



*Innovation for Our Energy Future*

# Future R&D Needs Moving Towards High Penetration



**Tutorial: Distribution  
Grid Codes for High  
Penetration DER**

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**December 6, 2010**

# Presentation Outline

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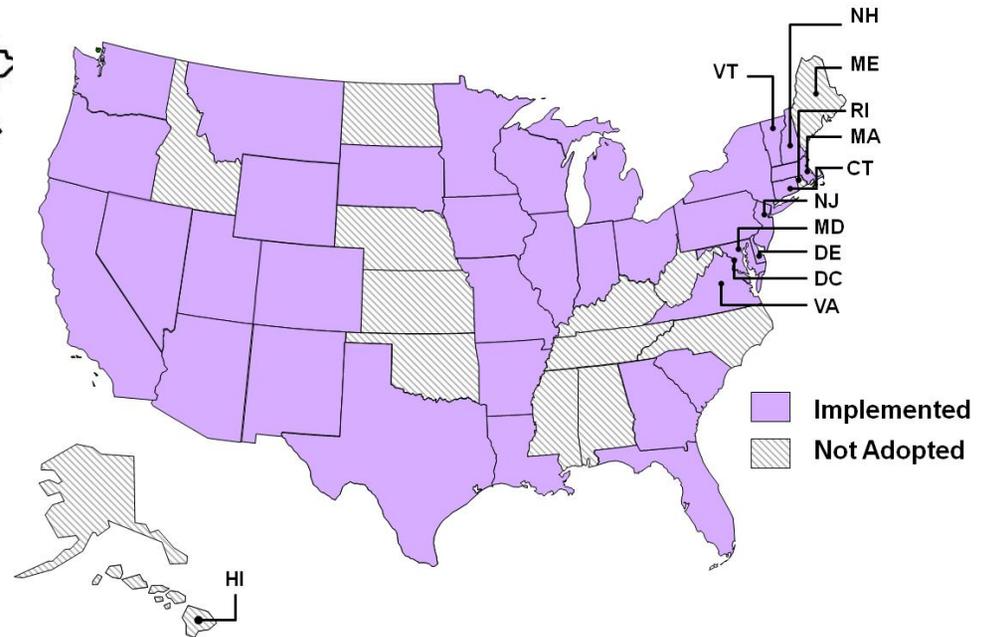
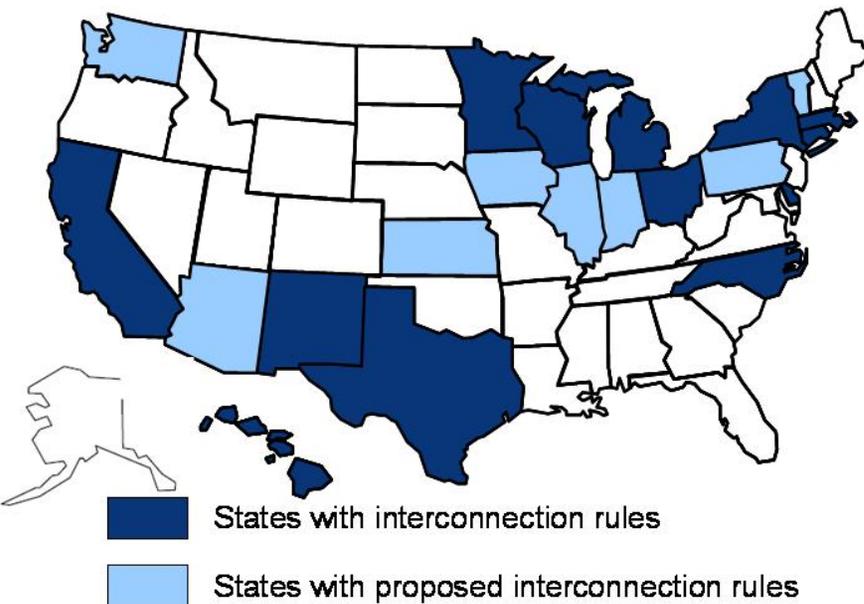
Where are we now?

Where are advances being made?

