Distributed Renewable Energy Assessment

Final Report

August 11, 2009

Public Interest Energy Research Program

California Energy Commission

- **DISCLAIMER**
- This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

Table of Contents

Table of Contents

This project assessed the potential for <u>distributed energy resources</u> (DRE) to contribute toward California's 33% RPS target.

Situation

- California lawmakers are considering legislation that will raise the state's Renewable Portfolio Standard (RPS) from 20% by 2010 to 33% by 2020.
- This translates into qualified renewable resource electricity generation of as much as 100,000 GWh.

Complication

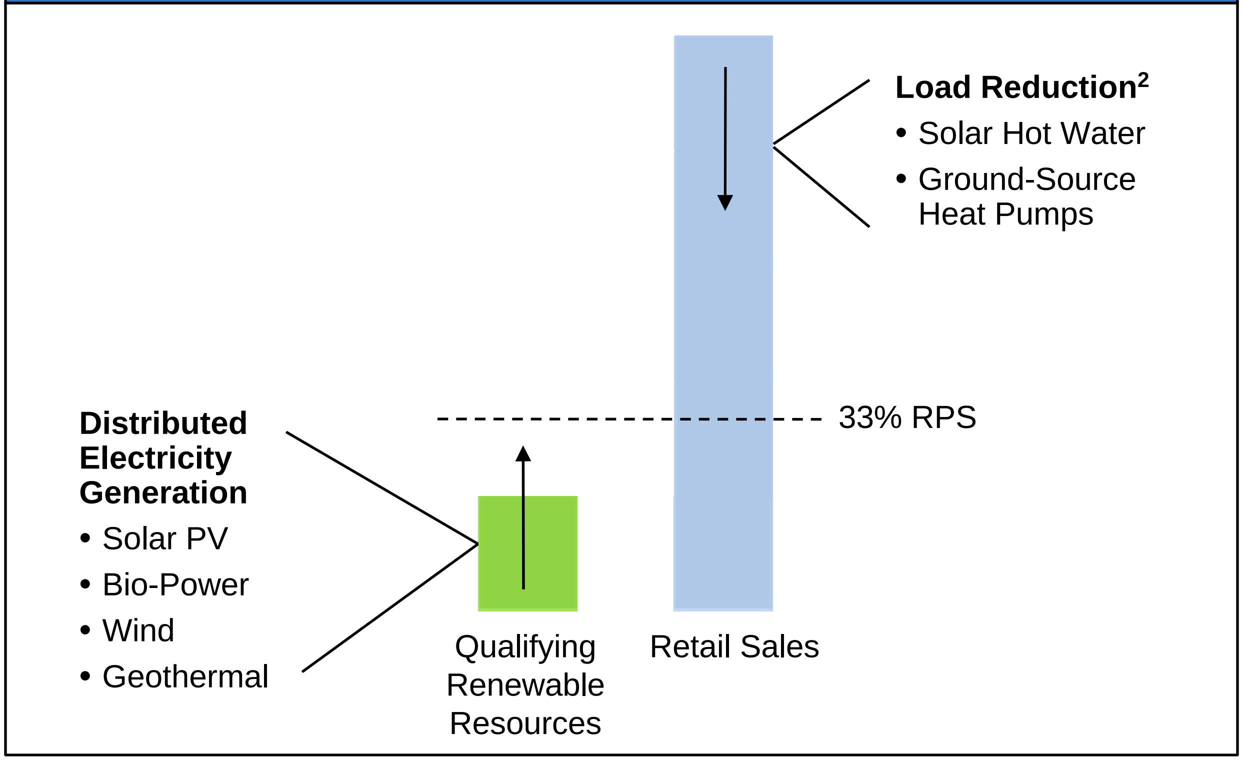
- The additional amount of remote renewable energy requiring transmission to meet the state's goal is referred to as the "renewable net short".
- Assessments of the net-short vary from 45,000 to 75,000 GWh (depending upon the inclusion of Assembly Bill 32 Scoping Plan energy efficiency, rooftop solar and CHP goals).
- New transmission is needed to interconnect central station renewable energy resources. However, the siting, permitting, and financing of new transmission infrastructure face many challenges.
- To mitigate the risk involved with new transmission development, the State would like to understand the potential for distributed renewable energy resources.

Questions

- What is the resource potential for distributed renewable energy in California?
- How much can it contribute to meeting the net-short of the RPS?
- What factors would impact the capture of this potential?

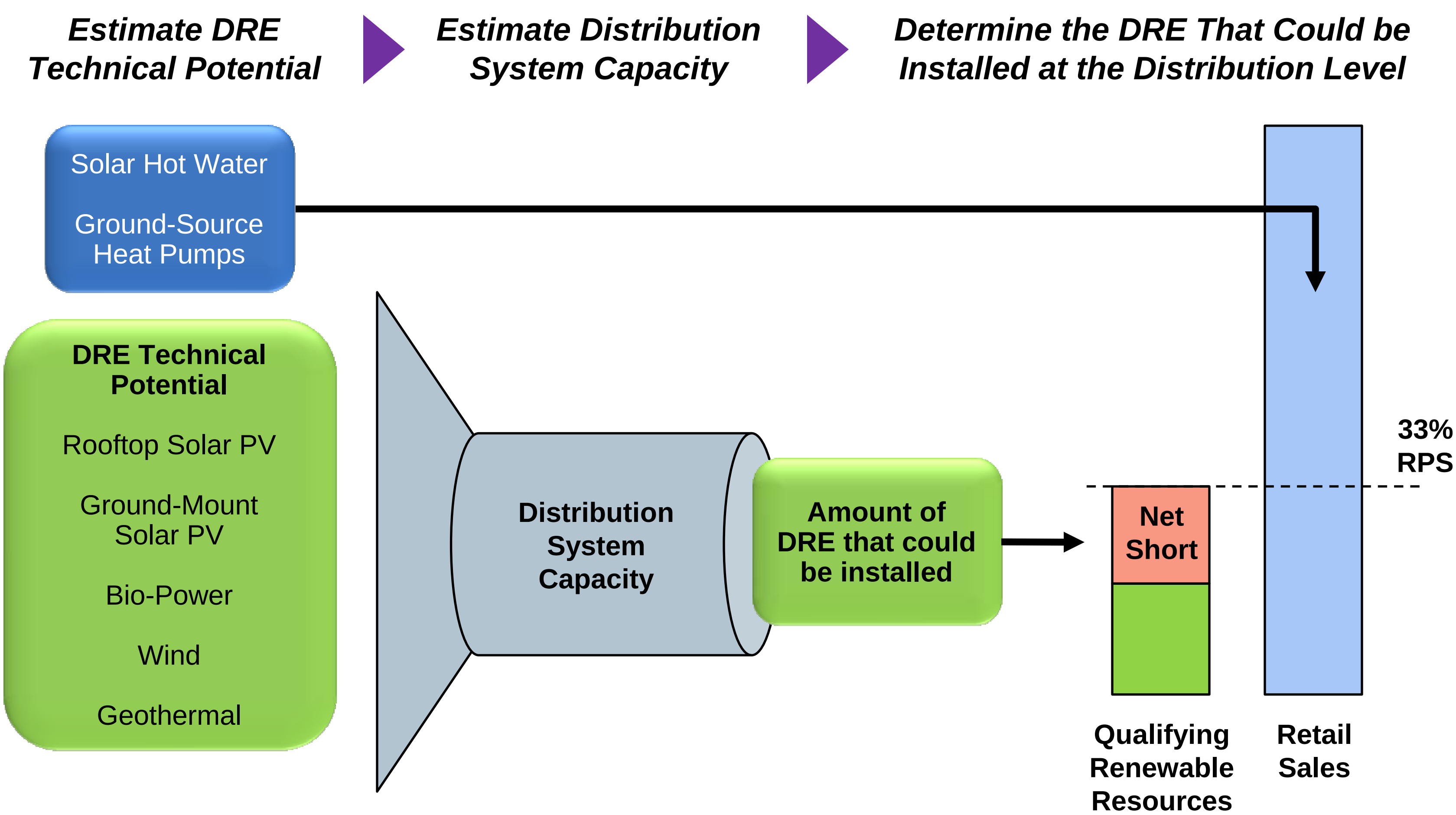
There are two main ways to impact the RPS: (1) increasing the amount of renewables moves the state closer to the RPS target, (2) reducing load lowers the RPS target.

Ways to Help Meet RPS Target with Distributed Renewable Energy[1]



Notes:
1.Shapes not drawn to scale.
2.The classification of solar hot water and ground-source heat pumps as either renewable energy resources or energy efficiency measures has been debated, and is open to interpretation. They are considered in this analysis for the purpose of understanding how they could contribute to achieving the RPS target by reducing load.

To estimate the amount of DRE that could be installed, gross technical potential was constrained by distribution system capacity.



"Technical Potential" begins with total resource potential, and screens out resources that cannot be accessed due to non-economic factors.

Definitions

Theoretical Potential

Total resource potential unconstrained by land use, building considerations, or other non-economic factors.

Technical Potential

Screens out resources that cannot be accessed due to non-economic reasons (shading from trees, poor building orientation, zoning limitations, emissions restrictions, etc).

Economic Potential

Factors in economics and system integration constraints. Includes impacts of RECs and incentives.

Market Penetration

Estimates the diffusion of the technology into the marketplace considering the relative economics and maturity of the options.

Due to size and location, some renewables are necessarily integrated at the distribution level, and can produce electricity or reduce electricity load.

Necessarily Integrated at Distribution Level	Potentially Integrated at Distribution or Transmission Level
• Solar PV (roof) • Solar Hot Water • Ground-Source Heat Pumps	• Solar PV (ground) • Bio-Power • Wind • Geothermal
• All systems will be under 20MW • Systems likely to be in close proximity to distribution system and load	• Many/most systems will be over 20MW due to cost effectiveness • DG systems are bounded by distribution system • **Stand-alone DG potential is difficult to assess**

Identify the key constraints in capturing the technical potential of each resource at the distribution level

Other renewable resources could be integrated at distribution or transmission depending on cost and technical factors. The technical potential of these resources as distributed must be considered carefully.

Table of Contents

The combined technical potential of the resources below far exceeds the renewable net short.

Technical Potential for Selected Technologies				
	Resource	**Estimated Potential (MW)**	**GWh[1]**	**% of Net-Short[2]**
Electricity Generation	Rooftop Solar PV	60,929	96,073	128-213%
Electricity Generation	Ground-Mount Solar PV	19,868,132	31,329,332	41,772-69,621%
Electricity Generation	Bio-Power	5,632	34,535	46-77%
Electricity Generation	Wind	65,782 – 99,945	213,214 – 323,940	284-720%
Electricity Generation	Geothermal	2,862 – 13,716	22,564 – 108,136	30-240%
Load Reduction	Solar Hot Water	N/A	1,246 (building) 218 (swimming pool)	2-3% (building) 0.3-0.5% (swimming pool)
Load Reduction	Ground-Source Heat Pumps	N/A	7,006 – 8,094	9-18%

(Highlighted: Ground-Mount Solar PV, Bio-Power, Wind, Geothermal) The technical potential of these resources could be captured at the distribution OR transmission levels

This assumes that 100% of the technical potential can be achieved, which is unlikely.

Source:
1.Preliminary capacity factors to be refined: Solar PV (18%), Bio-Power (70%), Wind (37%), Geothermal (90%)
2.Low and High Net-Shorts of 45,000 GWh and 75,000 GWh used.

For each DRE resource on the following slides, a standard template is used to summarize technical potential and constraints that limit its achievement.

Photo of technology discussed on each slide is placed here

Renewable Resource (e.g. Rooftop PV)

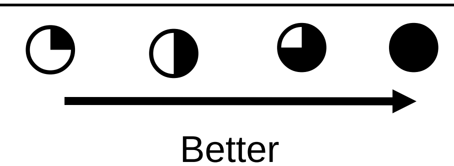
•Characterization of the resource
•Technical potential calculation methodology
•Assumptions

Technical Potential

Capacity (MW)	• Gross technical potential • Not limited to distributed applications
Energy (GWh)	• Energy generated from capacity above • Assumes a capacity factor
% of Net Short	• Energy potential divided by net-short estimates: 45,000-75,000 GWh
Technical Pot'l Relative to Other Resources	• Harvey Ball characterizing relative resource potential

Constraints

Proximity to Distribution System	• Characterizes the distributed nature of the resource
Ease of Siting and Permitting	• Assesses the extent of challenges faced in siting the resource (e.g. environmental, land use, etc.)
Low Operational Impact	• Evaluates level of impact on grid operation (considers intermittency, etc.)



