SMUD – Owned By Customers

- Not-for-profit, publicly owned utility (POU)
- Voter approved in 1923, began service in 1946
- Serves Sacramento County, small parts of Placer and Yolo counties
- 604,000 customers; population of 1.4 million
- Peak load: 3,299 MW (July 2006)
- Sixth-largest POU in U.S.
- Seven-member Board of Directors
- Independent of city and county governments
- Low rates, reliable, innovative and green
Smart Grid Investment Grant (SGIG)

- October 2009 DOE Announcement
  - SGIG grants to 100 entities
  - $203 million to California
  - $127.5 award to SMUD for a $308 million project
  - SMUD received 63% of the SGIG funds that went to California
Acknowledgement/Disclaimer

**Acknowledgement:** This material is based upon work supported by the Department of Energy under Award Number OE000214.

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What SMUD has Done

1. Smart meter installation
2. Consumer behavior study
3. Demand response
4. Distribution automation
5. Customer applications
6. Technology infrastructure
7. Cyber security
8. R&D Projects
Smart Grid Projects & Budgets

Smart Grid Budget $351M ($307.7M SGIG + $43.3M R&D)

- AMI, $145.2
- DA, $58.6
- R&D Projects, $43.3
- Technology Infrastructure, $27.1
- Cyber Security, $1.7
- Demand Response, $9.7
- Customer Applications, $53.7
- Smart Pricing Options, $11.6
Smart Meters

- Installed over 620,000 meters
- Completed installation of telecommunication network
- Allow customers to opt out of smart meters
- Remote connect/disconnect switch activated April 2011 reducing truck rolls by over 400,000 per year
Smart Meters

• Other utilities encountered publicity problems with AMI deployments

• Deployed 80k meters in hard-to-read areas and temporarily stopped deployment

• Tested system to ensure accuracy, data transfer capability, storage and communication

• Trained 40 staff plus executives and board members to present information in community
Smart Meter Benefits

- Yesterday’s data today
- TOU/CPP capable
- Communicate with HANs for demand response
- Meter tamper detection
- Automatic connect/disconnect
- ‘Ping’ meters after outage restoration to verify there are no imbedded outages
- System voltage reads

Potential Future Functionality Additions

- System/DER monitoring and optimization
- Transformer loading characteristics (future)
- Enable ‘Last Gasp’ functionality for outage notification
Outage Detection
Outage Detection
Imbedded Outages
Smart Pricing Options

Scope

• Dynamic pricing pilot offering opt-in and opt-out Time of Use (TOU), Critical Peak Price (CPP), and Time of Use with a Critical Peak Price (TOU-CPP) rates to residential customers to determine the impacts of various offers on peak load reduction & customer satisfaction
Key features of SPO pilot & enrollment

Total enrollment including deferred groups = 12,027; Total # of customers receiving offers (including deferred groups) = 53,798; Total # of customers in SPO including controls = 99,661
# SmartPricing Options

<table>
<thead>
<tr>
<th>Standard Residential CBS Rate</th>
<th>On-Peak Prices (Weekdays: 4-7 PM)</th>
<th>Off-Peak Prices (All Other Hours)</th>
<th>Monthly Service Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak Price</td>
<td>Critical Peak Price</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Time-Of-Use Peak Rate</td>
<td>$0.27</td>
<td>$0.00</td>
<td>$0.0846</td>
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<tr>
<td>Time-Of-Use with Critical Peak Pricing</td>
<td>$0.27</td>
<td>$0.75</td>
<td>$0.072</td>
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<td>Critical Peak Pricing (Stand-Alone)</td>
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<td>$0.75</td>
<td>$0.0851</td>
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</table>

<table>
<thead>
<tr>
<th>Low Income Residential CBS Rate</th>
<th>On-Peak Prices (Weekdays: 4-7 PM)</th>
<th>Off-Peak Prices (All Other Hours)</th>
<th>Monthly Service Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak Price</td>
<td>Critical Peak Price</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Time-Of-Use Peak Rate</td>
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<td>$0.00</td>
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<tr>
<td>Time-Of-Use with Critical Peak Pricing</td>
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<tr>
<td>Critical Peak Pricing (Stand-Alone)</td>
<td>$0.00</td>
<td>$0.50</td>
<td>$0.0553</td>
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</table>
Impacts For Opt-In TOU

*Results are quite similar for TOU with IHD offer treatment group*
% load reductions for TOU pricing plans were significant for both opt-in and default participants.

