Distributed Energy Resources: Current Landscape and a Roadmap for the Future

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ABSTRACT

This white paper is designed to help utilities, regulators, legislators, vendors, and other interested parties understand the current landscape of distributed energy resources (DER) in the United States by providing a benchmark status on technology, markets, applications, and business models that are active in this area. The white paper benchmarks various DER options and provides perspectives on trends, gaps, and critical factors for achieving pathways that will enable contributions to the future electricity enterprise. The document also lays out plausible pathways and scenarios of the industry's visions for the future of DER as part of a robust electricity enterprise.

According to the white paper, DER capacity that functions as part of the grid (grid-connected) is estimated at 30 GW, which accounts for only 3% of the U. S. electric grid capability of 953 GW. DER technologies are evolving in the direction of decreasing costs, increasing efficiency, lower emissions, higher reliability, and towards more integrated and packaged systems, which are easier for plug-and-play interconnection. Some DER can be cost-effective, compared to the delivered cost of energy to end-users, depending on rate structure and level and customer load factor. For utility-side applications, the system benefits of DER are highly area- and time-specific, and in practice, monetization of these values has been very limited. However, applications that capture both the private-owner and utility-owner benefits for DER hold the most promise for a "win-win."

Most regulated utilities are taking a "wait-and-see" approach to DER, but are monitoring technology developments. A number of non-regulated companies and new entrants are succeeding with packaged systems for targeted customer applications. End-use pathways are likely to continue to be the chief area of application through 2015. In many cases, opportunities exist for joint applications—to meet both end-use and grid support needs, or for both energy supply and grid support.

The white paper offers recommendations to close gaps and support progress in the areas of DER technology, applications, and policy.

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1 INTRODUCTION

In the mid to late 1990s, the energy industry in the United States witnessed a growing wave of interest in the alternative energy sector, and particularly in distributed energy resources (DER). The interest in DER[1] was fueled by several drivers, including electric utility deregulation, availability of cheap and plentiful natural gas, new non-utility entrants such as Enron, and the prospect on the horizon of exciting new breakthroughs in small generation options that could potentially change the landscape on how electricity was generated and delivered. By 2003, the picture had changed. Many of the preconditions and drivers anticipated for DER growth had experienced delays and reversals, and the prospects for large markets looked less hopeful.

Today, the electric utility industry faces continued challenges and uncertainties. Over the next decade, the cost structure of the generation sector is anticipated to increase considerably due to rising fuel costs, environmental regulations, and security concerns. There is a lack of consensus and uncertainty on future utility business models—whether they are supply-side-commodity-based or if they will be transformed into a more demand-side services business. In addition, substantial new investments in electric distribution system infrastructure are needed to address load growth and increase reliability.

These key industry uncertainties continue to drive interest in the role of distributed power, particularly because certain energy storage and high-efficiency options have the potential to significantly impact the course of supply-side and demand-side utility business models.

Within this context, the outlook for DER today has once again changed. Recent mega-city blackouts, dramatic reductions in investments in central-station plants, and an aging T&D infrastructure point to the need to continue to follow DER developments and to guide future applications that benefit the electric system and all stakeholders. In the regulatory arena, federal and state energy programs and certain state regulatory incentive programs are creating new opportunities for DER. Applications have also expanded and are now being pursued in three realms: end-use, grid support, and energy supply.

With these drivers, there is a renewed interest in DER. Increasingly, evidence suggests that DER could potentially have significant impacts on the future of the grid and its design, including allowing for better utility asset utilization and alleviating expensive system upgrades for new peak demand. Opportunities are also being explored for DER to be applied in joint utility/end-

[1] EPRI and its industry stakeholders have defined DER as "the integrated or standalone use of small, modular, electricity generation or energy storage resources by utilities, utility customers, and/or third parties in applications that benefit the electric system, specific end-use customers or both." DER is usually less than 60 MW, and used on-site or nearby. Our definition and scope include cogeneration and cooling, back-up generation, and on-site facilities that can serve industrial areas, a commercial building, a single residence, or a community.

user applications—to meet both customer end-use needs as well as utility grid support—and thereby to capture dual benefits. In some cases, these joint applications hold the most promise for a “win-win” in the near term.

As a result, it is important at this juncture to benchmark where distributed power is today—what is working and not working—in terms of applications, technologies, business models, and policies. In addition, industry stakeholders could also benefit from a look forward, to envision the future pathways for DER applications that might be pursued over the next 10 years and the technical and policy gaps that need to be closed in order to realize these destinations.

EPRI embarked on development of this white paper[2] with specific objectives to:

1. Benchmark the current landscape of DER, including applications, technology, costs and benefits, and business models.

2. Present the industry with a clear picture of where DER is today, and identify possible future pathways that will enable DER to contribute to the electricity enterprise over the next ten years.

3. Provide conclusions and recommendations for R&D strategies that will lead to these pathways, and provide input to help inform the development of policy.

[2] The full DER Benchmarking Report is available to EPRI DER Program 101A members and is downloadable from www.disgen.com

2
CURRENT LANDSCAPE OF DER IN THE U.S.

To understand the current landscape of DER, it is important to begin with a listing of DER technology options and their applications. More important than the specific DER technology options themselves are their applications and the specific energy solutions they enable. DER options may be employed in a variety of applications that can be broadly categorized as end-use, utility grid support, and energy supply. Table 2-1 maps technology options with these market needs and applications.