Summary

•Relative evaluation of resource potential

•Characterization of key constraints that limit the capture of gross technical potential

Rooftop PV is the best DRE resource to help California achieve its RPS target due to abundant potential and proximity to the distribution system.

Rooftop PV
- The energy generated from photovoltaic systems mounted on every rooftop in California
- Assumes roof space available after accounting for space that is already occupied or shaded
- Assumes a weighted average PV module efficiency

Technical Potential	
Capacity (MW)	60,929
Energy (GWh)	96,073
% of Net Short	128-213
Technical Pot'l Relative to Other Resources	◕

Constraints	
Proximity to Distribution System	●
Ease of Siting and Permitting	●
Low Operational Impact	◕

◔ ◑ ◕ ● → Better

Summary
- Strong contribution to net short compared to other resources
- Installing and integrating rooftop solar is relatively easy
- The economics of rooftop PV is a major constraint limiting the capture of technical potential
- While solar generation follows load more closely than wind, its output is variable

Ground-Mount PV has huge technical potential but distance from the distribution system and permitting may make it less attractive as DRE.

Ground-Mount PV

- The energy generated from ground-mounted photovoltaic systems placed on every acre of land in California
- Excludes land occupied by: buildings, bodies of water, forests/parks, agriculture, preserves, and sensitive habitats. Also excludes land with a slope greater than 5%.
- Assumes a weighted average PV module efficiency

Technical Potential	
Capacity (MW)	19,868,132
Energy (GWh)	31,329,332
% of Net Short	41,772-69,621
Technical Pot'l Relative to Other Resources	●

Constraints	
Proximity to Distribution System	◑
Ease of Siting and Permitting	◑
Low Operational Impact	◕

◔ ◑ ◕ ●
→ Better

Summary

- Largest technical potential, by far, of all resources
- Ability to capture even a small share of the total technical potential is challenging due to:
  - o System economics
  - o Lack of proximity to the distribution system of much of the resource
  - o Difficulty in permitting in areas with other uses

Bio-Power resources are plentiful. Gaseous-based plants, compared to solid biomass plants, are better suited for distribution system integration.

Bio-Power
•The energy generated from agricultural residue biomass, forest residues and thinnings, municipal wastes, and dedicated biomass crops
•Assumes different efficiency conversion rates for different technologies (direct combustion, gasification combined cycle, gas-to-electricity)

Technical Potential	
Capacity (MW)	5,632
Energy (GWh)	34,535
% of Net Short	46-77
Technical Pot'l Relative to Other Resources	◑

Constraints	
Proximity to Distribution System	◑
Ease of Siting and Permitting	◑
Low Operational Impact	●

◔ ◑ ◕ ● → Better

Summary

•Moderate technical potential
•Clean burning systems are needed to meet CA air quality standards
•Ability to capture technical potential is challenged by:
- o Lack of proximity to the distribution system of much of the solid biomass
- o Cost effectiveness of larger plants (>20 MW) for solid biomass

There is abundant wind technical potential but little of this is located near the distribution system. Fixed costs favor large-scale plants.

Wind

•The energy produced from wind turbines in all areas with low wind speed (300-500 W/m^2) and high wind speed (>500 W/m^2) at hub heights of 50m and 70m

•Excludes: grade > 20%, bodies of water, forested areas, urban areas, national parks and monuments, state parks, and other natural reserves (refuges etc.)

Technical Potential[1]	
Capacity (MW)	65,782 – 99,945
Energy (GWh)	213,214 – 323,940
% of Net Short	284-720
Technical Pot'l Relative to Other Resources	◕

Constraints	
Proximity to Distribution System	◑
Ease of Siting and Permitting	◔
Low Operational Impact	◔

◔ ◑ ◕ ● → Better

Summary

•Significant technical potential

•Ability to capture a small share of the total technical potential is challenging due to:

- Lack of proximity to the distribution system of much of the resource
- Relatively high fixed costs favor larger plants (>20 MW)
- Permitting difficulty (environmental and visual impacts)
- Variable output

Note:
1.Range denotes differences at hub heights of 50m and 70m

The geographic-concentration of Geothermal resources coupled with high exploration and development costs limit its potential as a DRE resource.

Geothermal

- The energy generated from all geothermal energy resources sized greater than one megawatt and with temperature greater than 212°F
- Excludes existing generation resources

Technical Potential	
Capacity (MW)	2,862 -13,716
Energy (GWh)	22,564 – 108,136
% of Net Short	30-240
Technical Pot'l Relative to Other Resources	◑

Constraints	
Proximity to Distribution System	◔
Ease of Siting and Permitting	◔
Low Operational Impact	●

◔ ◑ ◕ ● → Better

Summary

- Moderate technical potential
- Geothermal resources are geographically-concentrated rather than distributed
- Relatively high fixed costs such as those for exploration and development favor larger plants (>20 MW)
- Relatively lengthy permitting (exploratory, resource development, production, and restoration/reclamation phases)

Since less than 10% of California's water is electrically heated, Solar Hot Water technology adoption will contribute very little in meeting the RPS.

Solar Hot Water

•The electricity savings obtained from replacing electric water heaters for buildings (including homes) and swimming pools with solar hot water technology

Technical Potential	
Capacity (MW)	N/A
Energy (GWh)	1,246 (bld'g) 218 (pool)
% of Net Short	2-3 (bld'g) 0.3-0.5 (pool)
Technical Pot'l Relative to Other Resources	◔

Constraints	
Proximity to Distribution System	N/A
Ease of Siting and Permitting	●
Low Operational Impact	N/A

◔ ◑ ◕ ● → Better

Summary

•Limited technical potential – In California, <10% of water is heated with electricity
•Capturing technical potential is easier, relative to other resources, given the independence from the grid and ease of location/installation of solar hot water
•High upfront costs, despite long-term savings potential, can limit adoption

Ground-Source Heat Pumps have relatively small technical potential and have challenging economics in California due to the state's climate.

Ground-Source Heat Pumps
•The electricity savings obtained from replacing every electricity-based residential and commercial heating and cooling system with GSHP technology
•Assumes a range of savings rates based on climate as well as residential vs. commercial use

Technical Potential	
Capacity (MW)	N/A
Energy (GWh)	7,006-8,094
% of Net Short	9-18
Technical Pot'l Relative to Other Resources	◔

Constraints	
Proximity to Distribution System	N/A
Ease of Siting and Permitting	●
Low Operational Impact	N/A

◔ ◑ ◕ ● → Better

Summary

•Fairly small technical potential relative to the other resources
•Capturing the technical potential is difficult. The economics of ground-source heat pumps in California are challenging as the state uses less energy for space conditioning than other states (particularly the Northern and Mountain states) due to its relatively warmer climate

Of the DRE resources, PV and bio-power resources appear to be less difficult to implement in the distribution system between now and 2020.

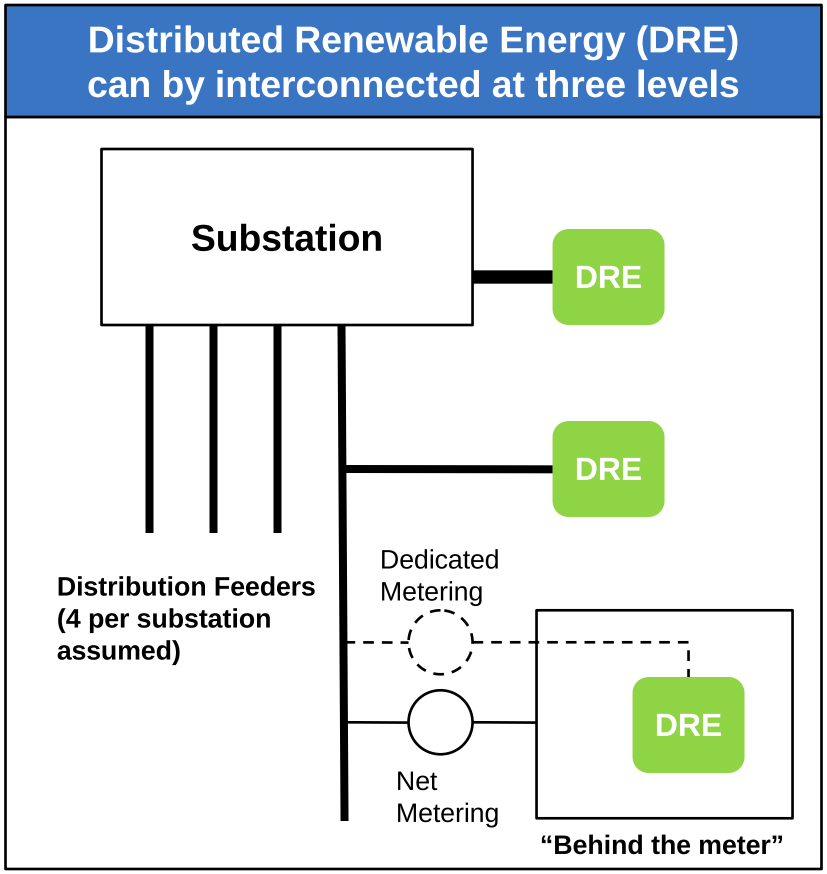
Constraints	Rooftop PV	Ground-Mount PV	Bio-Power	Wind	Geo	SHW	GSHP
Technical Pot'l Relative to Other Resources	◕	●	◑	◕	◑	◔	◔
Proximity to Distribution System	●	◑	◑	◑	◔	N/A	N/A
Ease of Siting and Permitting	●	◑	◑	◔	◔	●	●
Low Operational Impact	◕	◕	●	◔	●	N/A	N/A

Solar hot water and ground source heat pumps are also easy to integrate, but have a much smaller technical potential.

◔ ◑ ◕ ● → Better

Table of Contents

Interconnection of DRE can be done at three levels depending on the location and size of the resource.



Substation interconnection means that the DRE is physically located close to the substation, and a dedicated electrical connection to the low side bus would be made.

Example: at a rural 115/12 kV substation, a 10 MW ground-mounted PV farm adjacent to the substation could be connected to the 12 kV bus through a dedicated bank.

Primary Distribution interconnection assumes that the DRE is connected directly to the distribution system, and is not integrated with a customer's electrical system.

