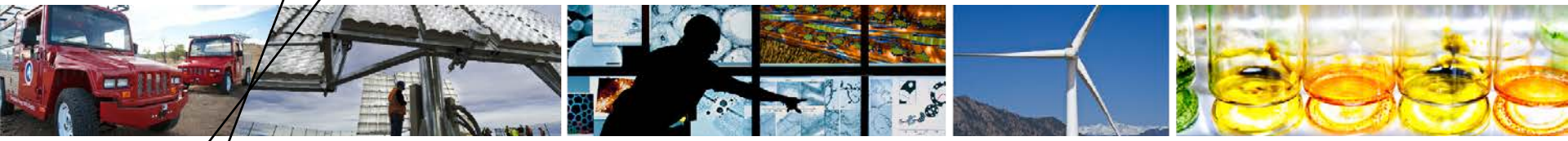
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Interconnection of Distributed Energy Resources



Delivered to: Transmission and Grid Basics for Tribal Economic and Energy Development

Dave Narang
Principal Engineer, NREL

March 30, 2016

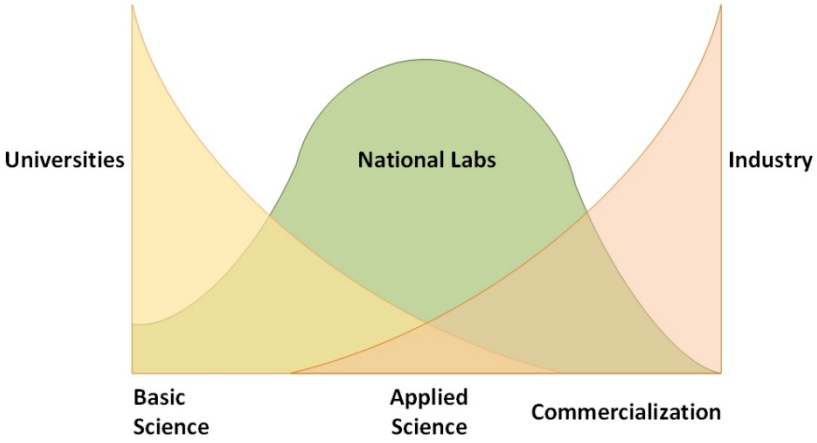
Discussion Topics

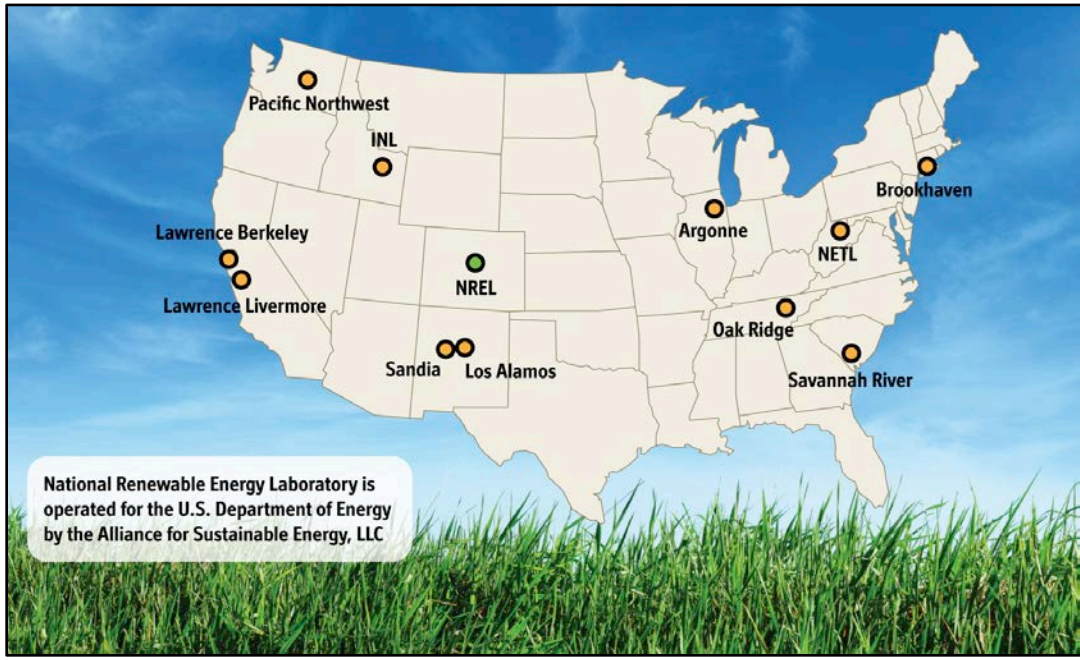
- **Distribution System Interconnections - Part 1**
  - Background
  - Distribution Systems Overview
  - Electric Utility Operations
  - Emerging Topics in Grid Integration
  - DOE Grid Modernization Initiative
- **Distribution System Interconnections - Part 2**
  - Permitting
  - Interconnection
- **Wrap up**
  - Additional Resources