Table 2-1
DER Technology Options Mapped to Applications and Market Drivers

Technology Options	End-User	Utility Grid Support	Energy Supply
	– CHP – Premium Power – Backup power – Peak shaving	– Asset mgt – Reliability	– In-city generation – Renewable
Recip engine/diesel	X	X	
Combustion turbine	X	X	X
Microturbine	X		
Fuel cell	X		
PV	X		X
Energy storage	X	X	X
Biomass & waste management	X		X

At the end of 2003, there was an estimated 234 GW of installed DER in the U.S., with DER defined as generation less than 60 MW in size. However, 81% of this capacity was comprised of small to medium reciprocating engines serving end-user needs for emergency/standby applications, and almost all of it was not interconnected with the electrical T&D system. DER capacity that functions as part of the grid (grid-connected) was estimated at 30 GW, which accounts for only 3% of the U. S. electric grid capability of 953 GW[3].

Figure 2-1 illustrates the total interconnected DER capacity in the U.S.; and Figures 2-2 and 2-3 illustrate how total DER capacity is distributed by technology type and application. Among technology types, recip engines dominate the current landscape, followed by combustion turbines. As regards applications, emergency/standby applications lead the field, followed by combined heat and power (CHP).

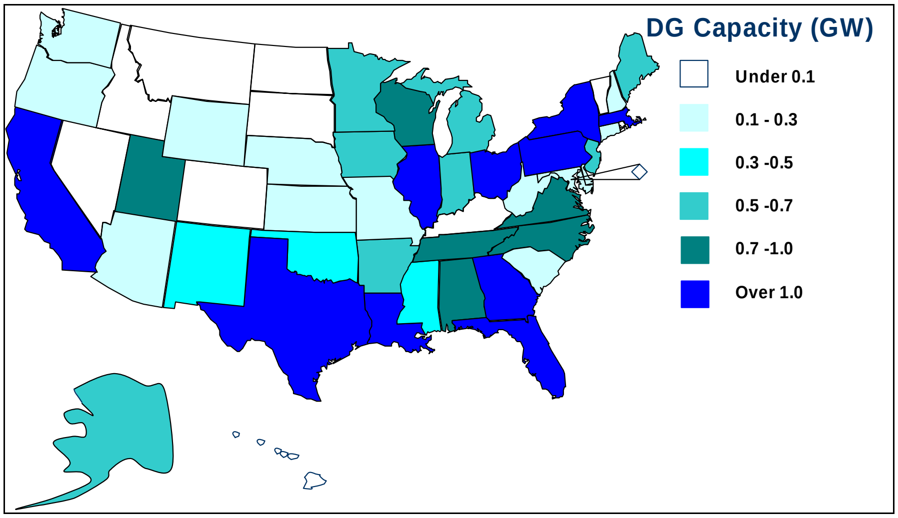

Figure 2-1
Interconnected DER Capacity in the U.S. (2003)

Source: The Installed Base of U.S. Distributed Generation, Resource Dynamics Corporation, with additional allocation by state.

[3] Energy Information Administration, Form 860, 2003.

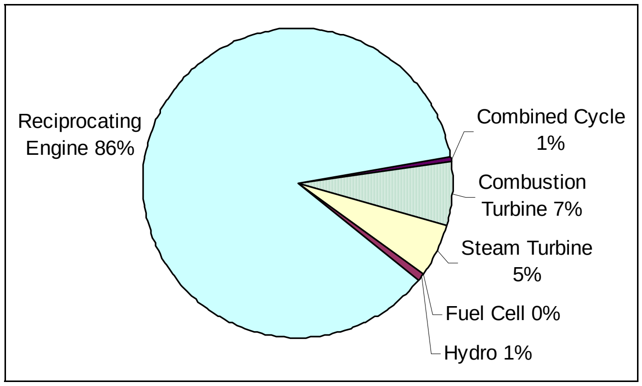

Figure 2-2
Percent of DER Capacity by Technology

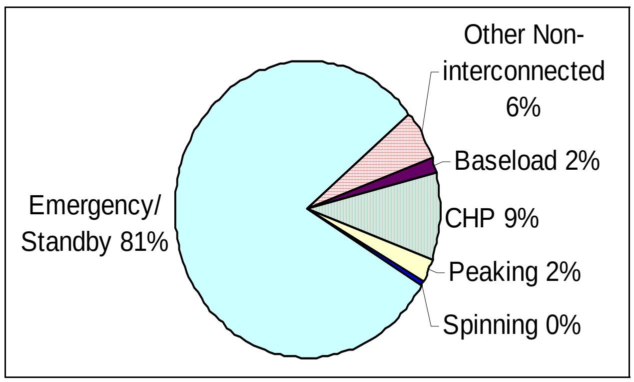

Figure 2-3
Percent of DER Capacity by Application

3
BENCHMARKING DER TECHNOLOGY TRENDS

DER technologies are evolving in the direction of decreasing costs, increasing efficiency, lower emissions, higher reliability, and towards more integrated and packaged systems, which are easier for plug-and-play interconnection.

