Teaching the Duck to Fly
Adapting Loads to Resources, and Resource to Loads

RAP Webinar
March 3, 2016

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Housekeeping

Please send questions through the Questions pane.
Our Experts

Jim Lazar

Carl Linvill
What’s a “Duck Curve?”

California Independent System Operator Duck Curve

Net load - March 31

Ramp need ~13,000 MW in three hours

Overgeneration risk

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Why is this an issue?

Solar helps meet daytime load.
Loads still rise in the early evening.
Compounded by wind coming and going.
How Do Utilities Manage This Now?
Guess What: Ducks Can Fly

A duck in water has very much the shape of the CAISO graphic. The “fat body” floats, and the tall neck breathes.

A duck in flight stretches out its body and straightens its neck in order to reduce wind resistance.
Our job is to straighten this duck out.
Ten Strategies To Align Loads to Resources (and Resources to Loads) with **Illustrative Values for Each**

1. Targeted energy efficiency
2. Peak-oriented renewables
3. Manage water pumping
4. Grid-integrated water heating
5. Storage air-conditioning
6. Rate design
7. Electricity storage in key locations
8. Demand response
9. Inter-regional exchanges
10. Retire inflexible older generating units

Not every strategy will be applicable to every utility.
The Objective:

An End-State Flatter than the Pre-Solar Load
Strategy 1: Targeted Energy Efficiency
Load Lower at All Hours –
But savings are concentrated in peak periods
Strategy 2: Peak-Oriented Renewables

- Late-afternoon wind
- Hydro re-dispatch
- Solar/thermal
- West-facing solar

Source: Gallegos Wind Farm, LLC
Slightly Lower Net-Load at Peak
Strategy 3: Manage Water Loads

7% of national electricity usage.

Water and wastewater systems have storage.

It may be cost-effective to augment the tanks and reservoirs.
Load After Strategy 3

Duck Curve After Strategies 1 Through 3

MW

Post Strategy Total Load

Pre Strategy Total Load

Post Strategy Net Load

Pre Strategy Net Load

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Strategy 4: Water Heating

14% of residential usage.

Every water heater is a thermal battery.

Heat the water when power is cheap; use the hot water as needed.

Above, Sequentric’s patented variable-capacity grid-interactive water heater.
45 Million Electric Water Heaters

Census Housing Survey Table 2.5 (2010)
Hawaii GIWH Pilot: Solar Charging; Ancillary Services
Yes, this works with Heat Pump Water Heaters

Grid Demand of 1,000 Homes

Thermal Storage into GeoSpring using selective use of heat pump and/or resistance heating

Demand Modification using 100 GeoSpring Units Sprinkled Among the 1,000 Homes

Peak Reduction thru Release of Thermal Storage and Application of Heat Pump Efficiencies

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Rule #1: No Cold Showers
No, You Don’t Run Out of Hot Water
New Report from Brattle / NRECA / NRDC / PLMA
Total Theoretical National Potential

Average Use / Water Heater: 4,522 kWh/year

= output of ~2.2 kW wind or solar

X

45 million water heaters

= ~100,000 MW of wind and solar on the system

Current: 75,000 MW
Load After Strategy 4

Duck Curve After Strategies 1 Through 4

- Post Strategy Total Load
- Pre Strategy Total Load
- Post Strategy Net Load
- Pre Strategy Net Load

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Questions?

Please send questions through the Questions pane
Strategy 5: Air Conditioning Storage
A/C is ~30% of Peak Demand

• Commercial load doubles;
• Residential load up 4X.
• Option:
  – Appliance standards
  – Service standards
  – Retrofit incentives
We Can Store “Cool” as Ice (in fact, most of us already do)
Small Buildings: Unitary Storage Air Conditioning
Large Buildings:
Separate Ice Storage

Calmac

Photo: © Gunther Intelmann for Cook+Fox Architects
Austin Energy: District Cooling System

Source: Austin Energy
Strategies 4 & 5: Very Inexpensive Compared With CAES, Batteries

Cost per Unit of Performance for Various System Flexibility Options

- H.P. capacitors
- H.P. flywheels
- L.D. flywheels
- Ni-Cd
- Li-ion
- Na-S
- Zinc-air
- Lead-acid
- Flow
- PSH
- L.D. capacitors
- Metal-air
- CAES
- Chilled Water/Ice Thermal
- H₂O heaters

Capital cost per unit energy - $/kWh
Capital cost per unit power - $/kW

Distributed demand-side
Battery
Grid-scale
Flywheel/capacitor
Load After Strategy 5