Load impacts for opt-in TOU are in the top quartile of those found in other TOU pilots.

Load impacts for default TOU were statistically significant which differed from what happened in the only other default pilot conducted in the industry.
Peak load reductions for CPP pricing plans were significant for both opt-in and default participants.

- Opt-in CPP, No IHD Offer: 22%
- Opt-in CPP, IHD Offer: 26%
- Default CPP, IHD Offer: 12%
- Default TOU-CPP, IHD Offer: 13%
Demand Response

- Procured and install a demand response management system (DRMS) software platform (Lockheed Martin SeeLoad)
- Implemented demand response pilots for residential customers:
  - 2012 PowerStat pilot (180 homes, pre-cooling strategy)
  - 2013 PowerStat pilot (825 homes, TOU-CPP rate, incentives paid per event, customer control or SMUD control)
- Developed and implemented an Automated Demand Response (AutoDR) program for medium and large commercial:
  - 3.5 MW signed up
  - Program expanding in 2014
Before the event, the 6 hour precool used significantly more energy
  - The 2 hour precool used the highest

During the event, the 6 hour precool reduced the most
  - The 2 hour and no precool was similar

After the event, no significant differences

Total daily energy use was lowest under the no precool
  - The 2 hour and 6 hour precool was not statistically different
How did the load impacts change with the outdoor temperature

- In all cases, results show that higher temperatures increase pre-peak and post peak loads and lower peak loads
Electric Bill Impacts

- Average monthly bill impacts for PowerStat® participants ranged from a $2 monthly bill savings (-1.2%) to a $0.55 monthly bill increase (+0.5%)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Monthly Bill Impact ($)</th>
<th>% Bill Impact</th>
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</thead>
<tbody>
<tr>
<td>No Precool</td>
<td>- $2.03</td>
<td>- 1.2%</td>
</tr>
<tr>
<td>2 hr precool</td>
<td>+ $0.55</td>
<td>+ 0.5%</td>
</tr>
<tr>
<td>6 hr precool</td>
<td>- $0.20</td>
<td>- 0.1%</td>
</tr>
</tbody>
</table>

- Bill impact estimates ranged from -$10 to $10 for the summer, representing between -3% and +5% of the August-September bills.
Distribution Automation

- Automated 118 distribution feeders
- Implemented SCADA (supervisory control and data acquisition) at 40 existing substations
- Implemented VVO/CVR at two substations in 2011 and 14 subs in 2013-14
- Field tested Automatic Sectionalizing & Restoration control logic
- Upgraded Outage Management System - Integraph’s OMS 8.2 and Mobile Thin Client
- Situational Awareness and Visualization Intelligence (SAVI) -- Distribution Dashboard
- Implemented an electronic wall map
- Outage Communication - designed and developed automated process for customer notification of outages
End customers continue to see acceptable voltage.

Voltage Profile - LTC & Capacitors
Voltage Profile - LTC control only
Voltage Profile - LTC control and VVO/CVR

Substation

Increasing Distance from Substation
CVR Impact Variation

- Impact of CVR varies depending on a variety of factors including load mix, load level, weather and season.

### Approx. Load Impacts (for 3% Voltage Reduction)

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Approx. Demand Reduction Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting - Incandescent</td>
<td>5%</td>
</tr>
<tr>
<td>Lighting - Fluorescent Tube / CFL</td>
<td>2-8%</td>
</tr>
<tr>
<td>Lighting - LED</td>
<td>0-6%</td>
</tr>
<tr>
<td>LCD TV</td>
<td>0%</td>
</tr>
<tr>
<td>Plasma TV</td>
<td>0%</td>
</tr>
<tr>
<td>Air Conditioning - Conventional</td>
<td>0.5-1.0%</td>
</tr>
</tbody>
</table>

SOURCE: PACIFIC NORTHWEST NATIONAL LABORATORY
2011 Pilot Deployment - CVR Results

Myrtle-Date 2% CVR Analysis

- MW: Test Day
- MW: Reference Day
- kV: Test Day
- kV: Reference Day
Pilot Test Findings

- Pilot test results illustrated a range of potential impacts depending on individual feeder load response to a voltage reduction.