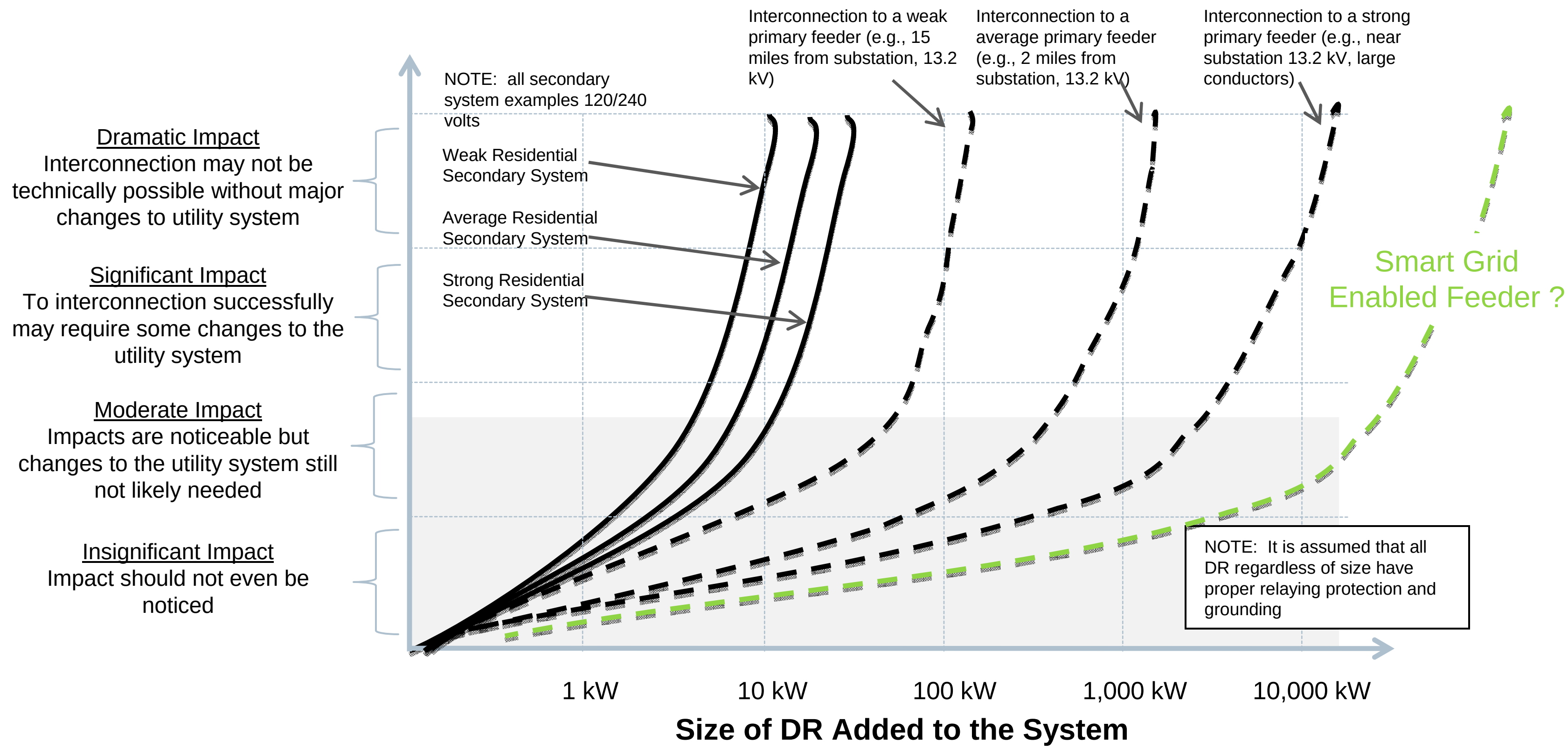
Example: at a landfill served by a 12 kV primary distribution feeder, a 2 MW landfill gas generator could be connected to the 12 kV feeder.

Behind the Meter interconnection assumes the DRE is integrated with a customer's electrical system, and either net metering or dedicated metering could be employed.

Example: at a residential dwelling, a 5 kW rooftop PV system is interconnected to the building's electrical system.

Each point of interconnection has a practical limit based on the impact of distributed generation on the distribution system.

A 2001 EPRI study shows that interconnecting DG on distribution feeders in amounts greater than about 500 kW can require utility system changes.



Source: *Integrating Distributed Resources into Electric Utility Distribution Systems: EPRI White Paper,* EPRI, Palo Alto, CA: 2001. 1004061.

More recent studies indicate that the amount of capacity that can be accommodated on distribution feeders varies widely.

Utilities have expressed concern about high DG penetration, but some studies indicated that typical feeders could tolerate it.

Some utilities have expressed concerns about high DRE penetration on feeders	Simulation and system analysis has shown that a significant amount of DRE could be integrated
• Interconnection of distributed generation, including PV, is evaluated on a case-by-case basis • Distributed generation capacity is limited to 15% of peak feeder load (Rule 21) • Regulating voltage along distribution feeders is a concern • High PV output and low load raises concerns for reverse power flow	• Recent analysis found that approximately 69% of the California IOU substations can interconnect DRE projects of 10 MW or smaller.[1] • Another study by GE examined the effect of DG on feeders and found that limits could range from 15% to 50% of feeder capacity depending on the location of the DG along the feeder, and how it was distributed.[2] • The Smart Grid and energy storage could help enable DRE penetrations at the higher end.

Source: Navigant Consulting, Smart Grid-PV Multi-Client Study, 2008.

Source:
1.Rulemaking 08-08-009, Administrative Law Judge's Ruling on Additional Commission Consideration of a Feed-In Tariff, Appendix B: Determination of Appropriate Feed-in Tariff Size. August 21, 2008.
2.US Department of Energy, The Potential Benefits of Distributed Generation and Rate-Related Issues That May Impede Their Expansion, February 2007. Referenced analysis done by GE Corporate Research and Development, 2003.

Complexities with modeling the distribution system on a large scale will mean that the impact of high penetrations of DRE may be unclear until large amounts are installed and operational.

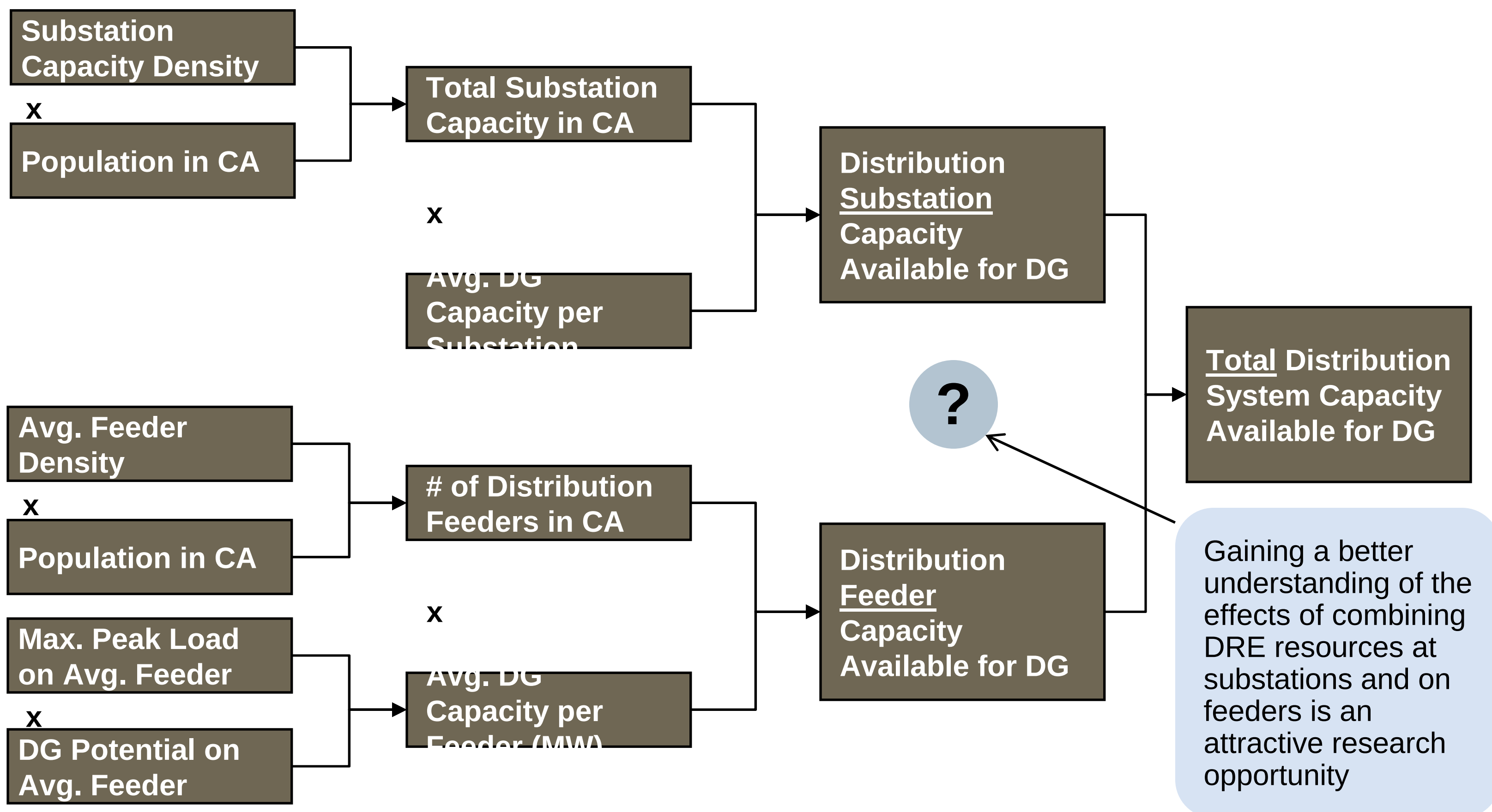
This study assumes that DRE is interconnected at substations or on feeders, either directly or behind the meter.

Level	DRE Size Range	Assumptions
Substation	20 MW or less	DRE is located near the substation and is interconnected by a short, dedicated connection to the low side substation bus (distribution). It is assumed that many substations may not be suitable for interconnecting DRE. Some substations are located in areas where it will be impractical to locate, site, or develop DRE resources. In other cases, it may be impractical to modify the substation to accomplish the electrical interconnection (e.g., size/space constraints in dense urban areas, or location in environmentally sensitive area)
Feeders	3 MW or less per feeder	DRE is interconnected directly to primary distribution or behind the meter, and varies in size depending on the resource. Given that a typical distribution feeder (12 kV) has a maximum capacity of about 10 MVA, this analysis assumes that aggregated DRE would not exceed 3 MW. Total DRE would most likely be limited to 10% to 30% of peak feeder load. (see following analysis) It assumed that most distribution feeders will be suitable for interconnecting some DRE, either directly, or mounted on buildings (behind the meter)

While some prior studies have examined the interconnection of DG at substations, and others have analyzed the impacts of distributed generation on distribution feeders, no studies have tried to estimate the combined capacity of a substation and the distribution feeders that emanate from it. For the purposes of this study, we are assuming that the total capacity of the DRE resources connected on distribution feeders would not exceed the limit assumed for DRE resources connected at a substation. Based on the analysis of substation and feeder data in California, on average, there are about four distribution feeders fed from each substation. With a limit of 3 MW per feeder, this means that a substation could integrate up to 12 MW of feeder DRE, plus another 8 MW of DRE connected at the substation, so long as the substation could handle a total of 20 MW.

The total capacity of the distribution system for integrating DRE is a combination of substation capacity and distribution feeder capacity.

The Total Distribution Capacity Available for DG in California Includes Substations and Feeders



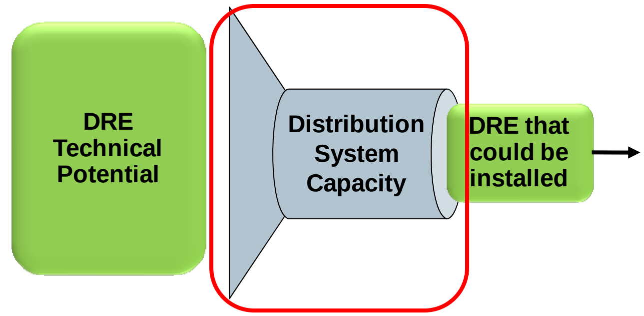
By 2020, gross distribution capacity could be 75 GW at the substation level, and 113 GW at the feeder level.

Overview Substation Capacity Approach

- Use FERC Form 1 data to identify all IOU distribution substations larger than 10 MVA
- Assign each substation to a county, and determine the correlation between the substation capacity in a county and the county's population density
- Use the capacity per population factor to estimate the substation capacity in counties not covered by IOUs

Overview of Distribution Feeder Approach

- Utilize publicly available data for the number of distribution feeders in various utility service areas
- Analyze correlations between the number of feeders in a utility service areas and the population of that service area
- Use correlations to estimate the number of feeders per county based on the population of the county



Estimated Distribution System Capacity

Level	2008	2020
Substations	66 GW	75 GW
Feeders	100 GW	113 GW
Total	166 GW	188 GW

Details for the estimation of distribution system capacity are included in Appendix B.

Estimating the amount of DRE that could be installed on distribution is described on the following slides.

The capacity of the DRE that could be connected on feeders and substations is estimated separately.

Process for Estimating the DRE That Could be Connected to Distribution

Estimate DRE Capacity That Could Be Connected on Feeders

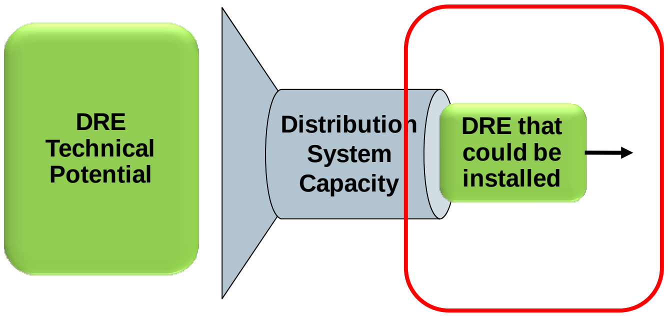
- Begin with the total number of feeders
- Estimate the peak load on each feeder (e.g., 10 MW)
- Multiply the number of feeders times the feeder peak load times the estimated potential DRE penetration on the feeder (e.g., 15%)

Estimate DRE Capacity That Could Be Connected at Substations

- Estimate the number of distribution substations at which a DRE resource could be connected
- Multiply the number of substations by the size of DRE resource (< 20 MW)

Estimate the Combined DRE Capacity That Could Be Connected

- Compare the estimates of DRE that could be connected on feeders and substations
- Limit the combination to the capacity that could be connected at substations[1]



Notes:
1.Assumes that the DRE capacity connected to feeders cannot exceed the amount of DRE capacity that could be connected at substations. With additional research, this limit could be raised.