What still needs to be done?

What the future holds.....

# Standards Implementation Enabling DER Interconnection



**Prior to 2005 EPACT Sec 1254 *Interconnection***

*(... states shall consider IEEE 1547 standards ...)*

**At the end of 2008...  
states that implemented  
1547 interconnection  
standards**

# IEEE 1547 Series Standards

**1547-2008** Standard for Interconnecting Distributed Resources with Electric Power Systems

**1547.1-2005** Conformance Test Procedures for Equipment Interconnecting DR with EPS

**1547.2-2008** Application Guide for IEEE 1547 Standard for Interconnecting DR with EPS

**1547.3- 2007** Guide for Monitoring, Information Exchange and Control of DR

## Current Projects

**P1547.4** Guide for Design, Operation, and Integration of DR Island Systems with EPS

**P1547.5** Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid

**P1547.6** Recommended Practice for Interconnecting DR With EPS Distribution Secondary Networks

**P1547.7** Draft Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection

**P1547.8** Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547

**Microgrids**

**Urban distribution networks**

**Impact Studies**

**Advanced Functionality of DR**

# IEEE 1547 Interconnection Standards Use

Federal, Regional, State and Local Authorities/Jurisdictions

## **IEEE 1547** **Interconnection System and Test Requirements**

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

## **IEEE 1547.1** **Interconnection System Testing**

- O/U Voltage and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

## **UL 1741\*** **Interconnection Equipment**

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

## **NEC**

Article 690 PV Systems;  
Article 705: interconnection systems (shall be suitable per intended use per UL1741)

## **PJM Interconnection, Inc.** ***Small Generator Interconnection Standards*** **FERC approved**

*(0-to<10MW and 10-to-20 MW;  
incorporate 1547 and 1547.1)*

\* UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1

Example  
of ISO  
using  
1547

# Where are we now?

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Clearly IEEE 1547 has been successful.

But....

1. Based on low penetrations
2. Takes time to update and integrate new technologies or functionality

IEEE 1547 can be used as a model to implement successful standards to address high penetrations of renewable and distributed energy technologies

# What programs are making advances?

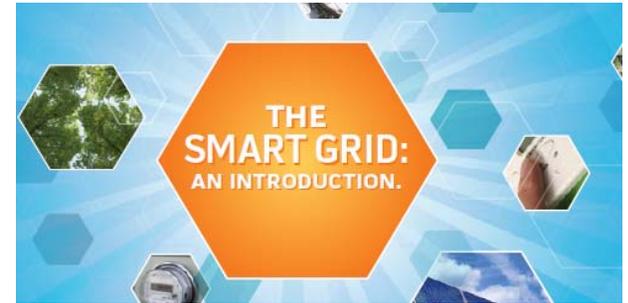
- DOE OE Smart Grid R&D Program
- EPRI Smart Grid Program
- DOE Solar – High Penetration Awards
- California PUC – High Penetration Awards
- National Laboratories
- Utilities



# DOE OE Smart Grid Program

## Renewable and Distributed Systems Integration Projects

- Allegheny Power Demonstration Project
- Alliant Techsystems (ATK) Launch Systems Demonstration Project
- Ft. Collins Demonstration Project
- Illinois Institute of Technology Demonstration Project
- San Diego Gas & Electric (SDG&E) Demonstration Project
- University of Hawaii Demonstration Project
- UNLV Demonstration Project



## NEW Smart Grid Awards

- **Areva T&D, Inc. (Redmond, WA)** is designing and testing an innovative platform for integrating distributed energy resources into the electric grid.
- **Boeing Company (Saint Louis, Missouri)** will demonstrate a smart, highly-automated, secure, and self-healing electric distribution management system that will allow for integration of a greater amount of customer-owned energy resources and automation into the distribution system, increasing the value of energy resources to both end-use customers and utilities.
- **ABB Inc. (Raleigh, North Carolina)** will research, develop, and demonstrate a real-time monitoring, control, and health management system to improve grid reliability and efficiency. It will utilize digital data from sensors and substation Intelligent Electronic Devices to continuously monitor system performance.
- **Varentec, Inc. (North Andover, Massachusetts)** will conduct research and development on a wide range of next-generation power electronics devices to better integrate renewable resources. Using an innovative circuit design with an integrated battery energy storage system, the project's goal is to deliver a fast response to rapid voltage changes arising from grid-connected renewable resources.
- **On-Ramp Wireless, Inc. (San Diego, CA)** will develop and demonstrate a wireless grid sensor and faulted circuit indicator capable of monitoring underground and other hard-to-reach distribution circuit locations.