Well-established technologies, such as reciprocating engines and combustion turbines, are making incremental improvements in cost, efficiency, and reliability. They are also now able to achieve single-digit NOx emissions cost-effectively (Figures 3-1 thru 3-3 represent examples of Mature DER Technologies).

Figure 3-1
4.6 MW Mercury 50 Combution Turbine Offered by Solar Turbines

Figure 3-2
Kawasaki Combustion 1.5 MW Turbine genset equipped with Catalytica's Xonon Technology to Reduce Emissions

Figure 3-3
Two Hess Internal Combustion Engine (ICE) gensets integrated into a Turnkey Cogeneration Package by RealEnergy

Figure 3-4
Caterpillar 3500 Natural-Gas-Fired ICE Aimed at the Distributed Generation Market

Figure 3-5
PureComfort 360 Capstone with UTC Chiller

In contrast, emerging technologies, such as fuel cells, microturbines, and photovoltaics, are not yet sufficiently widespread to benefit from familiarity or economies of volume production (Figures 3-4 to 3-7).

Figure 3-6
A Residential-Scale Photovoltaic System with Inverter and Battery Storage System from AstroPower

Figure 3-7
1 MW Molten Carbonate fuel cell demonstration unit sited at a Wastewater Treatment Facility in King County, WA. Technology provided by FuelCell Energy

Figure 3-8
Li-ion UPS Systems - 100kW, 30s

Figure 3-9
Vanadium Redox flow battery 250 kW 8 Hrs installed at PacifiCorp site at Castle Valley, Utah

Energy storage technologies offer new promising options that span many future applications (Figures 3-8 and 3-9). In some cases they may avoid the fuel cost and emission constraints of generation technologies. In addition, due to synergies with the transportation sector, development and improvement of energy storage technologies may be accelerated.

4
BENCHMARKING DER COSTS

The costs to design, purchase, and install DER remain critical—and often prohibitive—factors in the overall economics of distributed power options. Financing alternatives, high operational efficiency, and low or zero fuel costs can mitigate the upfront capital costs, but the fact remains that total capital equipment costs for DER are expensive and need to be significantly reduced for large market impacts.

Figure 4-1 summarizes the *total cost of energy* for several DER technologies, sorted from lowest to highest cost. While in practice these costs are very site and location specific, the assumed costs shown are within a representative range of industry-reported technology costs. The sensitivity range is driven by a combination of capital cost, financing cost, fuel costs, maintenance costs, and waste heat recovery[4]. These results also take into account capacity factors, which are based on a range of expected operation for each technology. This comparison confirms that, while the costs of DER do not compare with the all-in cost of a 500-MW combined-cycle gas turbine (CCGT), some DER can be cost-effective in comparison to the delivered cost-of-energy to end-users (retail rates), depending on rate structure and level, as well as customer load factor. Also, given the fact that future central-station costs are likely to increase, especially under scenarios of new clean coal technologies, the gap may be closing.

Natural gas prices can have a dramatic impact on the cost-effectiveness of DER projects compared to electricity purchased from a utility. Because high gas prices exacerbate the fuel-cost penalty of high-heat-rate DER projects—other than for DER used for combined heat and power—the higher gas prices become, the less cost-competitive gas-fired DER technologies will be relative to central-station power plants. This factor points to the need for DER options to have ultra-high fuel efficiencies and fuel flexibility, and to use alternative fuels. DER vendors need to specifically develop higher-efficiency systems and new lower-cost energy storage systems to offset the fuel charges.

Given the recent high natural gas prices, one current trend among some energy companies has been to take advantage of "low-cost or free opportunity fuels" such as anaerobic digester gas or landfill gas, or coal-bed methane to fuel DER systems. These alternative fuels can be economically effective and can help utilities in addressing compliance with renewable portfolio standards (RPSs). These environmental pressures will be a key driver to future DER deployment.

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[4] The assumptions and models underlying these cost calculations are detailed in *Economic Costs and Benefits of Distributed Energy Resources: EPRI Technical Update: August 16, 2004*, Energy and Environmental Economics, San Francisco, CA: 2004.