It is estimated that distribution feeders in California could accommodate between 15 GW and 34 GW of DRE by 2020.

Estimate for DRE Capacity That Could Be Connected on Feeders

	2008	2020
Feeder peak load	10 MW	10 MW
Number of Feeders	x 10,000	x 11,300[1]
DG penetration allowed	x 15%[2]	x 30%[3]
DRE Capacity	15,000 MW	33,900 MW

Notes:

1. Estimate of the number of feeders in California based on 2008 data. The estimate for 2020 assumes a 1% per year growth in population, and commensurate growth in the number of distribution feeders.
2. DG penetration allowance is based on California Rule 21 (http://www.energy.ca.gov/distgen/interconnection/california_requirements.html)
3. The allowance of 30% in 2020 is based on “Feed-in Tariff for Renewable Generators Greater Than 1.5 MW,” Appendix B: Determination of Appropriate Feed-in Tariff Size, Energy Division Staff Proposal, March 27, 2009.

It is estimated that substations in California could accommodate between 6.7 GW and 7.6 GW of DRE by 2020.

Estimate for DRE Capacity That Could Be Connected at Substations

	2008	2020
DRE Capacity that could be connected at IOU Substations	5,000 MW[1]	5,600 MW[3]
DRE Capacity that could be connected at all California Substations	6,700 MW[2]	7,600 MW[3]

Notes:

1. Estimate from "Feed-in Tariff for Renewable Generators Greater Than 1.5 MW," Appendix B: Determination of Appropriate Feed-in Tariff Size, Energy Division Staff Proposal, March 27, 2009. The study found that 500 substations could accommodate a PV installation, and that the size of each installation was 10 MW.
2. Estimate for IOU substation capacity from Note 1 scaled based on the estimated total substation capacity in California (see Appendix).
3. The estimate for 2020 assumes a 1% per year growth in population, and commensurate growth in substation capacity and available capacity for DRE.

For this study, it is estimated that between 6.7 MW and 7.6 MW of DRE could be connected at the distribution level.

Estimate of DRE Capacity That Could Be Connected at the Distribution Level

	2008	2020
DRE Capacity on Feeders	15,000 MW	33,900 MW
DRE Capacity that could be connected at Substations	6,700 MW	7,600 MW
	Capped at Substation Capacity (see Note 1)	
DRE Capacity that could be connected at Distribution	6,700 MW	7,600 MW

Notes:
1. Assumes that the DRE capacity connected to feeders cannot exceed the amount of DRE capacity that could be connected at substations. With additional research, this limit could be raised.

Table of Contents

By 2020, feeders could potentially accommodate 15-34 GW of DRE, and substations could potentially accommodate 7-8 GW.

Level	Range of DRE that could potentially be installed at distribution level by 2020
Feeders	15 GW to 34 GW
Substations	7 GW to 8 GW

Technical studies examining the combined effects of high penetrations of DRE on feeders and substations are needed to determine the total amount of DRE that could be implemented at the distribution level.

10 GW of DRE capacity installed by 2020 could produce about 15,000 GWh of renewable energy.

Estimate of DRE Capacity and Energy Production in California by 2020

Estimate of MW Potential Achieved				
DRE Resource	MW Installed	Capacity Factor	GWh Produced	
Roof PV	3,000	15%	3,942	Based on California Solar Initiative goal
Ground PV	6,500	15%	8,541	Based on wholesale distributed solar in CEC-REO high DG scenario[1]
Wind	-	25%	-	Assumes wind is implemented in larger plants (not distributed)
Bio-Power	500	60%	2,628	Based on biomass (RETI) and biogas (contracted) in CEC-REO high DG scenario[1]
	10,000		15,111	

1. Barker, Kevin, CEC, California's Existing Biopower and Progress toward Reaching the Bioenergy Executive Order S-06-06, Setting the Bar for Biopower, April 21, 2009.

DRE Resource	Tech Pot GWh	Capture Rate %	Captured GWh	Portfolio Contribution	Capacity Factor	Weighted Capacity Factor
Roof PV	96,073	4.10%	3,942	26%	15%	3.9%
Ground PV	31,329,332	0.03%	8,541	57%	15%	8.5%
Wind	10,000,000	0.00%	-	0%	25%	0.0%
Bio-Power	34,535	7.61%	2,628	17%	60%	10.4%
			15,111	GWh	Total WCF	22.8%
			45,000	GWh (Net Short)		
			22.8%	Capacity Factor of DRE Mix		
			22,505	MW of DRE Capacity Needed to Meet Net Short		

Source: Discussions with CEC-REO and Navigant Consulting analysis

About 22.5 GW of DRE capacity would be needed to meet the net short.

The technical potential of DRE and the distribution system of 2020 could make a significant contribution to meeting the Net Short of 45,000 GWh.

- The gross technical potential of renewable resources in California far exceeds the net short.
- A number of important constraints, including distribution system capacity, will limit the amount of DRE that can be integrated at the distribution level.
- Assuming that a sufficient amount of the gross technical potential of renewables can be captured, it appears that the distribution system may be able to accommodate enough DRE to help California meet the renewable net short.

Research and detailed technical studies must be completed to ensure that the distribution system can handle a large amount of DRE.

Key Research Questions and Feasibility Studies
• Key Research Questions - Can feeder penetration guidelines for DRE (e.g., 15% of peak load) be broadly applied? - Are some DRE technologies more easily integrated than others? (For example, PV's output profile tends to offset daytime feeder loads from air conditioning.) - What role will the Smart Grid play in managing higher penetrations of DRE on feeders and at substations? - What benefits could be derived from DRE in high penetrations? • Feasibility Studies to test DRE targets - 5,000 MW by 2015 [1] - 10,000 MW by 2020 [2]

Further research is needed to understand the impacts of installing high penetrations of DRE over large areas of the electricity distribution system in California.

Notes:

1.The purpose for the 2015 goal is to study how much of the roughly 5,000 MW of "capacity surplus" in the low-load sensitivity of the 33%RPS Reference Case could be avoided with wholesale distribution renewable energy. See CPUC, 33% Renewables Portfolio Standard, Implementation Analysis, Preliminary Results, Low-load sensitivity of the 33% RPS Reference Case, p. 29, 30, 61, 63, June 2009. http://www.cpuc.ca.gov/NR/rdonlyres/1865C207-FEB5-43CF-99EB-A212B78467F6/0/33PercentRPSImplementationAnalysisInterimReport.pdf.

2.Barker, Kevin, CEC, California's Existing Biopower and Progress toward Reaching the Bioenergy Executive Order S-06-06, Setting the Bar for Biopower, April 21, 2009. http://www.energy.ca.gov/2009_energypolicy/documents/2009-04-21_workshop/presentations/03-Barker_Biomass_Workshop_Presentation_KMB_pd_JO_go_4-16-09_pd.pdf

Table of Contents

A	Technical Potential of DRE Resources
B	Distribution System Capacity

A Technical Potential of DRE Resources

B Distribution System Capacity

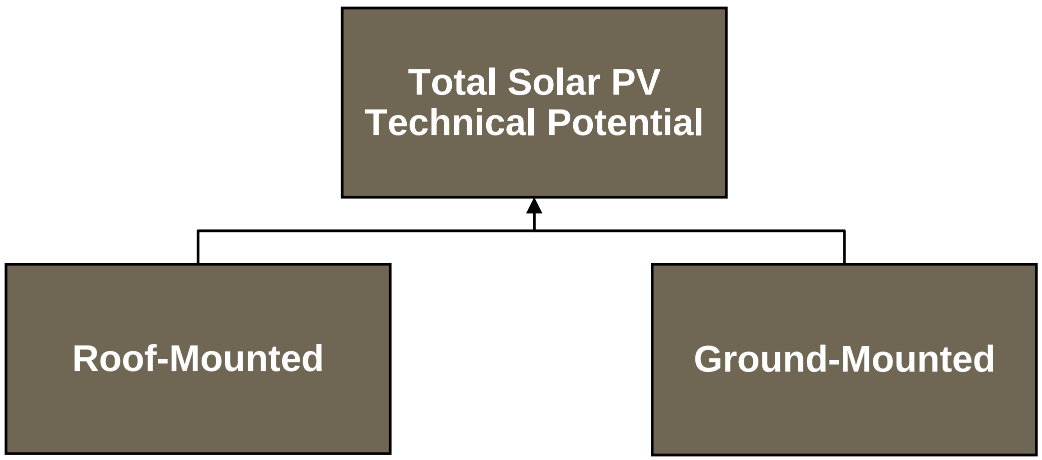
A Technical Potential of DRE Resources

- Solar PV
- Bio-Power
- Wind
- Geothermal
- Solar Hot Water
- Ground-Source Heat Pumps

B Distribution System Capacity

Total technical potential for solar PV considers both roof- and ground-mounted systems.

Key Components of Technical Potential Estimate for Distributed Solar PV in California



- Residential Buildings
- Commercial Buildings

- Suitable land

NCI used its previous work for PIER to estimate technical rooftop potential and projected the results forward using assumed efficiencies.

Roof-Mounted PV Technical Potential Methodology	
Estimate Floor Space	NCI started with the total amount of floor space in CA residential and commercial buildings, by county, provided by CEC for 2010. A compound annual growth rate was used to project to 2020.
Estimate Roof Space	NCI translated floor space into roof space based on the *Regional Economic Research Inc.* 2002 report for residential buildings and a 2003 EIA report for commercial buildings.
Estimate PV Access Factor	NCI developed PV access factors that were based upon a NCI study for a major U.S. utility company. The study was adjusted for California conditions based upon interviews with Ed Kern of Irradiance.
Estimate PV Power Density	NCI developed a weighted average module efficiency using market share for the three most prevalent technologies in CA (p-Si, m-Si, and a-Si). The power density of a module was calculated and adjusted to arrive at the power density of a PV system by applying a packing factor of 1.25, which accounts for space needed for the system.

Technical_Potential = Roof_space x PV_Access_Factor x PV_Power_Density

Source: *CEC-500-2007-048: California Rooftop Photovoltaic (PV) Resource Assessment And Growth Potential By County*

NCI used existing studies to estimate current ground mount technical potential and projected the results forward using assumed efficiencies.

Ground-Mounted PV Technical Potential Methodology	
Begin with GIS Assessment[1]	The 2005 CEC analysis entitled *California Solar Resources* performed a GIS analysis to estimate the technical land available for PV. The analysis excluded the following land types: •Bodies of water •Forests; Parks •Agricultural Land •Preserves •Areas with sensitive habitats and •Slope greater than 5%
Subtract Rooftop Technical Potential	The GIS assessment did not include an exclusion for building structures, thus NCI subtracted commercial and residential technical potential[2], by county, to arrive at an estimate for ground-mounted technical potential.
Add Additional Exclusions for Paved Surfaces[3]	An additional 25% exclusion criteria was applied to each county for paved surfaces and additional buffer zones that would exclude land from being developable by solar PV, which was not accounted for in the original GIs assessment.
Project to 2020	To project technical potential to 2020, NCI assumed a 2020 market weighted efficiency of 15.8% efficient modules.

Source:
1.2005 *California Solar Resources*
2.Based on both the 2005 *California Solar Resources* study and *CEC-500-2007-048: California Rooftop Photovoltaic (PV) Resource Assessment And Growth Potential By County*
3.25% is a rough estimate given the lack of readily available road-exclusion estimates in California.

As expected, ground mounted technical potential is very high.