NREL is Part of DOE's National Lab Complex

DOE Lab Mission Areas

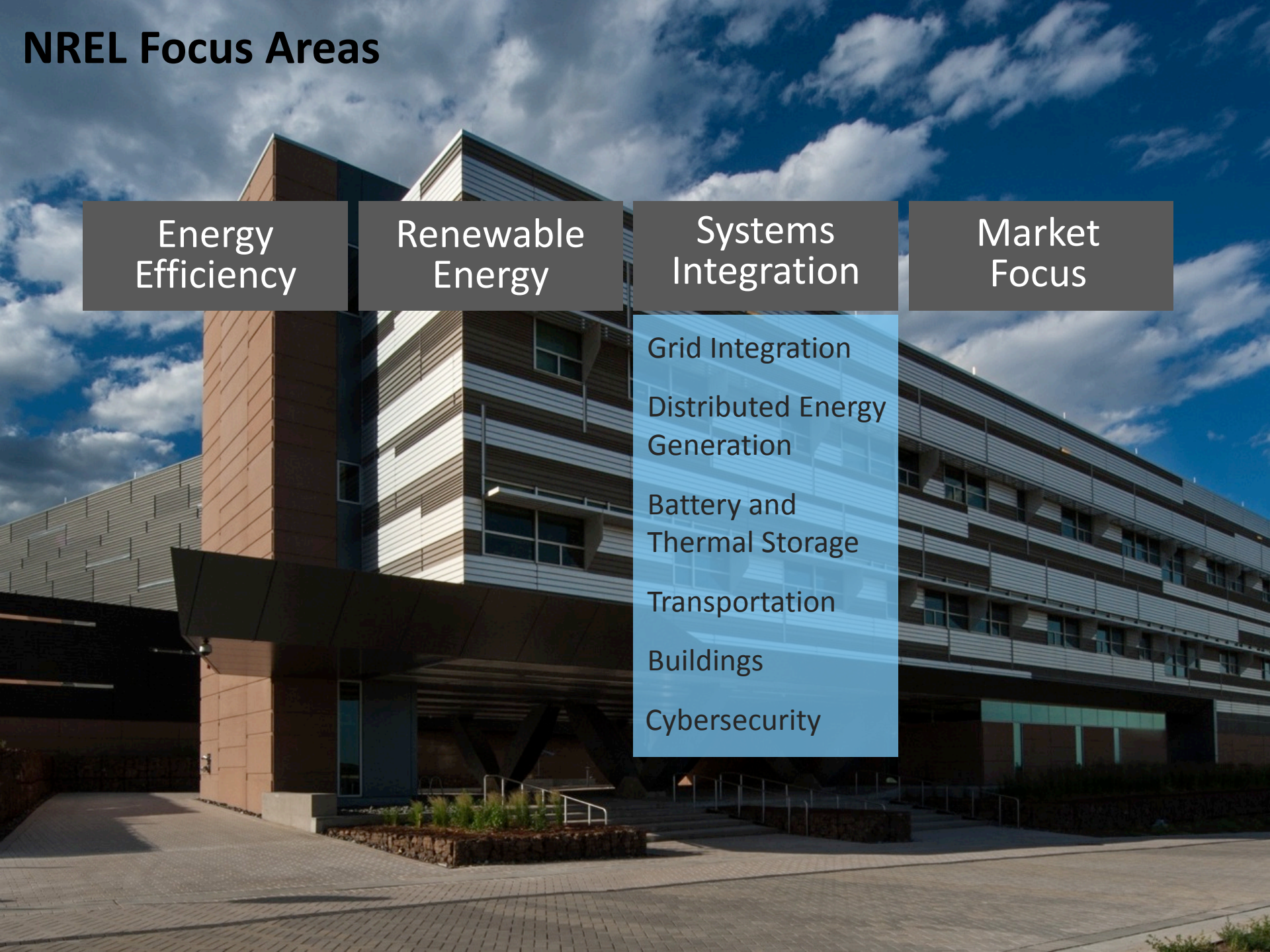
- Nuclear Security
- Science
- Energy
- Environmental Management





http://energy.gov/labcommission/downloads/final-report-commission-review-effectiveness-national-energy-laboratories
http://energy.gov/oe/about-us/strategic-plan

NREL Focus Areas



Energy Efficiency

Renewable Energy

Systems Integration

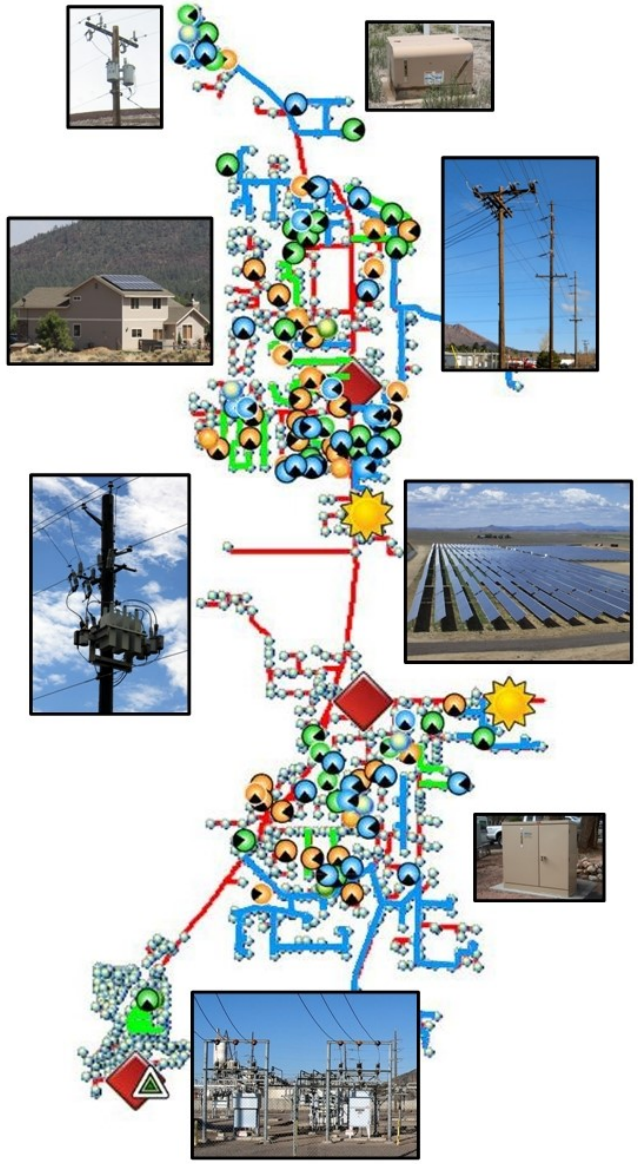
- Grid Integration
- Distributed Energy Generation
- Battery and Thermal Storage
- Transportation
- Buildings
- Cybersecurity