Duck Curve After Strategies 1 Through 5

- Post Strategy Total Load
- Pre Strategy Total Load
- Post Strategy Net Load
- Pre Strategy Net Load
## Strategy 6: Rate Design (Residential)

<table>
<thead>
<tr>
<th>Customer-Specific Charges</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Charge</td>
<td>$/month</td>
<td>$3.00</td>
</tr>
<tr>
<td>Transformer</td>
<td>$/kVA/month</td>
<td>$1.00</td>
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</table>

<table>
<thead>
<tr>
<th>Bi-Directional Energy Charges</th>
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</thead>
<tbody>
<tr>
<td>Off-Peak</td>
<td>$/kWh</td>
<td>$0.08</td>
</tr>
<tr>
<td>Mid-Peak</td>
<td>$/kWh</td>
<td>$0.12</td>
</tr>
<tr>
<td>On-Peak</td>
<td>$/kWh</td>
<td>$0.18</td>
</tr>
<tr>
<td>Critical Peak</td>
<td>$/kWh</td>
<td>$0.75</td>
</tr>
</tbody>
</table>
TOU and Critical Peak Pricing Works
SMUD: Customers Actually Do Things

Behavioral Actions Taken to Reduce Load Between 4 and 7pm

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# Strategy 6: Rate Design (Commercial)

<table>
<thead>
<tr>
<th></th>
<th>Conventional Rate Design</th>
<th>Smart Rate Design Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customer Charge</strong></td>
<td>$10/month</td>
<td>$10/month</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>$10/kW</td>
<td>$2/kW</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td><strong>All Hours</strong></td>
<td>$0.10/kW</td>
<td>7-10 AM $0.15/kW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-9 PM $0.20/kW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All Other Hours $0.10/kW</td>
</tr>
</tbody>
</table>
Load After Strategy 6

Duck Curve After Strategies 1 Through 6

- Post Strategy Total Load
- Post Strategy Net Load
- Pre Strategy Total Load
- Pre Strategy Net Load

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Strategy 7: Electricity Storage

Batteries Need to Do “Double-Duty” or “Triple-Duty” to be cost-effective.
Batteries Need to Do Double Duty

Kauai Island Utility Coop: Spinning Reserve

Batteries Need to Do Double Duty

Kauai Island Utility Coop: Solar Integration

Load After Strategy 7

Duck Curve After Strategies 1 Through 7

- Post Strategy Total Load
- Post Strategy Net Load
- Pre Strategy Total Load
- Pre Strategy Net Load

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Strategy 8: Demand Response

Source: Sojitz Corporation
Most Customers Will Consider DR

- Not interested at all: 21%
- Already use these services: 9%
- Extremely/very interested: 29%
- Moderately/a little interested: 42%

Load After Strategy 8

Duck Curve After Strategies 1 Through 8

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Strategy 9: Inter-regional Power Exchange

Transmission lines mostly used for baseload connections and economy energy.

Also useful for peak diversity exchanges
Diversity Between Regional Peaks

West Coast Electricity Consumption by Month

Source: http://www.eia.gov/electricity/data.cfm#sales.
Load After Strategy 9

Duck Curve After Strategies 1 Through 9

- Post Strategy Total Load
- Pre Strategy Total Load
- Post Strategy Net Load
- Pre Strategy Net Load
Strategy 10: Retire Inflexible Older Generation

Minimum load restrictions on older power plants force utilities to run them at hours when the generation is not needed.

In some places, this forces prices to zero or negative; in others it forces curtailment of renewables.
Wind Curtailment on Maui

![Wind Curtailment Graph]

- **Wind Accepted**
- **Wind Rejected**

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Many Retirements are Planned

Projected US Electric Capacity Additions and Retirements

End Result

<table>
<thead>
<tr>
<th>Load Factor and Maximum Hourly Ramping Requirements Before and After the Ten Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Load Without Renewables or Strategies</strong></td>
</tr>
<tr>
<td>Load Factor</td>
</tr>
<tr>
<td>Maximum Hourly Ramp</td>
</tr>
<tr>
<td>Total Difference Between Highest and Lowest Hour</td>
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Teaching the Duck to Fly

Requesting Permission for Take-Off
Questions?

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About RAP

The Regulatory Assistance Project (RAP) is a global, non-profit team of experts that focuses on the long-term economic and environmental sustainability of the power sector. RAP has deep expertise in regulatory and market policies that:

- Promote economic efficiency
- Protect the environment
- Ensure system reliability
- Allocate system benefits fairly among all consumers

Learn more about RAP at www.raponline.org

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