## Pilot Test Results for 2% Voltage Reduction

<table>
<thead>
<tr>
<th></th>
<th>Madison-Kenneth</th>
<th>Myrtle-Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave Peak Demand</td>
<td>15.0 MW</td>
<td>12.4 MW</td>
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<tr>
<td>Avg Peak Demand Reduction</td>
<td>150 kW (~1%)</td>
<td>310 kW (~2.5%)</td>
</tr>
<tr>
<td>Avg Energy Impact*</td>
<td>0.5 MWh</td>
<td>4 MWh</td>
</tr>
</tbody>
</table>

* Over 16 hour period
Situational Awareness and Visual Intelligence (SAVI)

• Provide a tool that would make data actionable
  – Implement a Dashboard for Distribution System Operators
    • Tool to geospatially display information from multiple source systems and allow for geospatial analysis
    • Ability to trend current and historical information
Customer Services & Solutions

Scope

• Developed expanded energy information and education toolset to help customers manage their energy use
• Provided technology solutions allowing customers to control and automate their electric use
• Deployed six residential and small commercial pilots to assess effectiveness of various levels of technology, automation, control and education enabled by the smart grid in comparison to more traditional methods
Customer Services & Solutions

- Projects completed for residential and small commercial pilots: Smart Thermostats, Low Income Energy Management and IHD Check-Out Pilot
- Vendor selected for med-large C/I Energy Information & Tools (Energy Profiler Online by Schneider Electric), working on real-time pilot
- Rebate programs developed for C/I EMS and Advanced Lighting—EMS program finished, Lighting program still active
- Some projects cancelled due to timing or lack of available products—Residential Energy Management Systems, Controllable Appliances, HAN Usability Study
Advanced Lighting Program

• Provided rebates for the installation of advanced, controllable lighting systems
• Combined efficient lighting technologies (technology neutral—LED, fluorescent, HID, etc.) with control strategies
• Energy savings in the 50% to 90% range
Savings from lighting upgrades: 2,505,672 kWh / year
Savings from controls: 1,661,322 kWh / year
Total estimated savings: 4,166,994 kWh / year
Case Study Results

Lighting load profiles for pre-retrofit baseline, new baseline, and with motion sensors.
Technology Infrastructure

Enterprise Service Bus
• Installed Enterprise Service Bus software platform to simplify integration of new smart grid systems and legacy systems
• Reduced the number, size, and complexity of integration interfaces between systems in order to reduce cost and improve speed of service to the customer

Customer Relationship Management (CRM)
• Installed Customer Relationship Management System software that integrates customer service call center with back office billing system
Cyber Security

Scope

• Procure and install cyber security hardware and software to prevent attack, monitor attempted attacks, and continuously check for vulnerabilities

• Incorporate cyber security at all levels of upgraded/new systems
Lessons Learned

• Executive support is essential for large-scale projects

• Customer communication is critical

• Flexible scope and schedule is important
  – Some of our scope was hard and fast
  – Other parts were flexible
  – Flexibility allowed us to move things around when projects didn’t work out as planned
Lessons Learned

• Data accuracy and timeliness is important
  – New applications allow highly detailed view of system
  – If data is bad, capabilities of advanced tools and applications cannot be fully realized
  – Results will not be reliable or timely
Lessons Learned

• Immature technologies--some of the smart grid products were not quite ready for broad-scale deployment:
  – Smart appliances were pulled from the market in the middle of our project
  – Certain software products were not as fully developed as expected (they are improving over time)
  – Early version products tend to be expensive and costs exceed benefits (some home controls/technologies)
• Products have come a long way, but there are still many early-stage products that need additional testing before being ready for prime time
Lessons Learned

• Heavily technology-dependent assets should be procured as close to implementation as possible
  – Product functionalities and capabilities are improving rapidly
  – Prices tend to come down over time

• Vendors sometimes overpromised and under-delivered
Next Steps

• Still a lot of work to do. Some projects implemented at 100% level (smart meters), others at a much lower level (automated feeders at 18%).