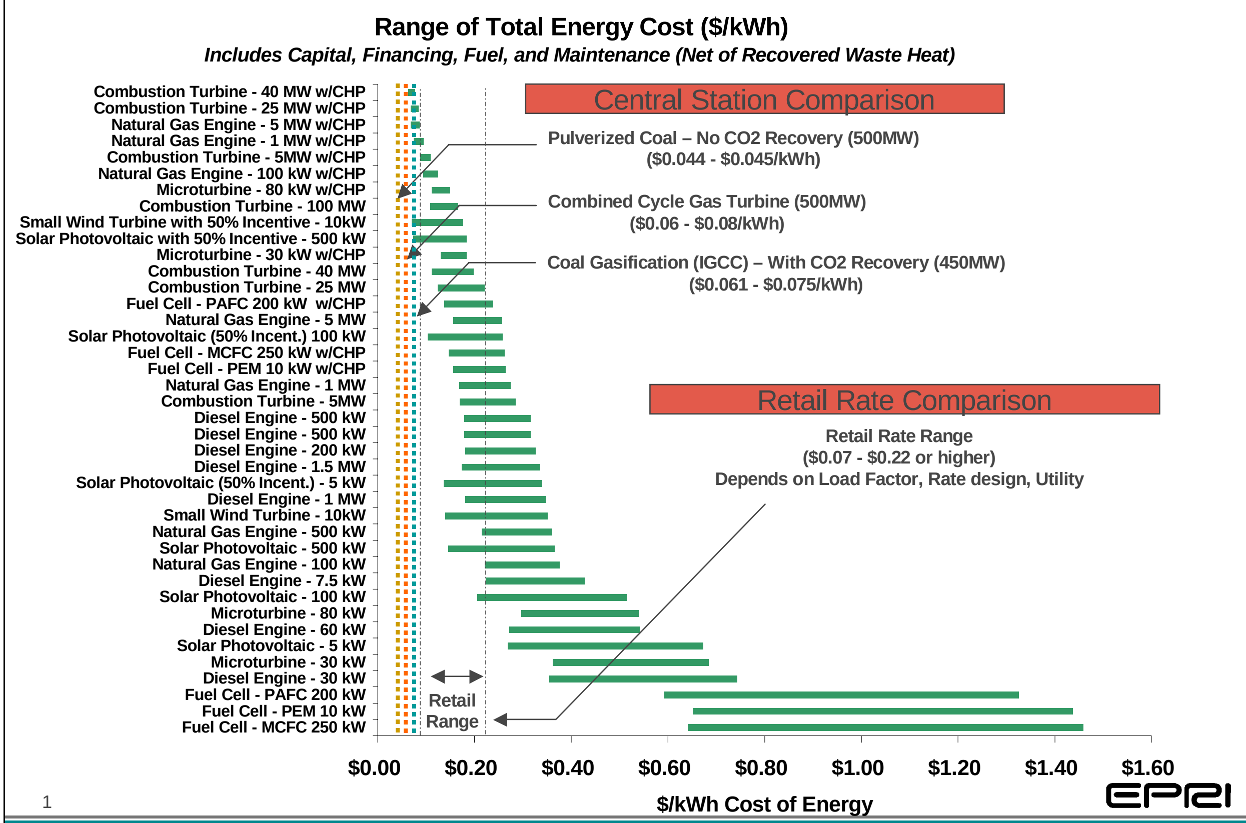

Figure 4-1
Range of Total Energy Cost for DER Technologies, Levelized $/kWh

Large corporations such as Caterpillar, UTC Power, Ingersoll-Rand, and others are serving the current market needs with proven and reliable systems, which are becoming more integrated and packaged into end-user energy solutions. However, investments in clean DER technologies continue by both the public and the private sector. Entrepreneurial interest in DER continues to grow, with an increasing number of small companies developing new products and services. Significant technological breakthroughs may still be possible and even anticipated. Indeed the breakthrough pathway for game-changing technology is anticipated to be via the private equity/small entrepreneurial companies that are currently forming and growing. Improvements in technology are anticipated through 2015 and beyond. A summary of trends in capital cost is provided in Figure 4-2.