Solar PV Technical Potential [MW_{pDC}]					
County	Roof-Mounted	Ground-Mounted	County	Roof-Mounted	Ground-Mounted
Alameda	2,417	121,492	Orange	4,763	162,276
Alpine	59	55,570	Placer	1,195	95,045
Amador	83	45,810	Plumas	66	84,821
Butte	407	94,698	Riverside	4,940	1,482,249
Calaveras	140	79,710	Sacramento	2,968	173,852
Colusa	35	68,717	San Benito	67	177,079
Contra Costa	1,357	107,270	San Bernardino	3,967	4,716,029
Del Norte	31	24,002	San Diego	4,950	714,186
El Dorado	446	80,008	San Francisco	1,154	8,394
Fresno	1,558	374,661	San Joaquin	1,519	107,185
Glenn	38	117,585	San Luis Obispo	516	491,841
Humboldt	163	104,287	San Mateo	960	55,073
Imperial	328	883,764	Santa Barbara	620	348,016
Inyo	27	1,895,896	Santa Clara	2,683	184,636
Kern	1,457	1,234,409	Santa Cruz	312	34,663
Kings	250	102,194	Shasta	337	194,444
Lake	75	115,841	Sierra	10	41,217
Lassen	61	583,186	Siskiyou	89	309,897
Los Angeles	13,260	774,714	Solano	649	98,334
Madera	267	165,265	Sonoma	729	126,017
Marin	304	53,408	Stanislaus	1,002	166,437
Mariposa	31	114,785	Sutter	197	19,469
Mendocino	108	146,930	Tehama	99	282,860
Merced	496	216,904	Trinity	17	75,863
Modoc	13	501,612	Tulare	683	256,335
Mono	44	413,553	Tuolumne	125	139,040
Monterey	528	389,249	Ventura	1,282	232,761
Napa	220	71,031	Yolo	447	67,893
Nevada	218	41,414	Yuba	160	44,253
Total				60,929	19,868,132

NCI's PV technical potential is significantly higher than other PV estimates because these other studies are not true technical potentials. Rather, they are constrained by the distribution system.

PV Potential Comparison			
Source/Report	**Estimated Potential (MW)**	**Approach**	
NCI/CEC 2007	60,929 (roof) 26,490,842 (ground)	Resource-based technical potential unconstrained by electrical distribution system	Pure Resource Technical Potential
CEC 2005	38,013 (roof)	Assumed 2.5kW system on each <u>new</u> home in 2005 and <u>existing</u> commercial building in 2005.	Pure Resource Technical Potential
CPUC	5,000 (roof + ground)	System size is limited by the Rule 21 interconnection standard[1]	Distribution System-Constrained Potential
E3[2]	15,000 (roof + ground)	Analysis used technical feasibility of PV based on % of feeder peak load (not to exceed 100%)	Distribution System-Constrained Potential
RETI[3]	27,500 (ground mount)	A proxy project was defined as a 20MW system at a suitable substation location (Two 20 MW projects if substation size permits)	Distribution System-Constrained Potential

Source:

1.Rule 21 specifies maximum generator size relative to the peak load on the load at the point of interconnection at 15%. In the CPUC report, the criterion was adjusted to 30% for solar PV.

2.Snuller Price, E3: *Revisions to Wholesale DG Potential.* 15 January 2009.

3.RETI Stakeholder Steering Committee (Phase 1B report). 6.0 Project Identification and Characterization. Section 6.4 Solar Photovoltaic 02 January 2009.

A Technical Potential of DRE Resources

- Solar PV
- Bio-Power
- Wind
- Geothermal
- Solar Hot Water
- Ground-Source Heat Pumps

B Distribution System Capacity

Bio-Power resources are mapped to specific conversion processes in order to estimate MW and MWh potential.

Key Components of Technical Potential Estimate for Distributed Bio-Power in California

Total Bio-Power Technical Potential

Solid Biomass

- Logging residues
- Mill residues
- Other forest biomass
- Agricultural residues
- Food processing waste
- Urban biomass residues
- Energy crops

Gaseous Biomass

- Landfills
- Food processing waste
- Wastewater processing waste
- Animal manure

Bio-Power resource potentials were drawn primarily from a 2008 draft report for CEC: *An Assessment of Biomass Resources in California, 2007*.

Bio-Power Resources: Primary Source of Data

Study Background

- The 2008 draft report by the California Biomass Collaborative, *An Assessment of Biomass Resources in California, 2007*, is an update to a previous biomass technical potential analysis for the state.
- The study provides technical resource (BDT[1]/year) and power potential (MW, MWh) for the following biomass categories, **without regard to distribution capacity limitations or typical project sizes**:
  - Agricultural residue biomass
  - Forest residues and thinnings
  - Municipal wastes
  - Dedicated biomass crops[2]

Resulting Potential

- The study finds the following technical potential in 2007.[3]

Technical Potential	Agriculture	Forest Residues	Municipal Waste	Dedicated Crops	Total
MM BDT/year	8.6	14.3	9.6	0	33
MW	891	1,907	1,027	0	3,820

NCI Approach

- NCI will rely upon the technical potential estimates (BDT/yr) provided in this Study and, when appropriate, will use the conversion factors to arrive at a MW and MWh technical potential. The following slide lists the conversion factors used in the analysis.

Source:
1. BDT = Bone Dry Ton
2. Dedicate biomass crops assumed in this study are not clearly defined; instead, several crops are mentioned as potential future resources.
3. The CA Biomass Collaborative Study also finds technical potential by 2020, which is used in NCI's estimates

NCI consolidated the resource categories found in the 2008 draft report.

2007 Draft Report Resource Categories
Agricultural Residue Biomass
Orchard and vineyard crops
Field and seed crops
Vegetable crops
Food & fiber processing residues
Animal manures
Forest Residues and Thinnings
Forest thinnings and slash
Mill residues
Shrubland treatment biomass (chaparral)
Municipal Wastes
Biomass fraction of municipal solid waste (MSW)
Biosolids from waste water treatment operations
Landfill gas
Sewage digester gas
Dedicated Biomass Crops

NCI Bio-Power Quantification Categories
Solid Biomass
Orchard/Vineyard crops
Field & seed crops
Vegetable crops
Food & fiber processing – non-meat
Forest Residues and Thinnings (all)
Dedicated Biomass Crops
MSW/Biosolids
Gaseous Biomass
Meat food processing
Animal manures
Landfill waste
Wastewater processing waste

Forest biomass and landfilled waste are the most abundant biomass resources in CA, estimated at 2,250 MW and 1,280 MW, respectively.

Bio-Power Technical Potential (includes biomass and waste currently used for energy production): by 2020				
Biomass Resource		Quantities (dry tons/yr)	MWh/yr	MW (85% cap. factor)[4]
Solid Biomass	Orchard & Vineyard Crops	2,198,900	2,984,368	401
	Field & Seed Crops	1,976,100	2,365,927	318
	Vegetable Crops	150,100	183,821	25
	Food & Fiber Processing	923280	1,071,654	144
	Forest Biomass[1]	14265700	18,062,082	2,426
	MSW[2]	4,467,550	7,597,977	1,020
	Biosolids Diverted	654,400	685,624	92
	Energy Crops	4,500,000	5,817,186	781
Gaseous Biomass	Food Processing	433200	428,868	58
	Animal Manure	13,349,630	2,676,113	359
	Landfill Waste[2]	N/A	9,554,858	1,283
	Wastewater Processing Waste	N/A	387,974	66
Total[3]		38,451,310	44,218,474	5,953

Results are Unconstrained by the Distribution System Capacity

Source:

1. Includes Forest Thinnings, Forest Slash, Shrub & Mill Residue
2. MSW can either be diverted for gasification or digested in landfills, thus technical potentials overlap. California has strict criteria for the development of MSW conversion plants, thus it is assumed that LFG systems are more likely to be developed.
3. Total excludes MSW under solid biomass, since that potential competes with landfill gas.
4. 67% capacity factor is assumed for Wastewater processing plant, per 2008 Draft Report.

Solid biomass conversion systems have an average size of slightly greater than 20 MW while biogas systems tend to be well below the DG threshold.

Average Installed Bio-Power System Size in CA, by Category			
Biomass Category	**Number of Facilities**	**Average Installed Plant Size (MW)**	**% of Systems within DG Size-Range**
Wood Waste Biomass	23	21	~65%
Agricultural Crop Biomass	1	28	0%
Municipal Solid Waste Conversion	3	24	25%
WWTP Gas	10	0.20	100%
Landfill Gas	81	4	100%
Animal Manure Digester Gas	13	0.35	100%

Sources:
Energy Velocity 2009; The California Energy Commission: Biomass – Anaerobic Digestion; EPA Landfill Methane Outreach Program; EPA AgStar Program.

A Technical Potential of DRE Resources

- Solar PV
- Bio-Power
- **Wind**
- Geothermal
- Solar Hot Water
- Ground-Source Heat Pumps

B Distribution System Capacity

Reviewed studies indicate that total wind potential (transmission-scale and distributed-scale) is between 66-100 GW.

Wind Potential Studies		
Source/Report	**Estimated Potential (MW)**	**Approach**
CEC[1]	65,782 – 99,945 (Combined low- and high-speed resources at 50m-70m hub height)	The 2005 CEC analysis entitled *California Wind Resources* performed a GIS analysis to estimate the technical land available for low-speed (300-500 W/m^2) and high-speed (>500 W/m^2) wind at different hub heights. The analysis excluded the following land types: •Grade > 20 percent •Bodies of Water •Forested Areas •Urban Areas •National Parks and Monuments •State Parks •Other Natural Reserves (refuges etc.)

Source:
1.*California Wind Resources.* California Energy Commission. CEC-500-2005-071D. May 2005.

A number of issues that will constrain the technical potential of distributed wind.

Key Wind Constraints	
Lack of economies of scale/ Proximity to Distribution	• "Solar PV and microturbines, for example, are particularly suited to addressing localized distribution requirements, while wind and geothermal require larger, site-specific installations."[1] • Where wind resources are favorable, utility-scale plants are more likely
Siting constraints	• Zoning and permitting are challenging, especially in urban areas due to height and noise restrictions • Solar PV is frequently roof-mounted and has few siting constraints compared to distributed wind
Fit with load	• Wind does not follow load. Wind power is greatest at night while load is highest in the late afternoon. • There is a lack of load in windy areas. The wind is where the people are not. Wind resource maps show bulk of accessible wind resource is found in sparsely populated areas of five counties: Yolo, Riverside, San Diego, San Bernadino, and Solano. • "Wind power for distributed applications is considered to be commercially available under limited conditions. Distributed wind systems can be a cost-effective option in remote locations where a utility connection would not be economically feasible."[2]
Turbine cost and availability – technology availability/feasibility	• While "distributed wind" is not synonymous with "small wind", smaller turbines can be sited closer to substations and distribution feeders than larger turbines due to set-back requirements. • There is a lack of available turbines in the 100kW to 1MW range • Small turbine cost per kWh is higher vs. large turbines • When 1+MW turbines are used, it has historically been difficult to procure small volumes of these turbines as manufacturers typically want to sign large contracts with developers of utility-scale projects.
Minimal storage potential	• While storage solutions exist to reduce intermittency issues with wind power, these technologies have not yet reached wide-scale commercialization and, as such, their deployment is not yet economical.

Source:
1.Energy and Environmental Economics, Inc and Electrotek Concepts, Inc. *Renewable Distributed Generation Assessment: Sacramento Municipal Utility District Case Study*. CEC-500-2005-028. January, 2005.
2.California Energy Commission Website: http://www.energy.ca.gov/wind/overview.html

Appendix

A Technical Potential of DRE Resources

- Solar PV
- Bio-Power
- Wind
- **Geothermal**
- Solar Hot Water
- Ground-Source Heat Pumps

B Distribution System Capacity

Existing studies on California's geothermal potential show a range of 3-14 GW, although the studies do not specify project size.