• Complete SmartSacramento project (over 99% complete, wraps up by 12/23/14)

• Develop Smart Grid Roadmap to guide future smart grid deployments
Next Steps - Roadmap

- Issued an RFP 8-Oct 2014 to hire a consultant to 1) evaluate SmartSacramento and 2) develop a smart grid roadmap
- Evaluation summary
  - Summarize existing evaluations (12)
  - Evaluate additional projects (11)
  - Summarize all evaluations into a single SmartSacramento evaluation
<table>
<thead>
<tr>
<th>Project Name</th>
<th>Evaluation Performed?</th>
<th>Evaluation Required?</th>
<th>Level of Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>SCADA</td>
<td>No</td>
<td>Yes</td>
<td>High-level evaluation of benefits compared to costs.</td>
</tr>
<tr>
<td>Line Automation</td>
<td>No</td>
<td>Yes</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>CVR</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>ASR</td>
<td>No</td>
<td>Yes</td>
<td>Evaluate benefits compared to costs and future potential.</td>
</tr>
<tr>
<td>SAVI</td>
<td>No</td>
<td>Yes</td>
<td>Identify benefits and potential value.</td>
</tr>
<tr>
<td>OMS Upgrade</td>
<td>No</td>
<td>Yes</td>
<td>Evaluate benefits vs cost.</td>
</tr>
<tr>
<td>PI</td>
<td>No</td>
<td>Yes</td>
<td>Evaluate benefits vs cost.</td>
</tr>
<tr>
<td>Outage Communication Tool</td>
<td>No</td>
<td>Yes</td>
<td>Look at benefits and future needs/potential.</td>
</tr>
<tr>
<td>Integrated T&amp;D Modeling</td>
<td>No</td>
<td>Yes</td>
<td>Look at benefits compared to current modeling tool.</td>
</tr>
<tr>
<td>Mobile Data Terminal Replacement</td>
<td>No</td>
<td>No</td>
<td>No need to evaluate under this contract.</td>
</tr>
<tr>
<td>SmartPricing Options</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
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<tr>
<td>DRMS</td>
<td>No</td>
<td>Yes</td>
<td>High level look at benefits and long-term capabilities.</td>
</tr>
<tr>
<td>PowerStat 2012</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>PowerStat 2013</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>Auto DR</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>Partner Projects</td>
<td>No</td>
<td>No</td>
<td>No need to evaluate under this contract.</td>
</tr>
<tr>
<td>Smart Charging Pilot</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>Smart Thermostats</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>Low-Income Weatherization</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
</tr>
<tr>
<td>In-Home Display Checkout</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
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<tr>
<td>Commercial EMS</td>
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<td>No need to evaluate under this contract.</td>
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<td>Res Smart Community</td>
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<td>No</td>
<td>Evaluation underway.</td>
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<td>Advanced Controllable Lighting</td>
<td>Yes</td>
<td>No</td>
<td>Already evaluated. Incorporate findings in final report.</td>
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<tr>
<td>Commercial Energy Information and Tools</td>
<td>No</td>
<td>Yes</td>
<td>High level look at what will be needed in the future as we progress with smart grid projects.</td>
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<tr>
<td>Enterprise Service Bus</td>
<td>No</td>
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<td>No need to evaluate under this contract.</td>
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<td>CRM</td>
<td>No</td>
<td>No</td>
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<td>Revenue Protection Detection Software</td>
<td>No</td>
<td>Yes</td>
<td>Look at the benefits compared to costs.</td>
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<tr>
<td>Cyber Security</td>
<td>No</td>
<td>No</td>
<td>No need to evaluate under this contract.</td>
</tr>
</tbody>
</table>

11 potential new evaluations
12 Completed evaluations that need to be reviewed and results incorporated into the Roadmap/Evaluation report
6 projects without evaluations and no plans to complete evaluations under this contract
Next Steps - Roadmap