Market Focus

Overview of Electric Distribution Systems

- **Physical Topology**
  - Central power generator → transmission system → distribution substation/transformer
  - Wires (feeders, main & laterals)
  - Distribution transformers
  - Loads (residential, commercial, industrial)
  - Voltage Regulation (capacitor banks, voltage regulators)
  - Protective devices (fuses, circuit breakers, relays, reclosers)
  - Switches, relays
  - Sensing & Controls (Energy Management Systems (EMS) /Supervisory Control & Data Acquisition (SCADA), Automated Meter Reading (AMI) – digital (wireless) meters
  - Special equipment for managing specific issues with power quality, real or reactive power
  - Distributed Energy Resources (distributed generation, renewables, energy storage,…)

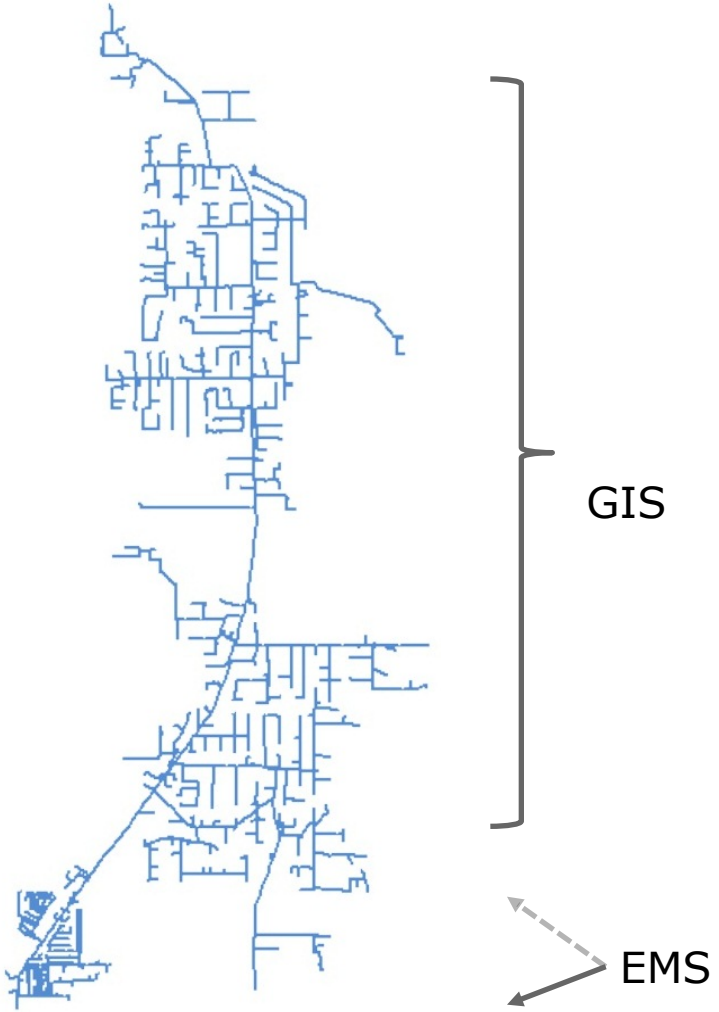
- **Operational Goals**
  - Maintain correct voltage range
  - Maintain power quality
  - Maintain load balance
  - Maintain safety of customers & work crews



The Electric Utility Balancing Act

- Reliability, Security
- Safety
- Affordability
- Innovation/Competitiveness
- Flexibility/Resiliency
- Energy mix
- Clean Resources/Environment
- …….

Distributed Generation Integration from a Utility Perspective



Situational Awareness

- feeder topology (GIS)
- feeder historic peak load (manual process - annual)
- substation transformer loading (EMS)
- equipment status/state/settings (reclosers, cap banks, fuses mix – EMS, manual)
- AMI extended dataset (power & voltage)
- ADMS – New capability

Power System Studies & Tools

- steady-state
  - load (power) flow
    - short-circuit/protection coordination
- dynamic
  - voltage stability (PSLF – Transmission planning)

Emerging Trends in Key Areas

Physical/Cyber Resiliency

Source: http://www.ucsusa.org/global_warming/science_and_impacts/impacts/extreme-weather-climate-change.html#.VvtYFvkrJaU

