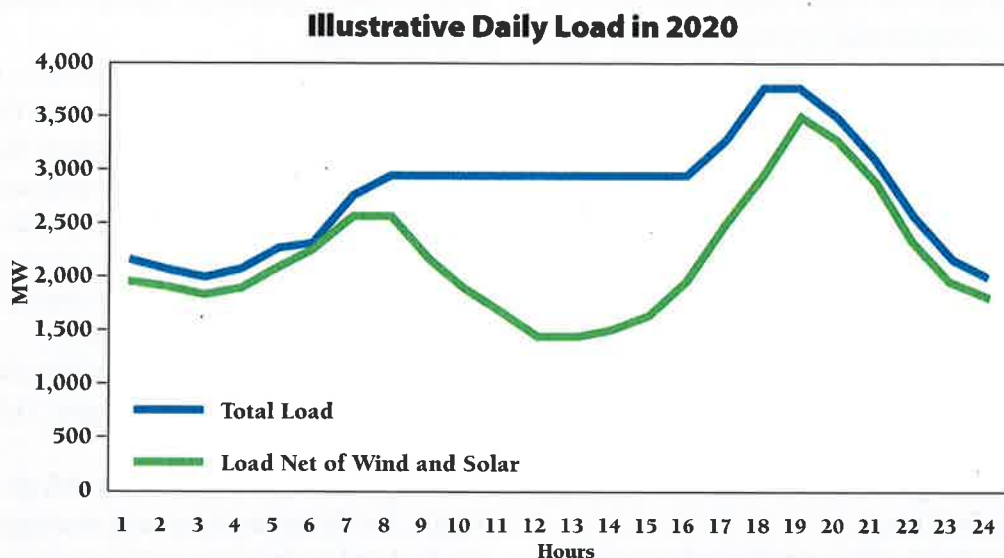


What is now being referred to as “the Duck Curve” (Figure 1) is a depiction of this emerging change that has become commonly recognized throughout the electric sector. Over time, as more solar and wind energy are added to the grid, the “net load” to be serviced from dispatchable resources (the duck’s belly) sags in the middle of the solar day when solar generation is highest, but the load to be served in the early evening after the sun goes down continues to grow (the head) and the transition between the two gets more severe (the neck).

This paper attempts to model the options for a hypothetical, illustrative electric utility facing its own duck curve. Our illustrative utility is expected to add 600 megawatts (MW) of distributed solar, 1,250 MW of utility-scale solar, and 725 MW of wind capacity in response to a state

¹ California ISO. (2013). What the duck curve tells us about managing a green grid.

Figure 2



renewable portfolio standard by the year 2020. Figure 2 illustrates an hourly demand and net demand (net of solar and wind) analysis for this utility on a sample day, before any of the options are considered.²

The total load line in Figure 2 shows the utility’s projected total load, by hour, during the day. The “load net of wind and solar” line shows the load that the utility will face after expected wind and solar generation serve a portion of the total load. Figure 2 shows that the overall load has a moderate diurnal shape, but when the wind and solar energy expected by 2020 are added to the mix,

the ramping down of conventional supply in the morning (as solar generation increases) and rapid ramping up in the afternoon hours (as loads increase but solar energy supplies drop off quickly) is even more sharp, creating operational concerns for the utility. This “net load” to be served by conventional dispatchable generating resources must be met with the existing or emerging generation fleet. This challenge is causing some utilities to assert that the proportion of energy needs met by variable generation resources needs to be limited. Although some utilities may argue that variable renewable energy can be relied on

Figure 3

Duck Sitting in Water



Figure 4

Duck in Flight



² It should be noted that this illustrative day is a light load: a heavy renewable energy generation day such as one that might be experienced in the spring or fall. It is not intended

to represent a “normal” or “summer peak” day. It is selected to illustrate the opportunities available to meet a particularly challenging situation.

only for a small portion of daily energy requirements, this paper discusses strategies that enable high levels of energy needs to be served, provided that pricing and technology to increase the flexibility of loads are employed.

This paper identifies a number of low-carbon strategies that can be applied to meet this challenge. These strategies are generally limited to existing commercially available technologies, but perhaps deployed in ways that have not been done on a commercial scale to date. These strategies not only enable greater renewable integration, they enhance system reliability and reduce generation and transmission capital and fuel costs by modifying the load profiles and better utilizing existing transmission assets. Not every strategy will be applicable to every region or utility around the country, and every region will have additional strategies that are not among these ten.

Specific implementation plans, which are beyond the

scope of this paper, will need to be tailored to address local resource capabilities, system constraints, and other considerations.