For more info: <http://www.oe.energy.gov/smartgrid.htm>

# EPRI Smart Grid Program

- AEP Smart Grid Demonstration
- Con Edison Smart Grid Demonstration
- EDF Smart Grid Demonstration
- FirstEnergy Smart Grid Demonstration
- PNM Smart Grid Demonstration
- ESB Smart Grid Demonstration
- KCP&L Smart Grid Demonstration
- Exelon (ComEd/PECO) Smart Grid Demonstration
- Duke Energy Smart Grid Demonstration Overview
- Southern Company Smart Grid Demonstration Overview



For more info: <http://www.smartgrid.epri.com/>

# DOE Solar – High Penetration Projects

- Arizona Public Service Company** - This project will develop, construct, manage, and study a high penetration of 1.5 megawatt (MW) of distributed photovoltaic generation on a typical residential feeder in Flagstaff, Arizona, including a mix of residential and commercial systems, as well as a 0.5 MW utility system.
- Commonwealth Edison Company** – This project will evaluate consumer reactions when a utility provides advanced metering and price signals for electric power without PV, with PV, and with both PV and energy storage. The impact will be a utility-based understanding of market response for photovoltaics.
- Florida State University** - The project will characterize the variation and impact of solar power as a function of system size (both kilowatt and MW), location, installation type and technology, including examination of variation within larger systems. The result will be technical solutions, from protection and control strategies and technologies, to converter, converter control, and PV system technologies, to address any issues identified with high-penetration levels of grid-connected photovoltaics.
- National Renewable Energy Laboratory** - This project will utilize modeling and simulation, laboratory testing, and field demonstrations to determine the effects of high penetrations of up to 500 MW of mostly commercial-scale rooftop PV on electrical distribution systems, including prototypical distribution circuits.
- Sacramento Municipal Utility District** – This project will evaluate the value of advanced metering infrastructure, PV, and storage for homes with advanced metering infrastructure and PV along with the variables of no storage, home-based storage, or community-based storage.
- University of California San Diego** - This project will develop advanced modeling tools and electric power control strategies to optimize electric power value and remove or reduce the impact of PV-sourced electricity on existing microgrids and the SmartGrid. Factors to be modeled and evaluated include monitoring of micro-climate effects and sky imaging systems to enable 1-hour-ahead PV-sourced electric power output forecasting in conjunction with a utility's dynamic price signals.
- Virginia Polytechnic Institute and State University** - The project will evaluate existing and Virginia Tech prototype power conditioners to identify cost-effective approaches to address issues associated with high-penetration PV systems, such as voltage regulation, reverse power flow, unintentional islanding, false inverter trips, reactive power control, fault contribution, protection, communications, and intentional islanding operation.

For more info: [http://www1.eere.energy.gov/solar/high\\_pen/](http://www1.eere.energy.gov/solar/high_pen/)

# Systems Integration – Distributed Grid Integration

## Southern California Edison



SCE  
MW scale  
rooftop  
installation

- SCE is installing 500MW of commercial rooftop PV systems over the next 5 years
- 250MW utility owned, 250MW IPP
- Interconnected at distribution circuit level

### Specific Issues:

Unsure of interconnection process for circuits with over 15% PV (Peak PV/Peak Load)

Need to develop quick study process for penetrations >15%

Issues include: voltage regulation, circuit ratings, circuit protection coordination, cloud variability

# California PUC – High Pen Projects

**High Penetration PV Initiative by Sacramento Municipal Utility District (SMUD)**, in partnership with the Hawaiian Electric Company, will demonstrate and test new hardware and software tools that will provide communication and management between PV systems and utility controls using advanced metering infrastructure (AMI).