Source: https://www.fireeye.com/cyber-map/threat-map.html

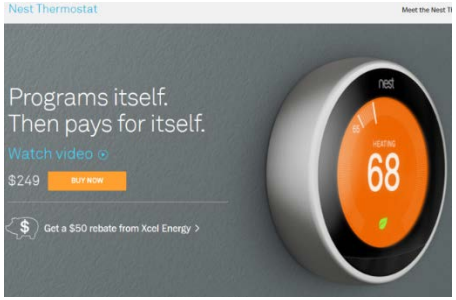
Electric Generation Mix

Source: https://www.epa.gov/cleanpowerplan

Source: APS

Emerging Trends in Key Areas

Customer Evolution



Source: https://nest.com/thermostat/meet-nest-thermostat/?alt=3

Source: https://www.teslamotors.com/powerwall

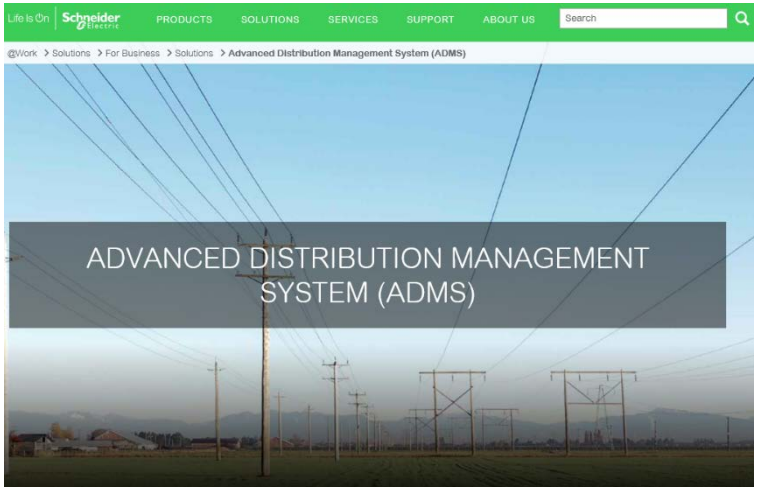
Source: http://energy.gov/articles/askenergysaver-led-lights

Source: http://www.toyota-global.com/showroom/vehicle_gallery/result/prius_plug-in_hybrid/

Source: http://www.solarcity.com/residential/backup-power-supply

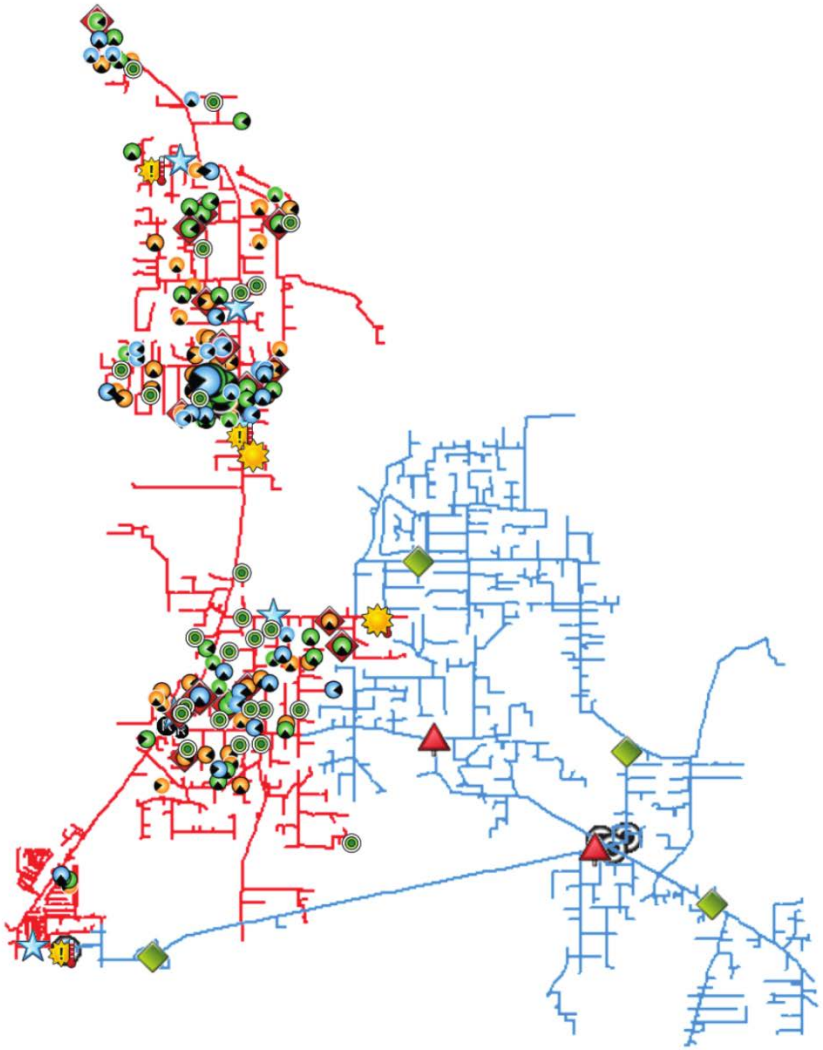
Technology Innovation

Source: http://www.nyserda.ny.gov/All-Programs/Programs/NY-Prize



Source: http://www.schneider-electric.com/b2b/en/solutions/for-business/s4/electric-utilities-advanced-distribution-management-system-adms/

Distributed Generation Integration from a Utility Perspective - Gaps



Situational Awareness

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- equipment status/state/settings (reclosers, cap banks, fuses mix – EMS, manual)
- AMI extended dataset (power & voltage)
- ADMS – New capability
- **equipment specifications/ratings**
- **DG size, location, orientation, specifications**
- **DG point of interconnection "stiffness ratio"**
- **adjacent feeder characteristics**
- **feeder minimum daytime load**
- **measurements interior to feeder**
- **settings for dynamic voltage control devices**
- **Solar irradiance (historic, real-time, forecast)**