Geothermal Potential Studies		
Source/ Report	**Est. Potential (MW)**	**Approach/Notes**
USGS Circular 790[1]	13,716	• "Recognized as the most thorough document assessing the potential of geothermal resources in the Untied States"[2] • Resources considered developable for power production were assumed to have temperature >150°C
NEMS[2]	12,170	• DOE National Energy Modeling System
EIA[2]	9,717	• EIA's Annual Energy Outlook
WGA Geothermal Task Force[3]	7,078	• Sum of near-term potential/low cost (10 years and/or up to 8 cents/kWh) and longer-term/higher cost (20 years and/or up to 20 cents/kWh). • On July 25, 2005, two dozen members of the geothermal community met in Reno, Nevada, to assess the potential for commercial development of roughly 140 known geothermal sites.
Petty 1992[4]	5,801	• Study develops estimates for the amount of geothermal power that could be on line in 20 years. • "An attempt to estimate the rate at which power could be on line constrained by the exploration, development and support infrastructure available to the geothermal industry, but not constrained by the potential market for power." [4] • "[This] work would fall into the category of "Probable Reserves" although some sites appear to approach 'Possible Reserves.'" [2]
GeothermEx, Inc.[5]	2,862	• "Estimated Total Generation Capacity minus Installed Gross MW" • Power generation potential greater than 1 MW • Resource temperature greater than 212°F • "This work comes closest to being characterized as defining 'Proven Reserves.'" [2]

Source:
1.Muffler, L.J.P. and M. Guffanti, eds. 1978. *Assessment of Geothermal Resources in the United States*, Circular 790. Washington DC: U.S. Geological Sciences.
2.Gawell, Karl. *California's Geothermal Resource Base: Its contribution, future potential, and a plan for enhancing its ability to meet the states renewable energy and climate goals*. Prepared for the California Energy Commission. 500-99-13. September 30, 2006.
3.Geothermal Task Force Report to the WGA Clean and Diversified Energy Advisory Committee, January 2006, http://www.westgov.org/wga/initiatives/cdeac/geothermal.htm pages 55-56.
4.Supply of Geothermal Power from Hydrothermal Sources: A Study of the Cost of Power in 20 and 40 Years, Petty S., Livesay B., Long W. & Geyer J., 1992, Sandia National Laboratory Report SAND92-7302
5.New Geothermal Site Identification and Qualification. Prepared by GeothermEx, Inc. for California Energy Commission. P-500-04-051. April 2004.

A number of issues that will constrain the technical potential of distributed geothermal.

Key Geothermal Constraints	
Lack of economies of scale	• "Costs of electricity are high because economies of scale work against small plants. This is especially true when exploration and drilling costs are necessary. These essentially fixed costs have a major impact on electricity costs for small plants."[1] • "Small-scale geothermal power plants have the potential for widespread application, but achieving cost effectiveness in small plant sizes presents a number of challenges."[2]
Siting constraints	• "The two factors most frequently cited for the limited development are permitting problems and the high costs of resource exploration and development."[3] In addition to the permitting required for drilling, other environmental permitting associated with the National Pollutant Discharge System and the California Toxic Rule may be required.[4] • "Without significant changes in the costs of development and/or the permitting process, geothermal market participants generally see limited potential for utilizing additional geothermal resources in California."[3]

Source:
1.Gawlick, K. and C. Kutscher. *Investigation of the Opportunity for Small-Scale Geothermal Power Plants in the Western United States*. Prepared for NREL. March, 2000.
2.*Small-Scale Geothermal Power Plant Field Verification Projects.* Prepared by C. Kutscher for the National Renewable Energy Laboratory. NREL/CP-550-30275. June 2001.
3.*California Renewable Technology Market and Benefits Assessment*, EPRI, Palo Alto, CA, and California Energy Commission, Sacramento, CA: 2001. 1001193.
4.Merrick, Dale, *Adventures in the Life of a Small Geothermal District Heating Project,* I'SOT Inc., Canby, CA.

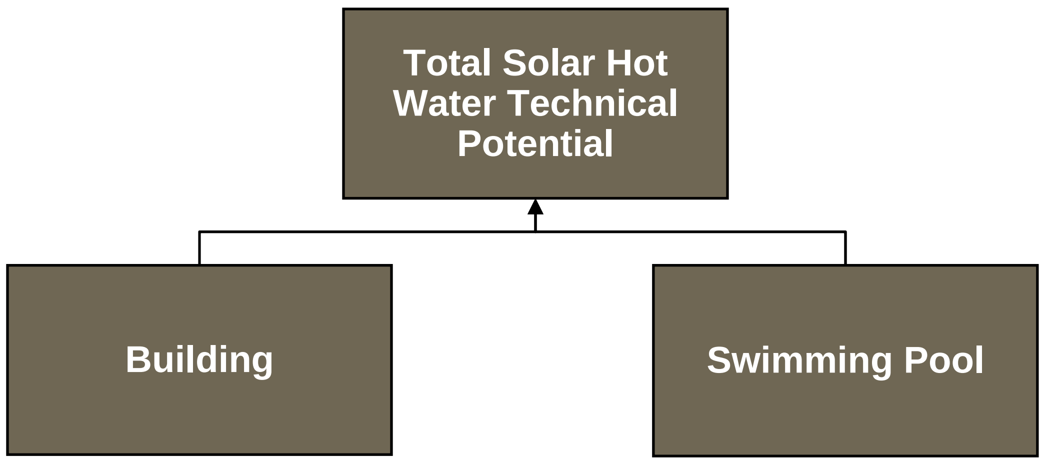
A Technical Potential of DRE Resources

- Solar PV
- Bio-Power
- Wind
- Geothermal
- **Solar Hot Water**
- Ground-Source Heat Pumps

B Distribution System Capacity

The technical potential for solar hot water considers water heating within residential and commercial buildings as well for swimming pools.

Key Components of Technical Potential Estimate for Distributed Solar Hot Water in California



- Residential Buildings
- Commercial Buildings

NCI used previous work by NREL and its previous solar PV work for PIER to estimate technical rooftop potential.

Building Solar Hot Water Technical Potential Methodology	
Estimate Electricity Use for Water Heating in 2020	NCI used the reported CEC forecasted 2020 residential and commercial electricity end-use.[1] The state-wide use was split among counties, based on electricity use by county.[2] Of the total electricity use, only 6% residential[3] and 1% commercial[4] are assumed to be attributed to use for water heating.
Estimate Solar Fraction	NCI used an average solar fraction by county, based on the Solar Fraction Calculator for Rated System excel tool available on the CEC website.[5] Solar fraction is the amount of energy for water heating that can be met by a solar system.
Estimate Residential Roof Space Required	NCI estimated the residential roof space required by county given the number of house dwellings by county and an average residential solar thermal system of 52sq-ft.[6] Given that a commercial solar system is industry-specific, and no "typical" system size can be estimated, no required roof space was estimated.
Estimate Feasible Roof Space	Based on an NREL report,[6] 75% of commercial roof space was assumed to be feasible for solar thermal systems. For residential systems, the feasible roof space was assumed to be the lesser of the required roof space and the technical roof space available based on NCI's rooftop solar PV methodology.

Sources:

1. California Energy Demand 2010-2020 Staff Draft Forecast. California Energy Commission: CEC-200-2009-012, June 2009.
2. CEC 2007 Electricity demand by county.
3. KEMA. California Statewide Residential Sector Energy Efficiency Potential Study. Volume 1 of 2. #SW063. April 2003.
4. Itron, Inc. California Commercial End-Use Survey. CEC-400-2006-005, March 2006.
5. Solar Fraction Calculator for Built-Up Systems Using SRCC Certified Solar Collector, CEC.
6. The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States. National Renewable Energy Lab. March 2007.

NCI used the California Residential Application Saturation Study to determine the solar thermal technical potential for swimming pools.

Swimming Pool Solar Hot Water Technical Potential Methodology	
Estimate Number of Pools in CA in 2020	NCI used a California survey[1] of pool saturation by household by income class to estimate the total number of pools in 2020. That saturation was applied to dwelling units, by income class in each county.[2] 1.5 million residential pools were estimated for 2020.[3]
Estimate Electric Energy Required to Heat Pool	NCI used the same California survey[1] to estimate the average annual energy required to heat a pool unit in California. Based on the survey sample, an estimated 3%[4] of CA residents who have pools, heat them electrically, and NCI assumed no new pools in CA would use electric heating.
Estimate % of Energy to be Met by Solar Thermal System	Based on industry expertise, NCI assumed that a solar thermal system would be installed to meet 100% of the energy required to heat a pool. Swimming pools may be used ~50% of the year, and require lower heating temperatures than domestic hot water.
Estimate % Savings with Solar Thermal	Based on the number of pools and the heat required per pool, the total technical potential for swimming pool solar thermal systems can be determined.

Source:

1. California Statewide Residential Appliance Saturation Study, KEMA, 2004. Only residential dwelling pools were estimated in this survey, and limited data exists for commercial swimming pools by county.
2. Census.gov 2007 3-year average data.
3. Insufficient data is readily available to determine non-residential pool stock.
4. Synapse Infusion Group, Inc. *Report on Solar Pool Heating Quantitative Survey.* NREL/SR-550-26485, April 1999.

Solar hot water potential is correlated with county population.

Solar Hot Water Technical Potential [MWh Saved]					
County	Building	Swimming Pool	County	Building	Swimming Pool
Alameda	46,610	10,076	Orange	98,581	20,052
Alpine	61	9	Placer	15,799	2,462
Amador	1,746	246	Plumas	864	127
Butte	8,274	1,062	Riverside	83,943	10,711
Calaveras	2,227	294	Sacramento	58,631	8,408
Colusa	950	92	San Benito	1,503	334
Contra Costa	31,273	7,710	San Bernardino	67,476	9,672
Del Norte	729	102	San Diego	88,629	18,963
El Dorado	5,795	1,294	San Francisco	18,327	6,168
Fresno	36,011	3,887	San Joaquin	24,500	3,360
Glenn	1,339	118	San Luis Obispo	8,209	1,656
Humboldt	2,903	633	San Mateo	18,084	5,668
Imperial	9,091	531	Santa Barbara	12,524	2,417
Inyo	697	144	Santa Clara	61,249	13,071
Kern	51,926	3,269	Santa Cruz	5,771	1,777
Kings	9,890	539	Shasta	8,780	907
Lake	1,744	284	Sierra	129	211
Lassen	943	146	Siskiyou	1,857	2,603
Los Angeles	311,809	51,380	Solano	11,816	3,258
Madera	6,281	594	Sonoma	9,185	2,394
Marin	6,516	2,270	Stanislaus	24,812	4,215
Mariposa	560	149	Sutter	3,229	491
Mendocino	2,026	434	Tehama	2,715	259
Merced	13,081	946	Trinity	403	117
Modoc	461	76	Tulare	11,733	1,576
Mono	1,416	106	Tuolumne	1,847	304
Monterey	8,771	2,176	Ventura	25,236	5,325
Napa	2,887	937	Yolo	7,330	1,120
Nevada	4,389	661	Yuba	2,436	306
Total				1,246,005	218,094

A Technical Potential of DRE Resources

- Solar PV
- Bio-Power
- Wind
- Geothermal
- Solar Hot Water
- **Ground-Source Heat Pumps**

B Distribution System Capacity

The total potential for electricity savings in 2020 from the use of ground-source heat pumps is approximately 7-8 TWh or 2.3-2.7% of total demand.

Ground Source Heat Pump Potential Savings Methodology	
Estimate CA Electricity Usage in 2020	NCI started with the CEC's most recent statewide electricity demand forecast for 2018 and projected it out to 2020 using the relevant CAGR.[1]
Estimate Electricity Used for Space Heating and Cooling	NCI used LBL's state electricity use report to determine the percentage of statewide electricity consumption used for residential and commercial air conditioning and space heating. We then applied those percentages to the statewide total to get GWh.[2]
Estimate per Unit Savings for GSHP	NCI used its ground-source heat pump (GSHP) study for the DOE to estimate the electricity savings of replacing every residential and commercial heating and cooling system with GSHP technology.[3]
Estimate Statewide Electricity Savings Potential from GSHP	We applied the residential and commercial savings percentages from the previous step to the respective heating and cooling consumption levels to determine the statewide electricity savings potential.

Source:

1.Kavalec, Chris and Tom Gorin. 2009. *California Energy Demand 2010 - 2020*, Staff Draft Forecast, California Energy Commission. CEC - 200 - 2009 - 012SD.
2.Brown, Richard E. and Jonathan G. Koomey. *Electricity Use in California: Past Trends and Present Usage Patterns*. Lawrence Berkeley National Laboratory. May 2002.
3.Navigant Consulting, Inc. *Ground - Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers*. Submitted to the U.S. Department of Energy's Geothermal Technologies Program. February 2009.

The total potential for electricity savings in 2020 from the use of ground-source heat pumps is approximately 7-8 TWh or 2.3-2.7% of total demand.