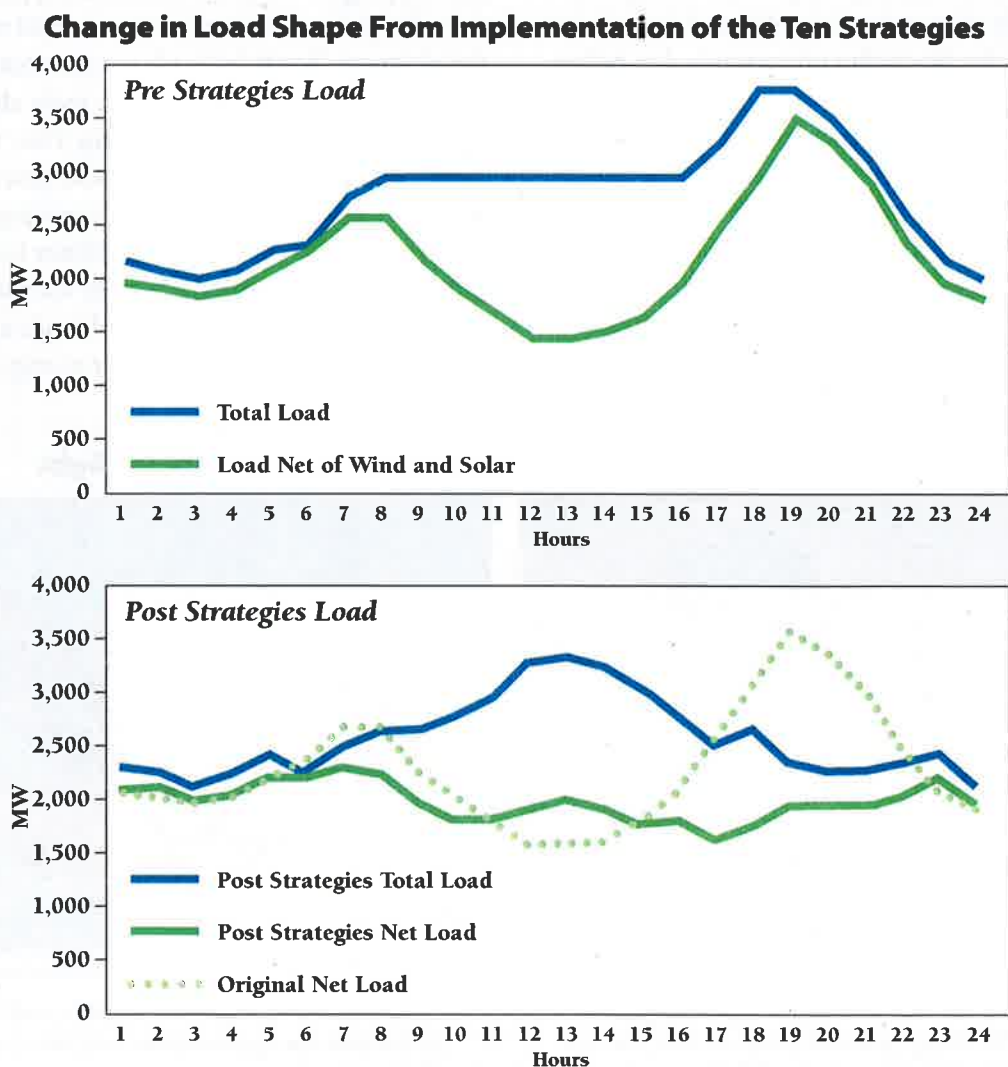
Depictions of future load like those in Figure 1 have entered the industry vernacular as “the Duck Curve” for obvious reasons. In actuality, however, ducks vary their shape depending on different circumstances, and as explained here, utility load shapes can do the same.

A duck in water tends to center its weight in the water, floating easily. Figure 3 shows the duck shape commonly associated with the graph in Figure 1.

A duck in flight, however, stretches out its profile to create lower wind resistance in flight. This is illustrated in Figure 4.

Metaphorically, our goal is to teach the “duck” in Figure 2 to fly, by implementing strategies to both flatten the load and to introduce supply resources that can deliver

Figure 5



more output during the late afternoon high load hours. Many of these strategies are already used on a modest scale in the United States and European Union, whereas others use technologies that have been proven in pilot programs but are not yet deployed on a commercial scale. None require new technology and each has a small (or negative) carbon footprint.

Figure 5 shows the change in shape of the Duck Curve from the cumulative application of the ten strategies we propose below. Like an actual duck, it becomes more streamlined and better able to “take flight.”

We include the following ten strategies in our analysis:

- Strategy 1.** Target energy efficiency to the hours when load ramps up sharply;
- Strategy 2.** Acquire and deploy peak-oriented renewable resources (Strategies 2 and 3 in the original paper);
- Strategy 3.** Manage water and wastewater pumping loads (new in the Second Edition);

Strategy 4. Control electric water heaters to reduce peak demand and increase load at strategic hours;

Strategy 5. Convert commercial air conditioning to ice storage or chilled-water storage (greatly increased in magnitude in the Second Edition);

Strategy 6. Rate design: focus utility prices on the “ramping hours” to enable price-induced changes in load;

Strategy 7. Deploy electrical energy storage in targeted locations;

Strategy 8. Implement aggressive demand-response programs;

Strategy 9. Use inter-regional power exchanges to take advantage of diversity in loads and resources;³ and

Strategy 10. Retire inflexible generating plants with high off-peak must-run requirements.

3 For a complete set of regional strategies consistent with this step, see: Schwartz, L., Porter, K., Mudd, C., Fink, S., Rogers, J., Hogan, M., Lamont, D., & Kirby, B. (2012).

Meeting Renewable Energy Targets in the West at Least Cost: The Integration Challenge. Western Governors' Association.