Power System Studies & Tools

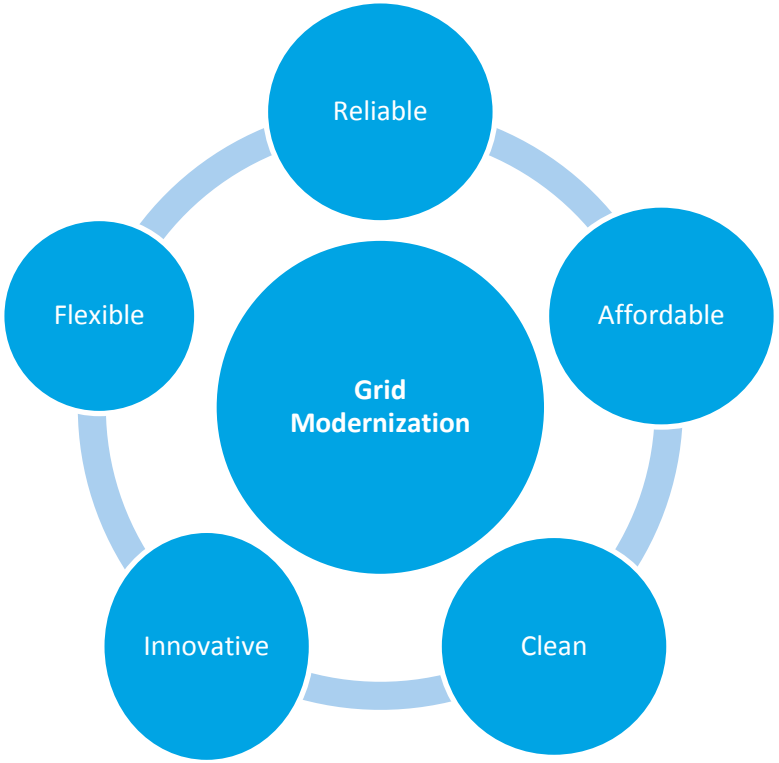
steady-state

- load (power) flow
- short-circuit/protection coordination
- **feeder PV hosting capacity**

dynamic

- voltage stability (PSLF – Transmission Planning)
- **interactions between smart grid devices**
- **dynamic PV hosting capacity**
- **advanced scenarios**
- **optimal location & size of energy storage**
- **control settings for smart inverters**
- **feeder reconfiguration**
- **microgrid applications**
- **aggregation of DG, forecast**
- **Transients - harmonics**

DOE Vision of Emerging Power System



A sustainable, affordable, secure, and reliable electricity grid that drives a clean-energy economy

How do we keep the lights on and protect against threats?

Reliability Goal: 10% reduction in the economic costs of power outages

How do we reduce our environmental impact?

Clean Goal: 50% cut in the costs of Distributed Energy Resources integration

How do we keep costs reasonable for consumers?

Affordability Goal: 33% decrease in cost of reserve margins while maintaining reliability

DOE Grid Modernization Initiative

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Home » Launch of the Grid Modernization Laboratory Consortium

Launch of the Grid Modernization Laboratory Consortium

November 17, 2014 - 9:51am

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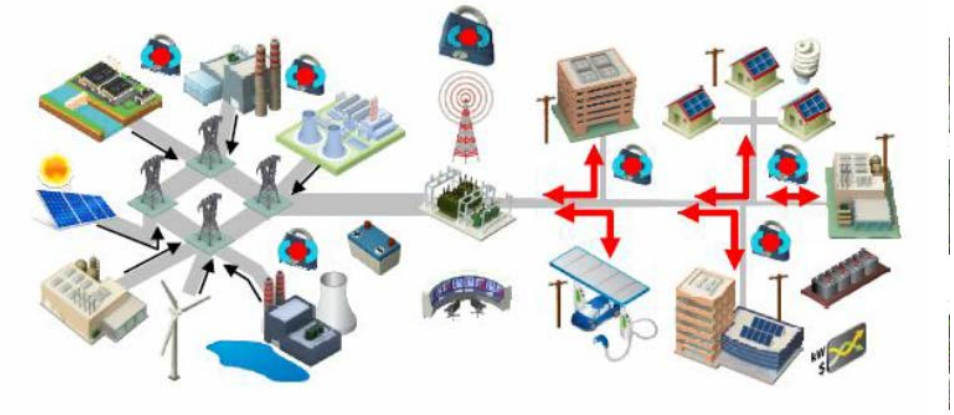

A modern electric grid must deliver reliable, affordable and clean electricity to consumers where and when they want it. Achieving this will require connecting clean energy sources to the grid in a distributed network that enables consumer choice, increased efficiency, and resilience against disruptions due to natural disaster or attack.

Source: http://energy.gov/articles/launch-grid-modernization-laboratory-consortium

Up to $220 Million for more than 80 projects.

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Sandia National Laboratories

OAK RIDGE National Laboratory

BROOKHAVEN NATIONAL LABORATORY

BERKELEY LAB

Los Alamos NATIONAL LABORATORY

INL Idaho National Laboratory

Argonne NATIONAL LABORATORY

NETL

SRNL SAVANNAH RIVER NATIONAL LABORATORY

SLAC NATIONAL ACCELERATOR LABORATORY

GMLC Technical Areas

- Sensing & Measurements
- Devices & Integrated Systems
- System Operations & Power Flow
- Design & Planning Tools
- Security & Resilience
- Institutional Support