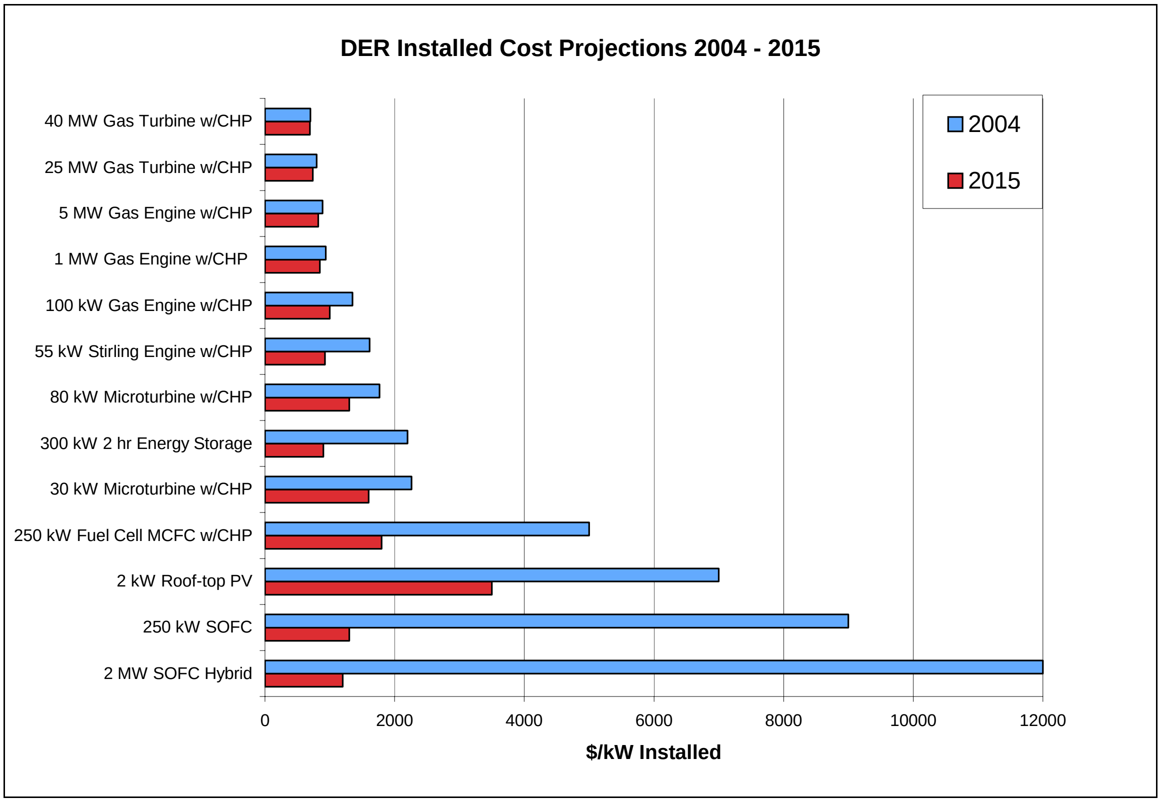

Figure 4-2
Trends in Capital Costs of DER Technologies

The role and value of electric energy storage options were a dominant theme in this benchmarking assessment and future pathway developments. Energy storage systems can be valuable for both customer side of the meter applications as well as utility side of the meter solutions to alternative grid investments. Figure 4-3 shows capital cost trends of the leading energy storages options for applications on the utility side of the meter.[5]

[5] *EPRI-DOE Handbook of Energy Storage for T&D Applications*, December 2003.

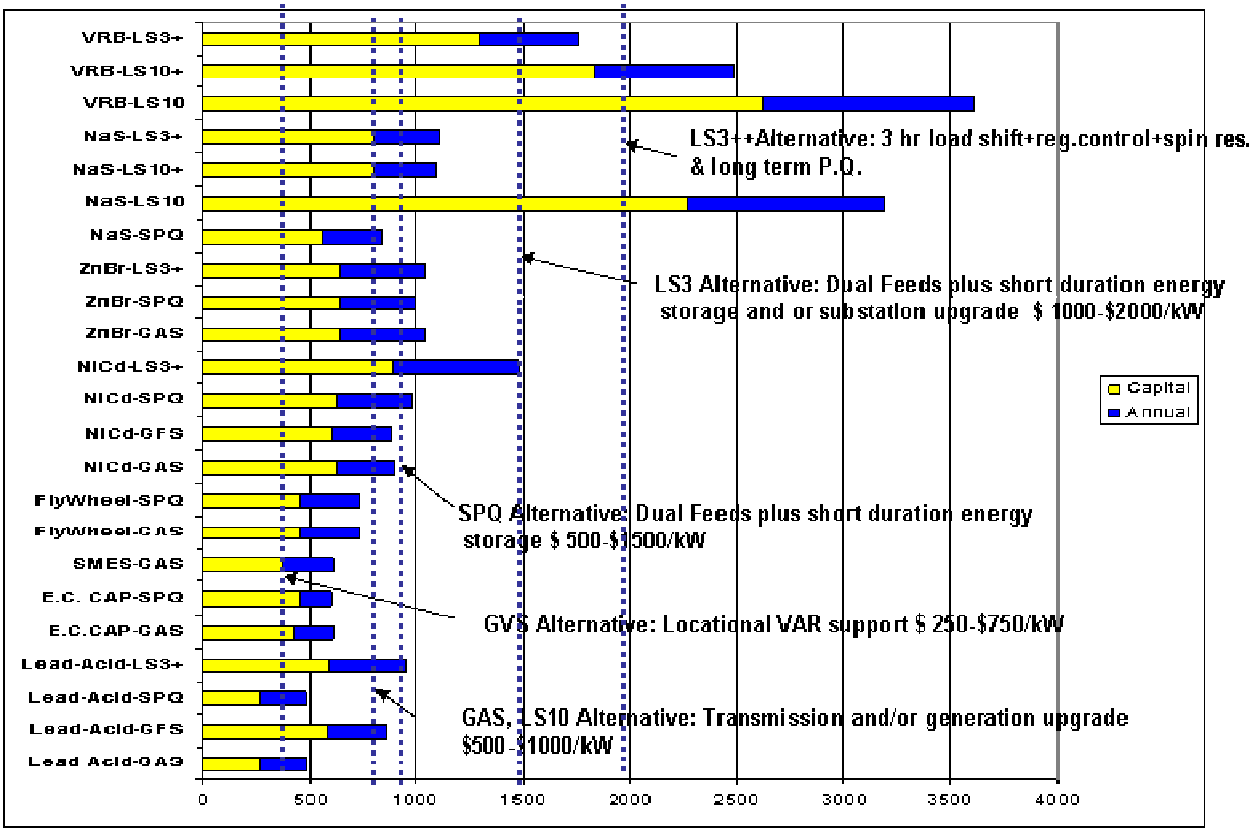

Figure 4-3
Capital and Operating Costs for Leading Energy Storage Options.

Values are for a 10-MW facility. Applications include: Grid Angular Stability (GAS); Grid Voltage Stability (GVS); Grid Frequency Support (GFS); Short-Duration Power Quality (SPQ); 10-h Load Shift plus regulation control and spinning reserve (LS10+); 3-h Load Shift plus regulation control, spinning reserve, and short-term PQ (LS3+). See reference for all assumptions. Annual costs represent 20-yr annualized costs for fixed and variable O&M, battery replacement, and property and insurance costs.)