**Advanced Modeling and Verification for High Penetration PV by Clean Power Research (CPR)** will develop a free solar resource model that builds upon an existing PV performance model platform to enhance the resolution of satellite-based resource data. The team will integrate PV modeling capabilities with an open-source distribution engineering and analysis tool and create a unique PV value assessment tool for use by utilities to select and target the best PV locations.

**Beopt-CA (EX): A Tool for Optimal Integration of Energy Efficiency, Demand Response, Energy Storage, and PV for California Homes by NREL** targets the development of the Building Energy Optimizer for California Existing Homes (Beopt-CA (EX)) modeling tool that aims to facilitate balanced integration of energy efficiency, demand response, and energy storage with PV in the residential retrofit market.

**Specify, Test and Document an Integrated Energy Project Model by kW Engineering** focuses on developing and verifying an Integrated Energy Project (IEP) software model that will help identify best practices for integrating energy efficiency measures with PV system deployment.

**Analysis of High-Penetration Levels of PV into the Distribution Grid in California by National Renewable Energy Laboratory (NREL)** focuses on accelerating the placement of high levels of PV penetration into the existing distribution circuits and identifying new circuit configurations that will help increase penetration levels of PV.

**Development and Analysis of a Progressively Smarter Distribution System by the University of California, Irvine (UCI)** is a collaboration between the Advanced Power and Energy Program (APEP) at UCI and PG&E. The goals of the project are to utilize modeling and simulation to quantify PV integration limitations; and to develop and evaluate progressively smarter distribution systems.

**Planning and Modeling for High-Penetration PV by SunPower Corporation** will produce an improved solar resource model with temporal resolution ranging from 10 minutes to 1 second and spatial resolution going to below 4 km<sup>2</sup>.

**Improving Economics of Solar Power Through Resource Analysis, Forecasting and Dynamic System Modeling by the University of California, San Diego (UCSD)** will research the economic effects of three issues associated with increased penetration of PV in California: 1) insolation data and PV performance that take into account passing cloud cover; 2) how inverter logic software can improve voltage regulation in transient light conditions due to passing clouds; and, 3) energy storage options to reduce voltage sag due to cloudiness.

For more info: <http://www.calsolarresearch.ca.gov/>

# National Laboratories

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The National Renewable Energy Laboratory and Sandia National Laboratories are working with industry on several High Penetration Projects.

Holding several workshops with Industry to discuss important topics related to high penetrations and integration of distributed energy