• Develop a smart grid roadmap that incorporates SmartSacramento lessons learned and current best practices

• The plan will include:
  – Evaluation results
  – Proposed new project descriptions, benefits, risks, budgets, staffing impacts
  – Relative project priority
  – Gap analysis

• Roadmap completion expected in June 2015
After the Roadmap

• Review project recommendations
• Develop business cases as needed
• Look for projects with positive ROI or where there is a compelling business need
• Request budget and resources to implement viable projects
Smart Grid Vision
Discussion and Questions

Jim Parks
Jim.parks@smud.org
<table>
<thead>
<tr>
<th>#</th>
<th>Project Name</th>
<th>Budget</th>
<th>DOE</th>
<th>CEC</th>
<th>3rd Party</th>
<th>SMUD $</th>
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<tbody>
<tr>
<td>1</td>
<td>AMI</td>
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<td>2</td>
<td>DA</td>
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<td></td>
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<td>Total SGIG Projects</td>
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<tr>
<th>#</th>
<th>Project Name</th>
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<td>8</td>
<td>Anatolia PV &amp; Energy Storage Integration</td>
<td>$6.0</td>
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<td>Microgrid Field Demonstration</td>
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</tbody>
</table>

|      | Grand Total                                       | $351.0 | $142.8| $6.5| $39.5     | $169.7 |
SMUD PV & Smart Grid Pilot at Anatolia
High Penetration Solar Development

- Anatolia SolarSmartSM Homes Community (280 homes)
  - High building efficiency measures
  - 2kW PV systems
- Installed 15 RES (10kW/8.8kWh) and 3 CES (30kW/30kWh) units
- Will firm renewables, reduce peak load and improve reliability
- Installed utility and customer portals to monitor PV, storage, customer load
- Sent price signals to affect changes in customer usage
- Quantifying costs and benefits of this storage deployment to gain insights to broader application for SMUD
SMUD Microgrid Project Overview

310kW demo of Microgrid concept for our central utility plant and Field Reporting Facility

- 3-100kW natural gas engines
- 10kW PV
- Absorption chiller
- Seamless separation and isolation from utility grid and resynchronization

- 2 centrifugal chillers (600 ton and 200 ton)
- 2 boilers
- 15,000 ton-hour chilled water energy storage (760,000 gallons)
Dairy Manure Digesters

Collection

Covered Anaerobic Lagoon

Biogas/Methane Recovery & Flare

Biogas Engine & Electricity Generator

Electricity for the farm and the SMUD grid

Separates out solids
Dairy Digester Projects

- **Warmerdam Dairy**
  - 600 kW with Selective Catalyst Reduction (SCR), covered lagoon digester
  - About 1,200 milk cows
  - Completion Q1 2013

- **New Hope Dairy**
  - 450 kW SCR above ground, high solids tank digesters
  - Complies with strictest NOx and SOx emission limits
  - 1,200 milk cows
  - Completion Q1 2013
Electric Vehicle Potential Load Impacts

- Load becomes significant around 2025
- Local distribution impacts will be felt sooner
  - Will need to manage load

### PHEV Average Projection
- Adjusted EPRI Model
- CARB Model (Oct. 2009)
- Charles River Associates

### Load Calculation Assume
- 50% of PHEV’s at 1.5 kW charge level
- 25% of PHEV’s at 3.3 kW charge level
- 25% of PHEV’s at 6.6 kW charge level
- 100% of BEV’s at 6.6 kW charge level

### Energy Calculation Assume
- 365 days a year of charging (worst case)
- PHEV require 7.5 kWh of charging/day
- BEV’s require 15 kWh of charging/day

<table>
<thead>
<tr>
<th>Year</th>
<th>PHEV</th>
<th>BEV</th>
<th>% Sac</th>
<th>Load</th>
<th>Energy</th>
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<tbody>
<tr>
<td>2015</td>
<td>9,225</td>
<td>1,045</td>
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<td>53 GWh</td>
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<td>16,322</td>
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<tr>
<td>2030</td>
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<td>33,481</td>
<td>30.3</td>
<td>1,097MW</td>
<td>956 GWh</td>
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