5
BENCHMARKING DER BENEFITS

Because DER systems can provide power closer to the point-of-use, they may have the potential to save customers money, provide back-up reliability, minimize investments in new transmission and distribution facilities, reduce energy losses, and reduce air pollution and greenhouse gases (CO_2). However, sweeping claims about the “cost-effectiveness” and the “benefits” of DER are not useful for industry stakeholders who are trying to make informed business and policy decisions about the suitability of DER options for planning and procurement.

In practice, it is increasingly difficult to monetize the benefits of DER because many benefits are both time- and location-specific. Also, competitive markets have not been able to monetize DER benefits, and many utility business units have been disaggregated into separate energy supply, transmission, and distribution entities, compounding difficulties to capture and monetize value from decentralized systems.

EPRI’s 2004 technical update on DER costs and benefits[6] provides quantitative and objective information about the current costs and benefits. At present, the majority of DER applications are installed on the customer-side of the utility meter. A summary of customer-side benefits monetized is shown in Figure 5-1.

Figure 5-1 shows the net benefit results for both customer-side and utility-side DER applications categorized by type: peaking, combined-heat-and-power baseload, and renewable. In the figure, the points indicated by squares and accompanying error bars represent a utility-side benefit and sensitivity range for the given technology. Points indicated by diamonds and accompanying error bars represent customer-side benefit and sensitivity range. Technologies that display overlapping error bars or net benefits greater than zero could potentially offer cost-effective DER solutions for customers and/or utilities. In real-world applications, DER projects will have individual costs, expectations of benefits, and non-monetary drivers that affect their adoption. While this type of analysis does not identify all cases where DER could be cost-effective, it does provide insights as to the type of applications that are most likely viable from each ownership perspective.

For example, the figure shows that combustion turbines and natural gas engines used in combined-heat-and-power (CHP) applications offer potentially mutual benefits to both customers and utilities. We estimate up to 20 GW of CHP market opportunity, or 28 GW of CHP and other DER, even at today’s high natural gas prices.[7] In contrast, a diesel engine, used in peak-shaving applications, may offer modest benefits to a customer but very little to a utility.

[6] *Economic Costs and Benefits of Distributed Energy Resources: EPRI Technical Update: 1011305, November, 2004*, Energy and Environmental Economics, San Francisco, CA: 2004.
[7] *The Potential U.S. Market for Distributed Generation*, Resource Dynamics Corporation, Vienna, VA, June 2004.

The figure also suggests that emerging technologies such as microturbines and fuel cells have not yet demonstrated their benefits to either customers or utilities. In fact, the figure shows that peak-shaving DER applications as a whole may or may not be beneficial to customers, but uniformly provide little benefit from the utility perspective, though they may offer other advantages that help offset financial disincentives.

While customer-side applications of DER will continue to be important in the type and amount of future DER applications installed, "utility-side" applications are increasingly being considered. In certain cases, when electric distribution capacity shortfalls are examined, DER can be economical. Our current estimates of DER costs and benefits show fewer instances of cost-effective utility-side DER applications. Therefore, it becomes almost necessary to capture both the private owner and utility owner benefits for DER to be an economical choice, and it is the intersection between the two perspectives that holds the most promise for a "win-win."

When coordinated with the utility planning process to provide enough capacity where needed, and then dispatched during times of peak load, utility-side DER application can be used to manage distribution system demand and, in certain low-growth-rate areas, defer planned transmission and distribution capacity investments. The value of investment deferral depends on the size of the investment, the required DER capacity, and the utility's cost of capital.