Ground Source Heat Pump Potential Savings Calculation		
2018 California Electricity Demand (GWh)[1]	297,104	
2018-2020 CAGR[1]	0.82%	
2020 California Electricity Demand (GWh)	301,996	
	Residential	*Commercial*
Heating & Cooling (% of load)[2]	4%	6%
Heating & Cooling (GWh)	12,080	18,120
Savings from GSHP (%)[3]	28%-31%	20%-24%
Savings from GSHP (GWh)	3,382-3,745	3,624-4,349
Total Savings from GSHP (GWh)	7,006-8,094	

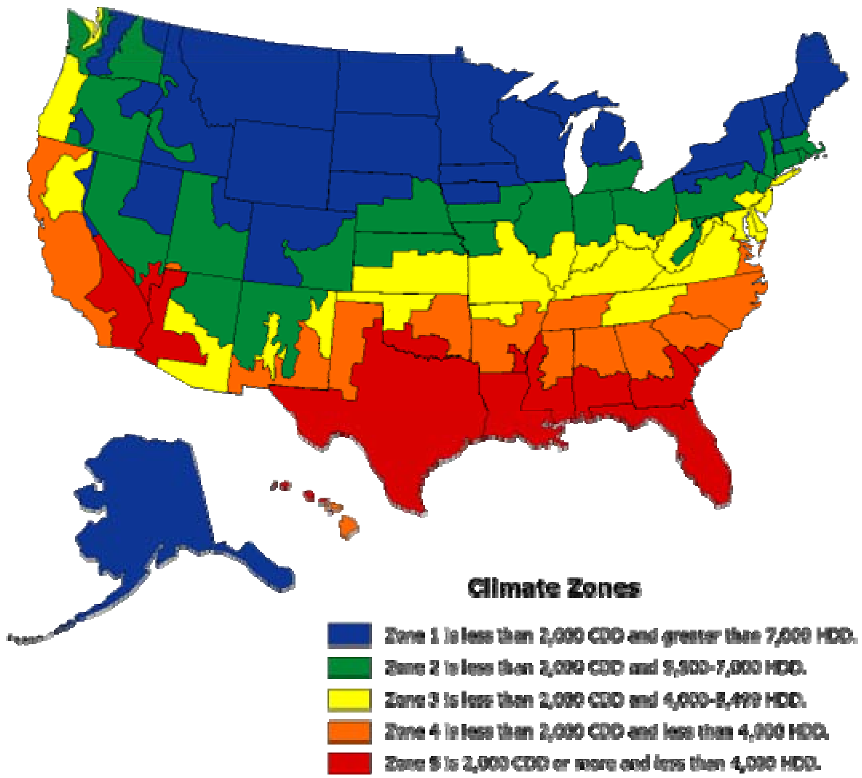
Source:
1.Kavalec, Chris and Tom Gorin. 2009. *California Energy Demand 2010 - 2020*, Staff Draft Forecast, California Energy Commission. CEC - 200 - 2009 - 012SD.
2.Brown, Richard E. and Jonathan G. Koomey. *Electricity Use in California: Past Trends and Present Usage Patterns*. Lawrence Berkeley National Laboratory. May 2002.
3.Navigant Consulting, Inc. *Ground - Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers*. Submitted to the U.S. Department of Energy's Geothermal Technologies Program. February 2009.

A number of issues that will constrain the technical potential of GSHP.

- Reduced economic potential
  - "There is a limited market for direct-use and ground-source heat pumps in California due to the relatively high costs of utilizing these technologies."[1]
  - Ground-source heat pumps have a longer payback period on the West coast as compared to other US geographies due to the lower load used for space conditioning.[2]

Source:
1. *California Renewable Technology Market and Benefits Assessment*, EPRI, Palo Alto, CA, and California Energy Commission, Sacramento, CA: 2001. 1001193.
2. Navigant Consulting, Inc. *Ground‐Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers*. Submitted to the U.S. Department of Energy's Geothermal Technologies Program. February 2009.

Most of California's population falls into the Energy Information Administration's (EIA) Climate Zones 4 and 5[1].



Source:
1.http://www.eia.doe.gov/emeu/cbecs/climate_zones.html

We developed a range for energy savings potential from ground-source heat pumps by using the reference data from Climate Zones 4 and 5.

	Primary Energy Savings (Typical GSHP)			Representative City Used	
Region	Resid'l	Comm'l	Climate Zone	Resid'l	Comm'l
New England	39%	43%	1	Boston	Minneapolis
Middle Atlantic	36%	20%	2	NYC	DC
East North Central	43%	30%	2	Chicago	Chicago
West North Central	52%	43%	1	Minneapolis	Minneapolis
South Atlantic	28%	20%	4	Atlanta	DC
East South Central	31%	20%	4	Nashville	Houston
West South Central	28%	20%	5	Dallas	Houston
Mountain	38%	30%	2	Salt Lake City	Chicago
Pacific	28%	24%	4	Sacramento	Los Angeles
Range (excl. CZ 1,2)	**28-31%**	**20-24%**	NA	NA	NA

We eliminated the reference data from Climate Zones 1 and 2 as these are colder climates. The load profile of colder climates creates greater savings potential from GSHPs.

Source:
Navigant Consulting, Inc. *Ground - Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers*. Submitted to the U.S. Department of Energy's Geothermal Technologies Program. February 2009.

A Technical Potential of DRE Resources

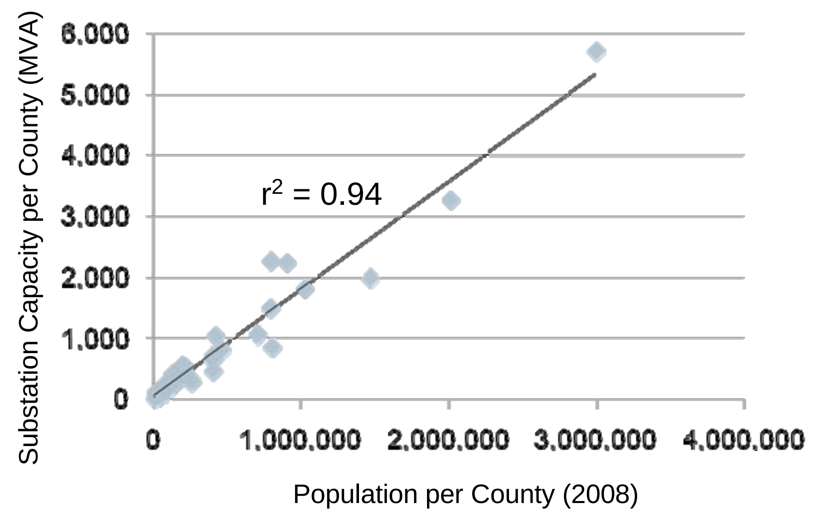
B Distribution Capacity

Substation capacity in non-IOU counties can be estimated using the relationship between population and substation capacity in IOU counties.

Substation Capacity Approach

- Utilize FERC Form 1 data to generate list of all >10 MVA distribution substations for the IOUs[1,2,3]
- As the city is listed for each substation, assign each substation to a county
- Analyze correlations between the substation capacity in a county and the county's population demographics (e.g. population density)
- Use correlations to estimate the substation capacity in counties not served only by IOUs

Within counties served only by IOUs, there is a strong correlation between population and total substation capacity



- California IOUs only cover about 36 of the state's 58 counties.
- We can use the data for the counties served only by IOUs to extrapolate the substation capacity in each of the other counties.

Source:
1. https://www.pge.com/regulation/FERC-Form1/form1-2008.pdf
2. http://www.edison.com/images/cms_images/c7221_FERC_CPUC_2008_4795.pdf
3. SNL Financial

Estimated total substation capacity for California to be approximately 66 GW in 2008.

Counties Served only by IOUs - Substation Capacity (from FERC Form 1)

County	Sub. Capacity (MVA)	County	Sub. Capacity (MVA)
San Diego	5,707	Santa Cruz	329
San Bernardino	3,262	Marin	302
Kern	2,263	San Luis Obispo	274
Fresno	2,235	Sutter	266
Alameda	1,984	Napa	258
Contra Costa	1,812	Kings	242
Ventura	1,487	Yuba	217
San Mateo	1,055	Lake	188
Tulare	1,032	Tehama	159
San Francisco	846	Tuolumne	144
Sonoma	799	Glenn	111
Solano	707	Mendocino	106
Santa Barbara	638	Amador	106
Yolo	553	Colusa	105
Butte	525	San Benito	95
Monterey	455	Calaveras	40
Humboldt	401	Mariposa	32
Madera	373	Mono	13

Counties not served only by IOUs* - Substation Capacity (estimated based on population)

County	Sub. Capacity (MVA)
Los Angeles	17,465
Orange	5,346
Riverside	3,735
Santa Clara	3,141
Sacramento	2,486
San Joaquin	1,209
Stanislaus	923
Placer	624
Merced	455
Shasta	338
El Dorado	331
Imperial	310
Nevada	191
Siskiyou	98
Lassen	81
Del Norte	71
Plumas	55
Inyo	50
Trinity	45
Modoc	36
Sierra	25
Alpine	21

* Some of these counties are served by both IOUs and non-IOUs

Source:
1.U.S. Census Bureau (2008)

Assumed a statewide annual population growth rate of 1% and estimated total substation capacity to be approximately 75 GW in 2020.

Counties Served only by IOUs - Substation Capacity (from FERC Form 1)

County	Sub. Capacity (MVA)	County	Sub. Capacity (MVA)
San Diego	6,431	Santa Cruz	371
San Bernardino	3,676	Marin	340
Kern	2,550	San Luis Obispo	309
Fresno	2,518	Sutter	300
Alameda	2,236	Napa	291
Contra Costa	2,042	Kings	273
Ventura	1,676	Yuba	245
San Mateo	1,189	Lake	212
Tulare	1,163	Tehama	179
San Francisco	953	Tuolumne	162
Sonoma	900	Glenn	125
Solano	797	Mendocino	119
Santa Barbara	719	Amador	119
Yolo	623	Colusa	118
Butte	592	San Benito	107
Monterey	513	Calaveras	45
Humboldt	452	Mariposa	36
Madera	420	Mono	15

Counties not served only by IOUs* - Substation Capacity (estimated based on population)

County	Sub. Capacity (MVA)
Los Angeles	19,681
Orange	6,024
Riverside	4,209
Santa Clara	3,539
Sacramento	2,801
San Joaquin	1,362
Stanislaus	1,040
Placer	704
Merced	513
Shasta	381
El Dorado	373
Imperial	349
Nevada	216
Siskiyou	111
Lassen	91
Del Norte	80
Plumas	62
Inyo	56
Trinity	51
Modoc	40
Sierra	28
Alpine	24

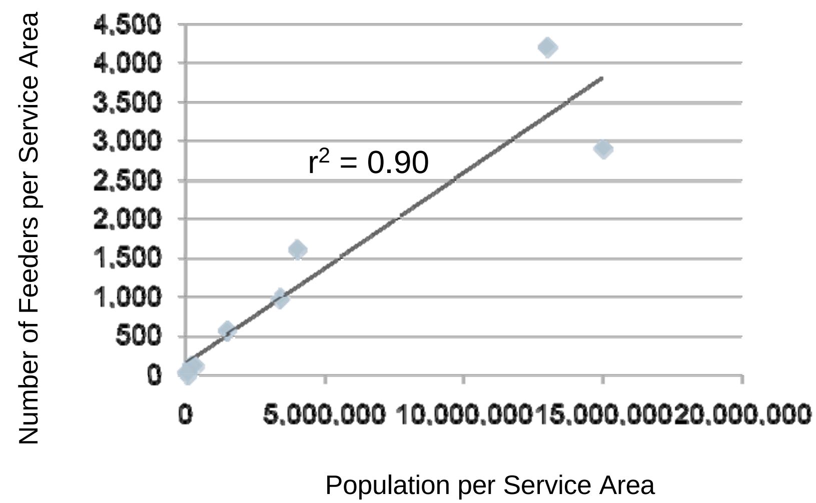
* Some of these counties are served by both IOUs and non-IOUs

The number of distribution feeders per county can be estimated using the relationship between population and number of feeders in utility service areas.