- PV Variability
- Solar Users Group
- High Pen Standards and Codes

For more info: <http://www.nrel.gov/eis/>

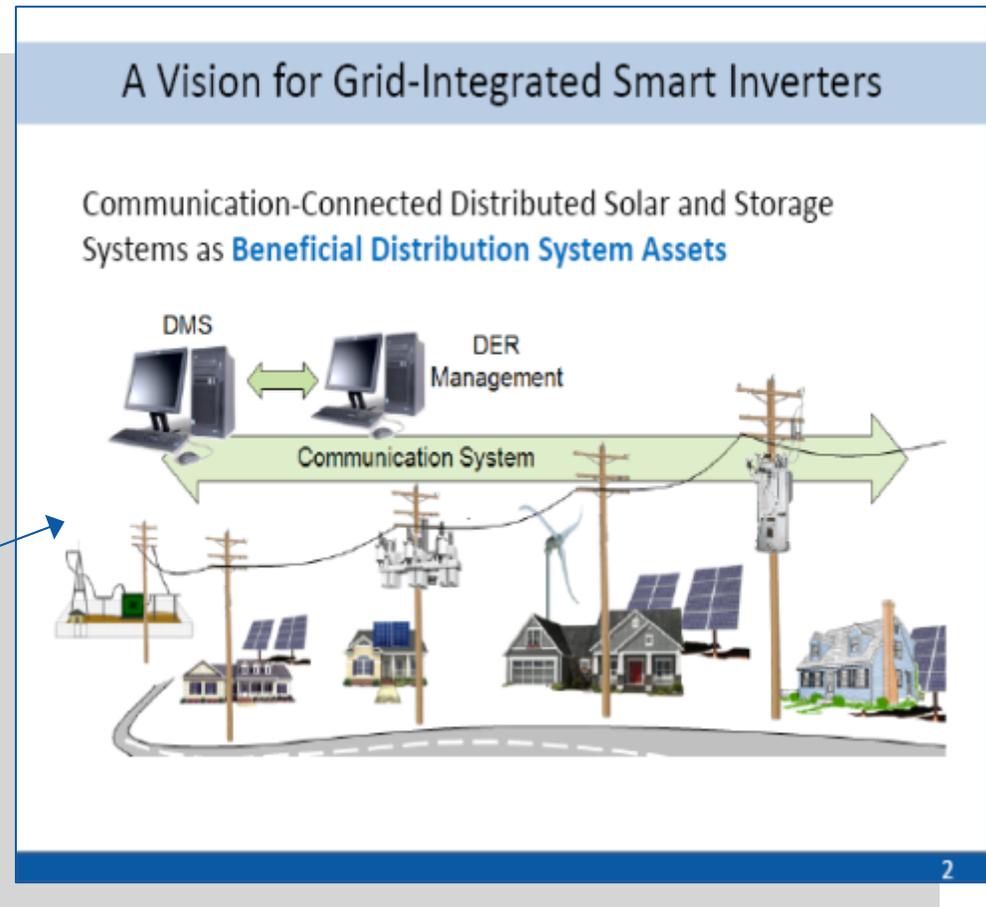
# Systems Integration – Codes and Standards

## High Penetration PV Workshop

In May 2010 NREL held a workshop on high penetration PV standards and codes.

Addressed:

- High Penetration PV Concerns
- Gaps in Existing Standards and Codes
- High Penetration PV Technical Solutions
- High Penetration PV Solutions: Modeling and Studies



Workshop information available at:

[http://www.nrel.gov/eis/high\\_penetration\\_pv\\_wkshp\\_2010.html](http://www.nrel.gov/eis/high_penetration_pv_wkshp_2010.html)

# Utilities

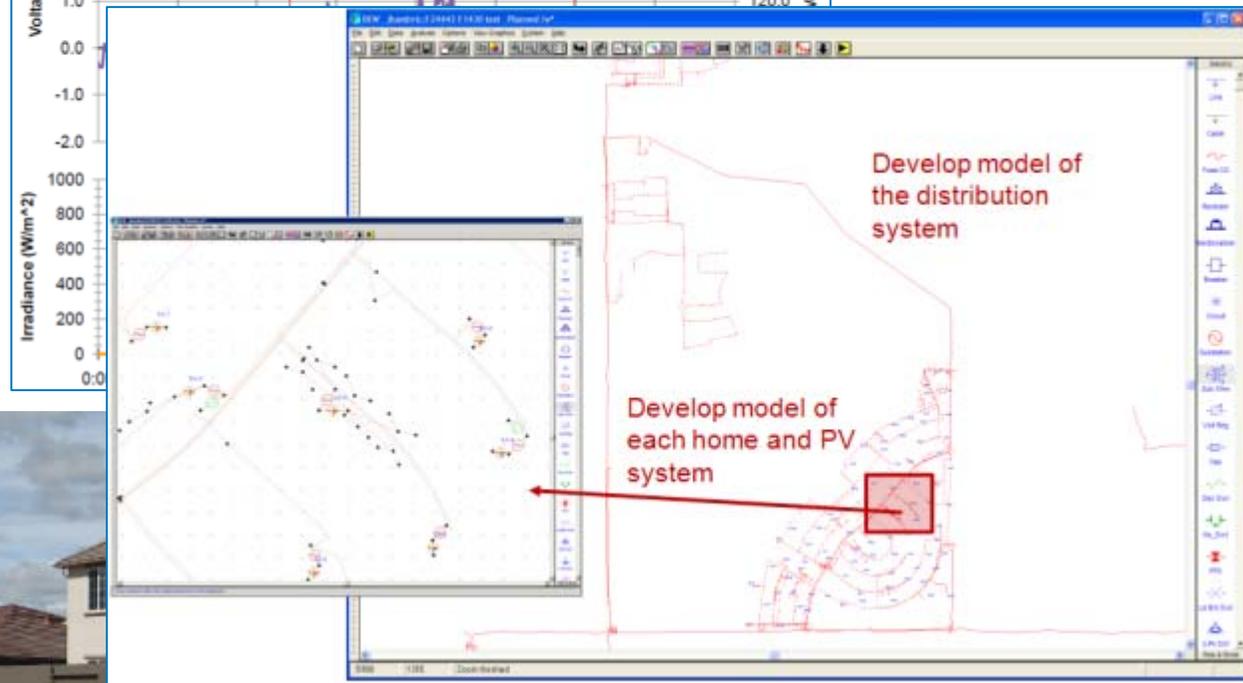
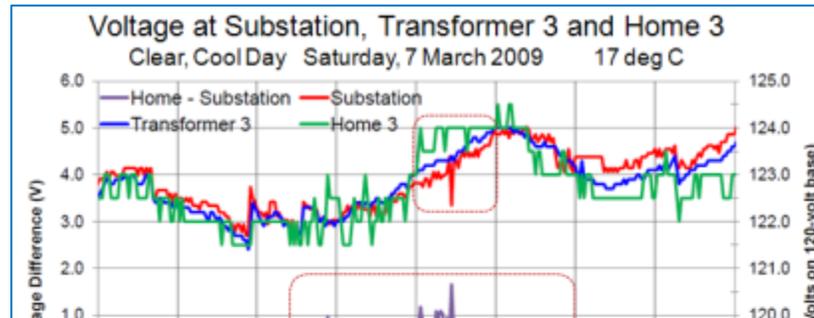
Some utilities are working proactively to operate system with increasing levels of PV penetration on distribution circuits