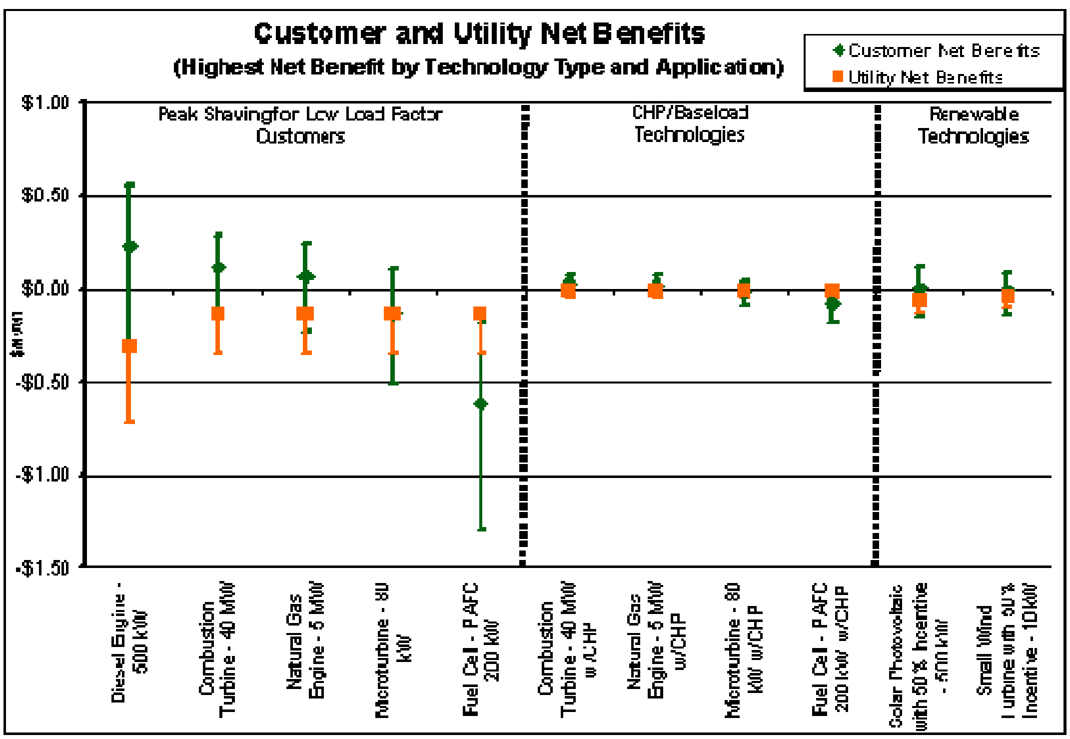

Figure 5-1
Net Benefits of Technologies

Table 5-1 shows the range of transmission and distribution capacity value for different combinations of fully loaded project costs and the capacity of DER required to defer the project. For example, if a 2-MW DER project could be installed in an area and defer a $2 million investment, it would save the utility customers $38/kW-year.

Table 5-1
Deferral Benefit (in $/kW-year)

		DER Capacity Required to Defer T&D Project (MW)					
		1.0 MW	**2.0 MW**	**5.0 MW**	**10 MW**	**20 MW**	**30 MW**
		($/kW-yr)	**($/kW-yr)**	**($/kW-yr)**	**($/kW-yr)**	**($/kW-yr)**	**($/kW-yr)**
Full Cost of T&D Project ($ Millions)	**$1**	38	19	8	4	2	1
	$2	75	38	15	8	4	3
	$5	189	94	38	19	9	6
	$10	377	189	75	38	19	13
	$20	755	377	151	75	38	25
	$30	1,132	566	226	113	57	38

Note: Calculations assume a 6% weighted average cost of capital (WACC) and 2% inflation.

While the table provides a range of T&D capacity values, results are obviously very dependent on the particular area in which the DER is located and the ability of the DER to provide reliable capacity. In addition, only some areas have capacity constraints that can be addressed through DER installation. Recent RFPs in New York and pending RFPs in California are testing the feasibility of this approach.

6
BENCHMARKING DER BUSINESS MODELS

Most DER systems today are being installed by a fragmented industry comprised of small engineering firms and consulting companies responding to end-user needs. This is, by far, the most prevalent business model, especially for solutions involving standby/back-up generation and to a certain extent CHP systems. Electric utilities, including their resource planning functions, are involved to some degree with installations that seek to interconnect with the existing system.

Electric utility companies, energy companies, and systems developers are approaching DER market opportunities with a variety of different business models. Table 6-1 summarizes the current trends in DER business models.

Regulated Utilities

Generally, most regulated utilities are taking a "wait-and-see" approach to DER, but are monitoring technology developments, with several conducting piloting demonstration projects and public relations projects to become more familiar with the risk and business case. A few companies are offering standby/emergency back-up solutions to their customers. Some are trying to obtain special rates from their regulatory commissions, so they can offer DER energy solutions to commercial and industrial customers and receive an adequate return on investment. Others are exploring the economic potential for a possible future utility offering involving DER. In certain jurisdictions, regulated utilities are also being required by the PUC to include DER assessments within their distribution planning efforts. In still other jurisdictions, electric utilities are prohibited from owning and operating DER altogether.

Non-regulated Energy Companies

Although once believed to be the primary business model for DER, bundling DER solutions as part of a non-regulated retail energy services business strategy has diminished from the once heightened interest in the late 1990s as a result of the current state of deregulation and the economics of DER. However, a few companies are still working to develop a business and growth vector involving DER. For example, DTE's Energy|Now product line encompasses a range of technologies developed in cooperation with strategic partners. Representative customer applications include manufacturing plants and institutional facilities that can make efficient use of both electricity and waste heat. Pepco Energy Services is involved with installing packaged microturbines in New York City and surrounding areas. Others like TXU Energy monitor DER technology developments and market activities to stay current on leading advancements and applications, but do not offer DER-related services. Many companies would re-evaluate the business opportunity if the technologies were to get to the point of having a performance and costs that are going to make them more viable than they are today.

New Entrants

A few new companies have emerged who provide packaged systems for C/I and government facilities. Most are providing customer-owned systems, while a few companies actually own and operate the systems and pass the energy savings on to end-users. RealEnergy, Northern Power Systems, Siemens Building Technologies, and UTC Power/Carrier all have active efforts in implementing DER solutions for end-users.

Table 6-1
DER Business Models

Type of Company	Business Model / Activity	Application / Market
Regulated Utility	Packaged systems for C/I backup; customer standby generators for utility peaking; applications to meet state mandates; monitoring DER; pilot demonstrations; considering future offerings.	End-use: grid support; energy supply for constrained areas.
Non-Regulated Utility	Provide back-up power; provide customer-owned CHP systems.	End-use: CHP, premium power.
System Developers, or “New Entrants”	Develop customer-owned projects; develop, own, and operate DER.	End-use: CHP, renewables.
Consultants, small engineering firms	Specify, design, and implement customer-owned DER.	End-use: emergency/backup; and CHP.