Discussion Topics

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Permitting

Tribal Role Options & Project Teams

Resource/ Land Owner

Off-taker/
Energy User

Project Operator/ O&M

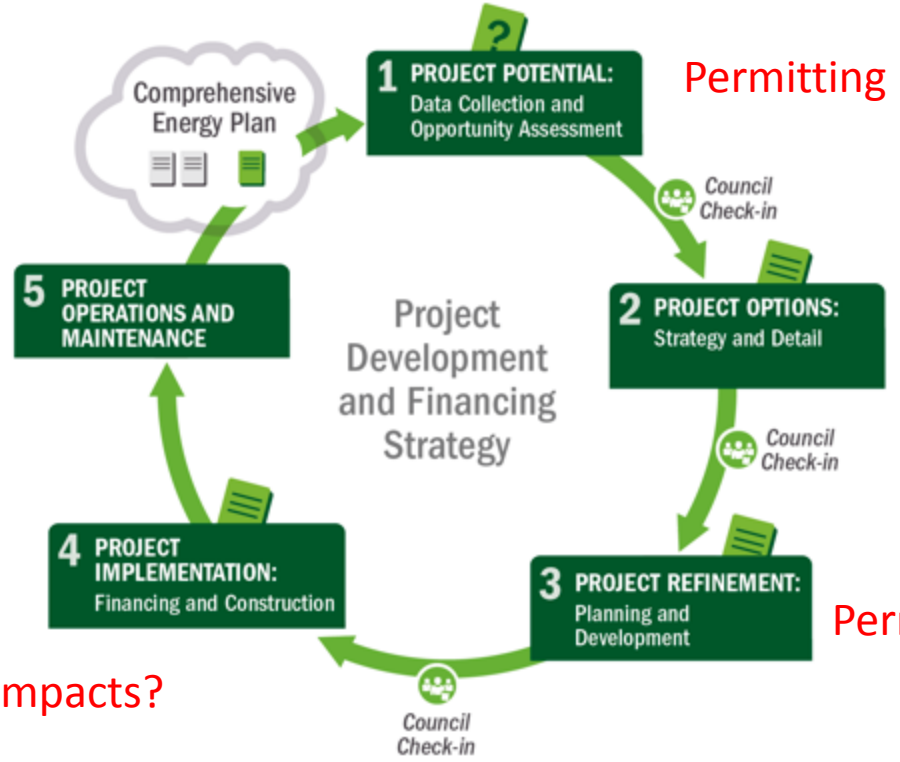
Lender/
Debt Provider

Equity Investor/
Gen. Owner

Project Developer

- **Tribal Members**
  - **Leadership, staff**, community members
  - **Attorneys**, **engineers**, professionals
- **Developer**
  - Business managers, **engineers**, **permitting specialists**, investors, banks, **attorneys**, accountants, power marketers, **procurement specialists**, communications, public relations, **government relations**, corporate finance, project finance, **construction managers**, O&M specialists, asset managers, etc.
- **Utility**
  - **Engineers, attorneys**, **planning specialists, operations specialists, regulatory specialists,** finance, accounting, public relations, communications, systems operators, **construction and field personnel**, maintenance and emergency operations, etc.
- **Government**
  - Tribal government, federal, state, local entities, regulating bodies (public utilities commission), Bureau of Indian Affairs, DOE, Federal Energy Regulatory Commission, etc.

Permitting Impacts



Permitting impacts?

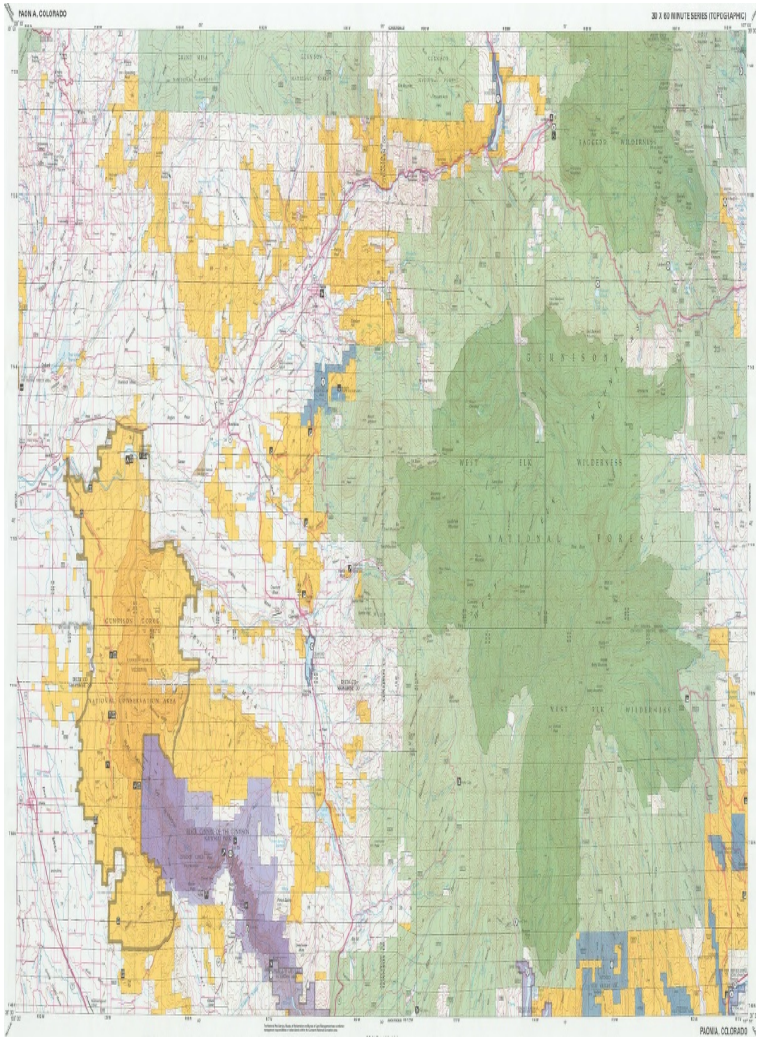
Permitting impacts?

Permitting impacts?

Permitting impacts?