Distribution Feeder Approach

- Utilize publically available data for the number of distribution feeders in various utility service areas
- Analyze correlations between the number of feeders in a utility service areas and the population of that service area
- Use correlations to estimate the number of feeders per county based on the population of the county

Within utility service areas, there is a strong correlation between population and number of distribution feeders



- Distribution feeder information is not readily available by county. It is, however, available for a number of utilities.
- Use the feeder data at the utility service area level to extrapolate the number of feeders in each county

The total number of distribution feeders in California was estimated to be approximately 10,000 in 2008.

Number of Distribution Feeders per Service Area (from public sources)

Utility	Distrib. Feeders
SCE	4,200
PG&E	2,900
LADWP	1,600
SDG&E	977
SMUD	561
Glendale Water & Power	111
Anaheim Public Utilities	109
Riverside Public Utilities	89
Azusa Light & Water	20
Lodi Electric Utility	8

Number of Distribution Feeders per County (estimated based on population)

County	Distrib. Feeders	County	Distrib. Feeders	County	Distrib. Feeders
Los Angeles	2,539	Santa Barbara	114	Tehama	26
Orange	782	Placer	98	Tuolumne	24
San Diego	779	San Luis Obispo	78	San Benito	24
Riverside	549	Santa Cruz	75	Calaveras	22
San Bernardino	527	Marin	74	Siskiyou	21
Santa Clara	462	Merced	73	Amador	20
Alameda	388	Butte	66	Lassen	19
Sacramento	367	Yolo	61	Del Norte	17
Contra Costa	274	Shasta	56	Glenn	17
Fresno	243	El Dorado	55	Colusa	15
San Francisco	217	Imperial	52	Plumas	15
Kern	215	Kings	48	Mariposa	15
Ventura	215	Madera	48	Inyo	14
San Mateo	193	Napa	44	Trinity	14
San Joaquin	182	Humboldt	43	Mono	13
Stanislaus	141	Nevada	35	Modoc	12
Sonoma	130	Sutter	34	Sierra	11
Tulare	119	Mendocino	32	Alpine	10
Monterey	115	Yuba	29		
Solano	114	Lake	27		

A statewide annual population growth rate of 1% was assumed, resulting in 11,300 feeders by 2020.

Number of Distribution Feeders per Service Area (from public sources)

Utility	Distrib. Feeders
SCE	4,733
PG&E	3,268
LADWP	1,803
SDG&E	1,101
SMUD	632
Glendale Water & Power	125
Anaheim Public Utilities	123
Riverside Public Utilities	100
Azusa Light & Water	23
Lodi Electric Utility	9

Number of Distribution Feeders per County (estimated based on population)

County	Distrib. Feeders	County	Distrib. Feeders	County	Distrib. Feeders
Los Angeles	2,861	Santa Barbara	128	Tehama	29
Orange	881	Placer	110	Tuolumne	27
San Diego	878	San Luis Obispo	88	San Benito	27
Riverside	619	Santa Cruz	85	Calaveras	25
San Bernardino	594	Marin	83	Siskiyou	24
Santa Clara	521	Merced	82	Amador	23
Alameda	437	Butte	74	Lassen	21
Sacramento	414	Yolo	69	Del Norte	19
Contra Costa	309	Shasta	63	Glenn	19
Fresno	274	El Dorado	62	Colusa	17
San Francisco	245	Imperial	59	Plumas	17
Kern	242	Kings	54	Mariposa	17
Ventura	242	Madera	54	Inyo	16
San Mateo	217	Napa	50	Trinity	16
San Joaquin	205	Humboldt	48	Mono	15
Stanislaus	159	Nevada	39	Modoc	14
Sonoma	146	Sutter	38	Sierra	12
Tulare	134	Mendocino	36	Alpine	11
Monterey	130	Yuba	33		
Solano	128	Lake	30		

Other research indicates the variable nature of some DRE can limit penetration on feeders due to technical challenges.

Limitations on PV Penetration on Distribution Feeders Based On Technical Challenges

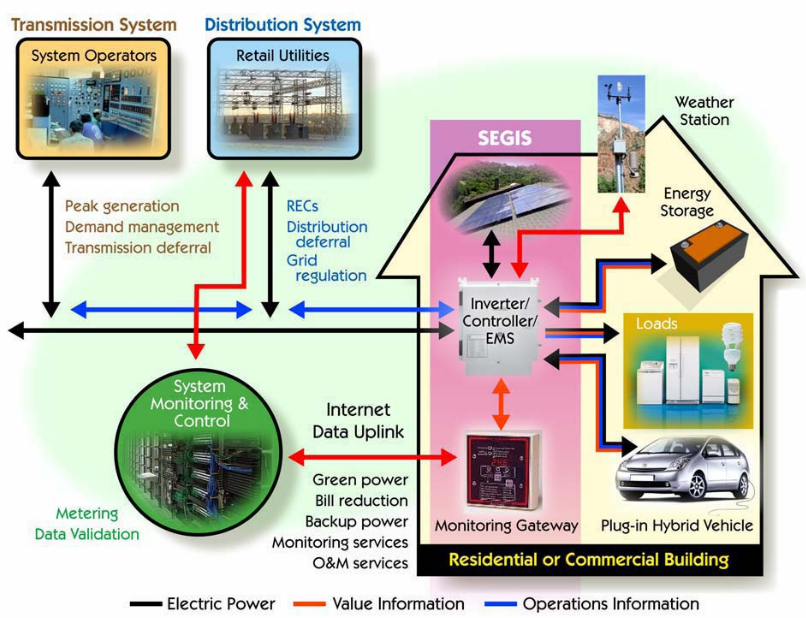
Technical Challenge	Description of Impact	Recommendation for Maximum PV Penetration on Feeder Peak Load
Voltage Regulation	Adequate voltage regulation may be difficult due to changes in feeder load and power flow while PV is producing. Also of concern is voltage depression after a feeder restoration, when load is restored but PV systems have not come back online.	< 40%
Reverse Power Flow	Changes in PV output can cause the power flow on distribution feeders to vary, and in some high generation/low load cases, the flow could reverse.	5% to 30%
Power Fluctuation/ Frequency Regulation	The variability of PV output due to cloud transients has been shown to create power fluctuations, and may be incompatible with the ramp rates of some central station generation. This variability may require higher levels of system frequency regulation, increasing the cost of accommodating higher penetrations of PV.	5% to 30%

Source: Distributed Photovoltaic Systems Design and Technology Requirements, C. Whitaker, J. Newmiller, M. Ropp, and B. Norris, February 2008, and Navigant Consulting analysis, 2008.

Enhancing the capability of PV inverter/controllers could enable distributed PV to become a distributed grid resource.

Researchers are focused on the interface between the PV system and the utility distribution system

Solar Energy Grid Integration Systems "SEGIS"



An advanced DRE interface increases performance and provides grid benefits

Key Features

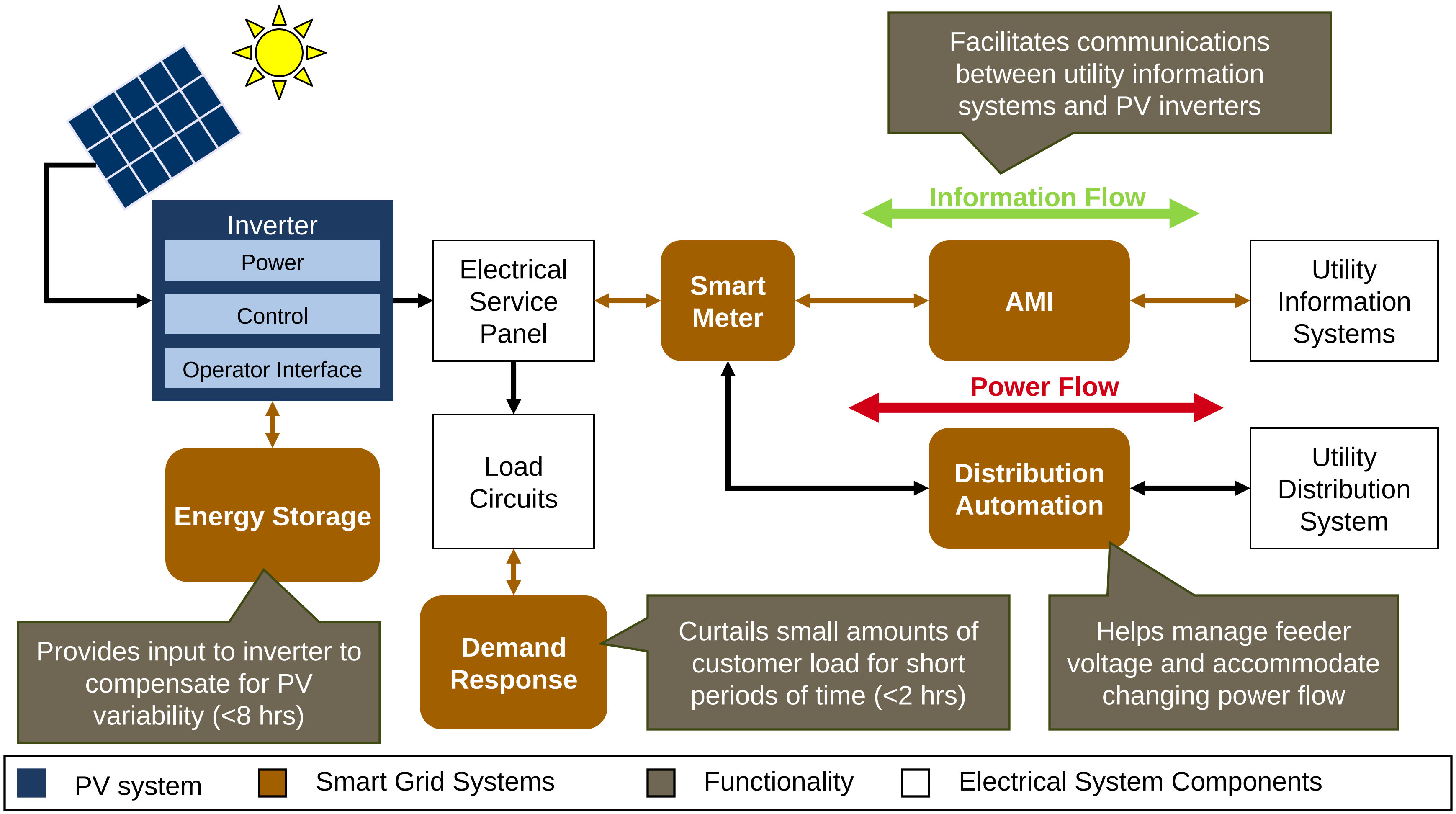
- Advanced inverter/controller/EMS
- Two-way communications based on open system standards
- Adaptive logic systems that consider energy resources, real-time prices and optimal power flow schemes

Potential Grid Benefits

- Interactive control of the inverter grid connection by the distribution system, including ride-through and tripping
- Voltage regulation and reactive power support from inverters
- Management of steady state and transient power injection to the distribution system through load management and energy storage

Source: Solar Energy Grid Integration Systems, Program Concept Paper, October 2007, Sandia National Laboratory, NCI analysis

Smart Grid systems could be used to address technical challenges and improve the integration of distributed PV with the distribution system.



Source: Navigant Consulting, Smart Grid-PV Multi-Client Study, 2008.

Advanced Smart Grid technologies such as AMI, distribution automation and energy storage could address these challenges.

	How Smart Grid Systems Address Key T&D Challenges to High PV Penetration			
	AMI	**Distribution Automation (DA)**	**Demand Response (DR)**	**Energy Storage**
Voltage Regulation	◒ Metering points can be used to monitor voltage along the feeder for input to distribution automation	● Reactive control devices can be operated in a coordinated way to control feeder voltage	● Loads with high reactive demand could be curtailed to improve feeder power factor	● Energy could be stored or delivered to change load/ circuit power factor
Reverse Power Flow	◒ Helps manage end-use load and devices depending on configuration	● Relays and circuit configurations could be changed to account for changes in power flow	◒ Loads could be switched to change feeder power flow	● Energy could be stored or delivered to change feeder real power flow
Power Fluctuation/ Frequency Regulation	○ Offers minimal ability to affect real power demand	○ Offers minimal ability to affect real power demand	○ Response time is likely too slow to meaningfully address power fluctuations	● Energy could be stored or delivered to change net load/generation in a region

Relative Contribution to Addressing Challenge: High: ● Moderate: ◒ Minimal: ○

Source: Navigant Consulting, Smart Grid-PV Multi-Client Study, 2008.