- California – SCE, PG&E, SDG&E, SMUD
- Hawaii – HECO, MECO, HELCO, KIUC
- NJ/DC – PEPCO
- TX -
- CO – Xcel Energy
- NY – ConEd
- IL - ComEd



# Systems Integration – Distributed Grid Integration

## Sacramento Municipal Utility District – PV on Residential Circuit



# What still needs to be done?

- Updating DER interconnection standards (low voltage ride thru; volt-ampere reactive support; grid support; advanced/interactive grid-DR operations; high-penetration/multiple interconnections)
- Defining end-to-end communications infrastructure (two-way communications and control; interactive inverters; energy storage; electric vehicles; etc.)
- Harmonization of national and international standards
- NIST Smart Grid Standards Roadmap & Interoperability Framework
- Testing and demonstrations of advanced concepts, high penetration, and Smart Grid functionality

# IEEE 2030 Series Standards

## Current Projects

### **P2030** Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System and End-Use Applications and Loads

Provides guidelines in understanding and defining smart grid interoperability of the EPS with end-use applications and loads.

Focuses on integration of energy technology and information and communications technology .

### **P2030.1** Draft Guide for Electric Sourced Transportation Infrastructure

Addresses applications for electric-sourced vehicles and related support infrastructure used in road-based personal and mass transit .

### **P2030.2** Draft Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure

Guidelines for discrete and hybrid energy storage systems that are integrated with the electric power infrastructure, including end-use applications and loads.

# Systems Integration – NEW Testing Facility

## Energy Systems Integration Facility (ESIF)



180,000 sq. ft.  
24 Laboratories  
200 Teraflop Computer  
200 researchers  
Design 2009 - 10  
Construction start 2011  
Completion 2012

# ESIF's Advanced Capabilities

- Multiple parallel AC and DC experimental busses (2MW power level)
- Flexible interconnection points for electricity, thermal, and fuels
- Microgrid testbed at medium voltage (15kV)
- “Hardware in the loop” simulation capability
- Virtual utility operations center and visualization rooms
- Smart power testing lab for advanced communications and control
- Interconnectivity to external field sites for data feeds and model validation
- Integrated 200+ teraflop computer with petabyte data center