Permitting impacts?
(Compliance)

Permitting/Land Ownership/ Technical Specifications



Source:
http://www.blm.gov/co/st/en/BLM_Programs/geographical_sciences/gis/100kMapIndex.html

Define Scope of Work

- What is the project scale
- Type of RE technology
- Site information:
  - Location
  - Interconnection requirements as known
  - Applicable codes and standards
  - Roof structure, soils, other (as applicable and available)
  - Site prep: fencing, roads, grading limitations, etc.
  - Installation requirements: min/max heights of equipment, vegetation mitigation, design standards for structural/electrical
- Equipment minimum standards and warranties
- Expected minimum performance (recommended) or capacity
- Commissioning plan

Permitting Examples – Federal Level

Environmental Protection Agency
-Underground Injection Control

Council on Environmental Quality
Environmental Impact Statement / Assessment

National Park Service
Prevention of Significant Deterioration (if impacting National Park)

Dept. of Homeland Security
Bridge Permit, Rivers & Harbors, Marine & Harbor Activities

National Oceanic And Atmospheric Administration
Incidental Take Statement /Permit (Endangered Species), Letter of Authorization, Incidental Harassment Authorization

Fish & Wildlife Service
Incidental Take Statement /Permit (Endangered Species)

Federal Aviation Administration
Notice of Proposed Construction or Alteration in Airspace

Mineral Management Services
Outer Continental Shelf Renewable Energy Project Lease, Easement, or ROW Grants

Bureau of Land Management
Project Authorization/lease

Federal Energy Regulatory Commission
Project Authorizations, Operating Licenses & Exemptions

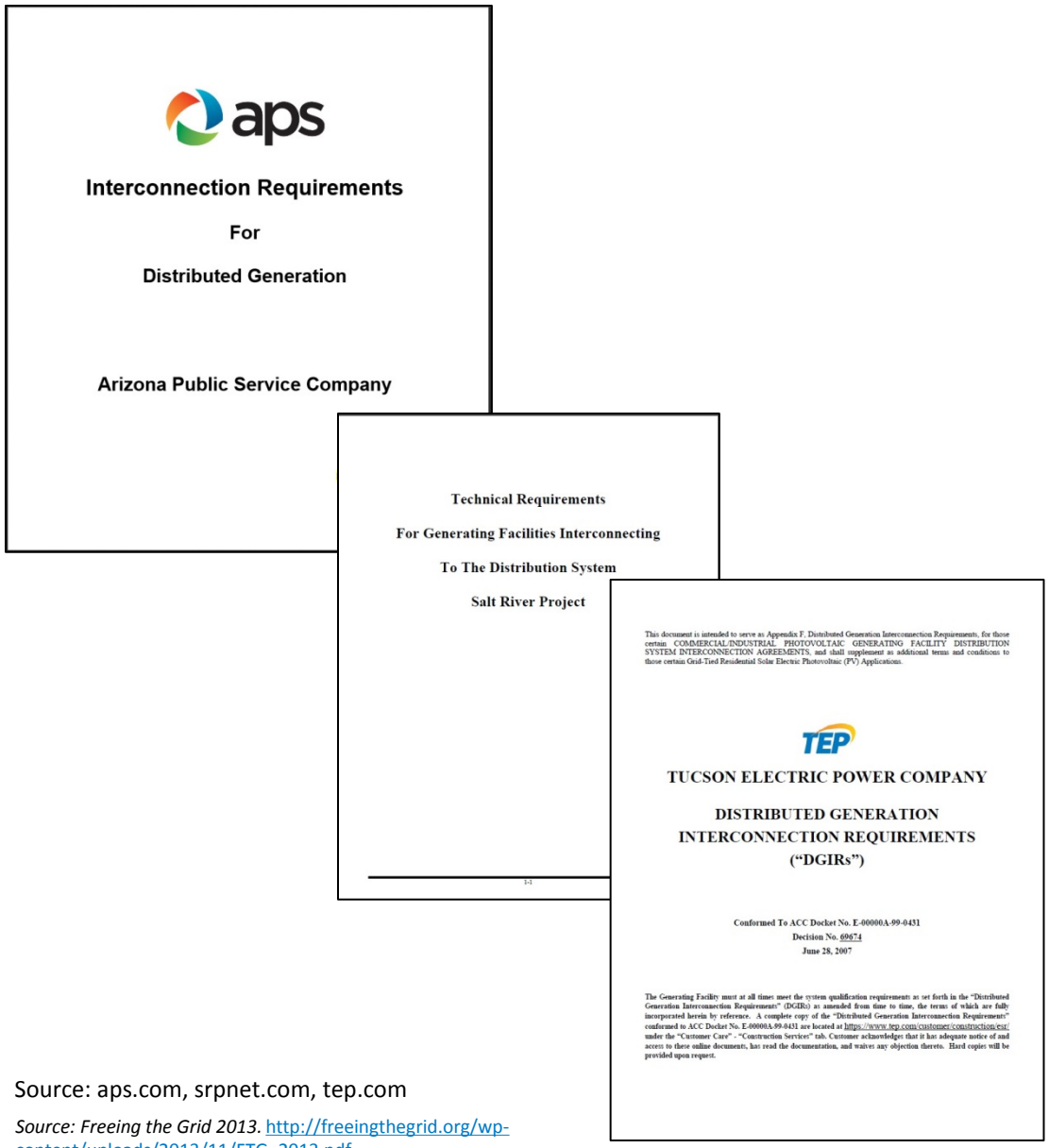
Army Corp of Engineers

Coast Guard

Source: energy.hawaii.gov

Interconnections

Interconnection Agreements



Source: aps.com, srpnet.com, tep.com

Source: Freeing the Grid 2013. http://freeingthegrid.org/wp-content/uploads/2013/11/FTG_2013.pdf

Interconnection Elements

- pre project discussion
- **Application**
- **Technical Scoping**
- **Technical Studies**
  - Feasibility
  - System Impact
  - Facilities Study
- **Interconnection Agreement**

Standards & Codes for Interconnection & Interoperability

IEEE 1547

DER Interconnection System Requirements

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Anti-islanding

IEEE 1547.1

DER Interconnection System Testing

- Over/Under Voltage
- Over/Under Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

UL 1741

DER Interconnection Equipment

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

IEEE 2030

Smart Grid Interoperability Requirements

- Energy Technologies
- End-Use Applications
- Loads

NEC

Article 690 PV Systems:

Article 705 Interconnection Systems:

Utility Interconnection Requirements

Specific to utility

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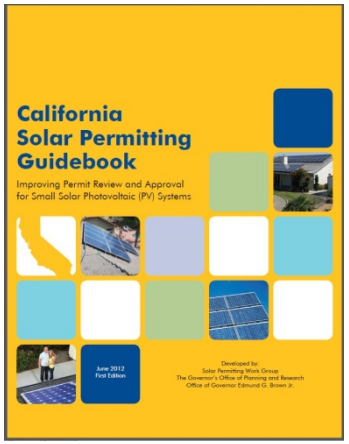
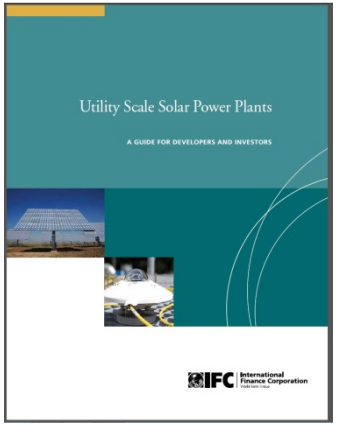
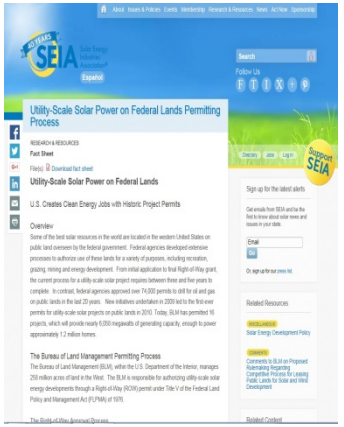


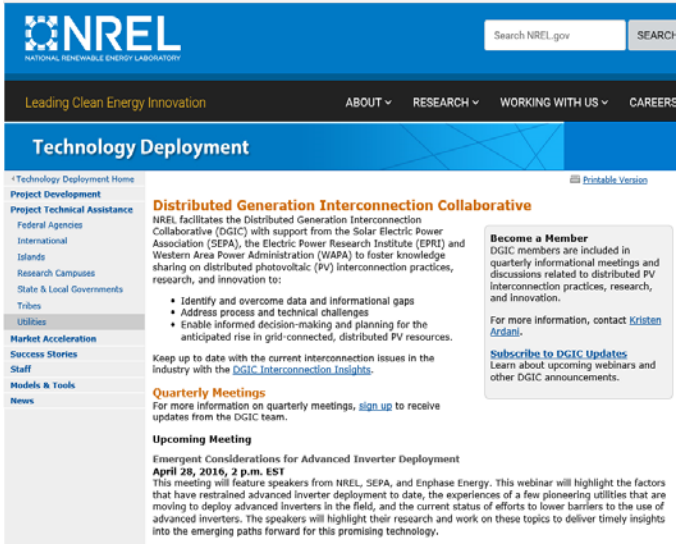
http://opr.ca.gov/docs/California_Solar_Permitting_Guidebook.pdf



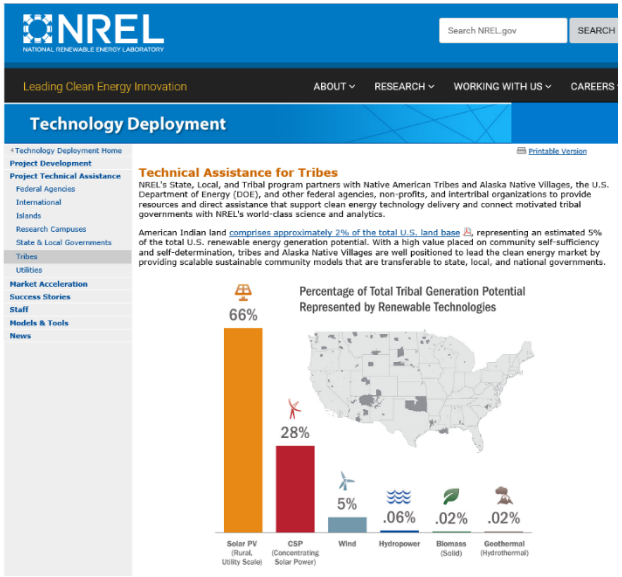
http://www.ifc.org/wps/wcm/connect/04b38b804a178f13b377ffdd29332b51/SOLAR%2BGUIDE%2BBOOK.pdf?MOD=AJPERES



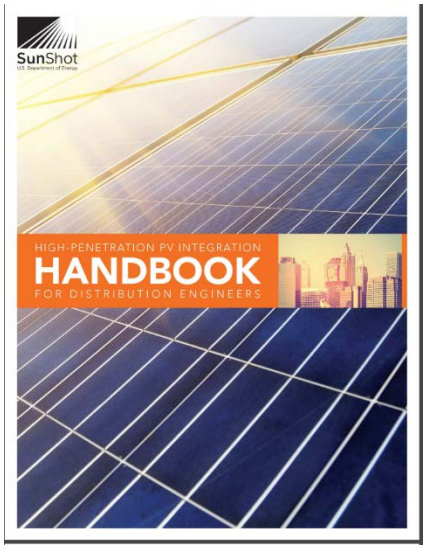
http://www.seia.org/research-resources/utility-scale-solar-power-federal-lands-permitting-process



Source: http://www.nrel.gov/tech_deployment/dgic.html



Source: http://www.nrel.gov/tech_deployment/tech_assistance_tribes.html



http://www.nrel.gov/esi/news/2016/21629.html

Other resources: IREC, BLM, solarpermit.org, EERE…..

Thank You!

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National Renewable Energy Laboratory (NREL)
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