7
PATHWAYS TO THE FUTURE: “THE ART OF THE POSSIBLE’

The industry’s future vision of DER can be summarized as “...a future where DER options are cost-effectively and reliably integrated into the electric enterprise, serving the needs of end-users, as well as complementing the supply and delivery of electricity to communities...” But just how the future of DER continues to evolve and the pathways forward will depend on market- and technological-driven scenarios.

This white paper explores a number of pathways in which DER might evolve in the coming years, illustrated here in Figure 7-1. The end-use pathway represents customers employing DER options in order to achieve energy cost savings and higher reliability. The grid-support pathway comprises both transmission and distribution applications, in which utilities seek to avoid or defer infrastructure investment or to improve asset utilization. The energy-supply pathway describes DER applications to provide alternative supply resources.

In addition, in many cases, opportunities exist for joint applications—to meet both end-use and grid support needs, or for both energy supply and grid support. In Figure 7-1, these pathways are labeled “Joint End-Use/Distribution Pathways” and “Joint Supply/Transmission Pathways.”

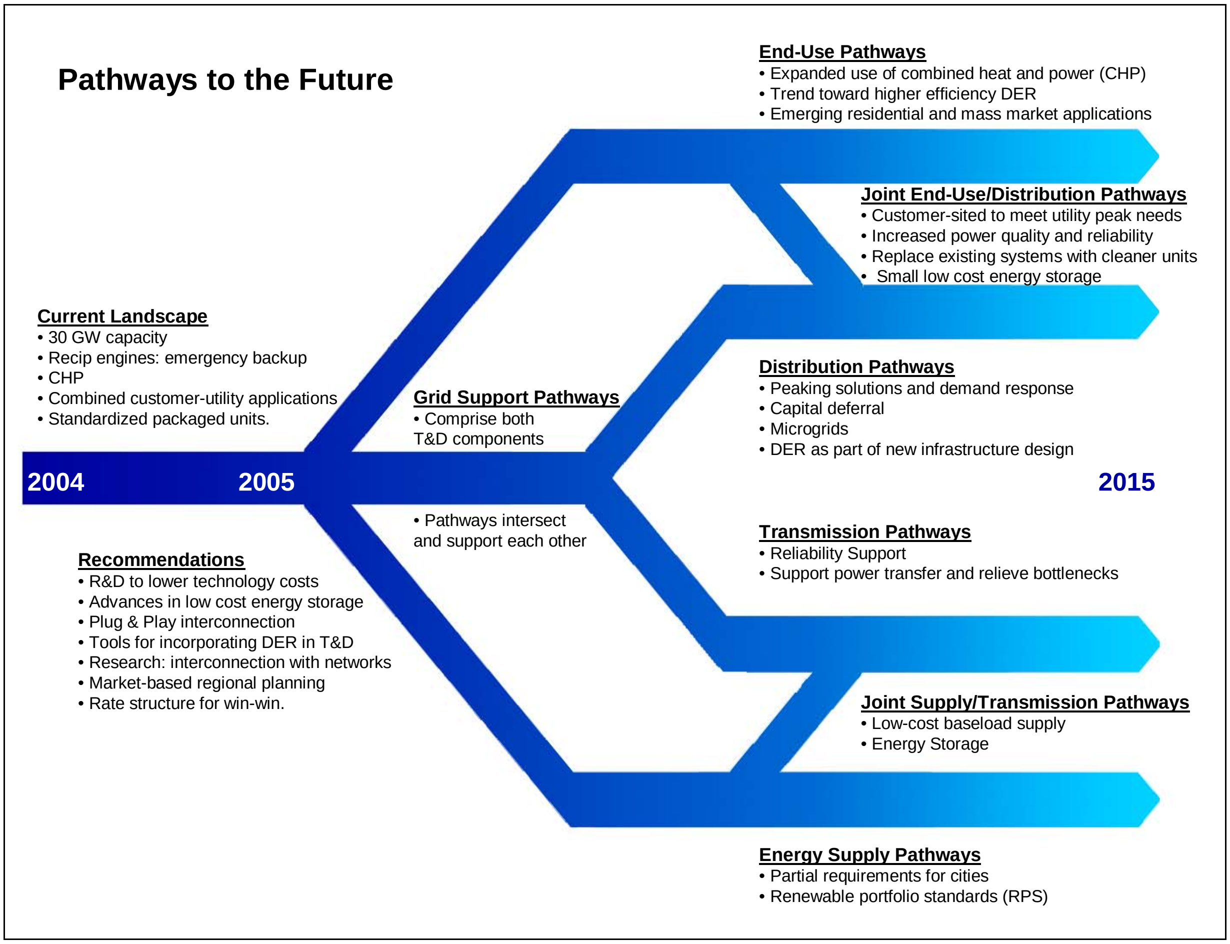

Figure 7-1
Pathways to the 2015 Vision of DER

The future pathways can also be seen against the backdrop of six market scenarios, summarized here in Table 7-1. As noted in this table, DER might be most expected to grow in end-use applications under scenarios of increased environmental regulations, concerns for reliability and security, and DER technology breakthroughs. The role and use of DER options as part of a regulated carbon emission management plan could also impact the use of future DER applications. Breakthroughs in DER technology, especially lower cost energy storage and high efficient fossil fueled systems, have the greatest potential to impact all future pathways. As shown in Table 7-1, in the grid support pathway, little DER development can be expected until regulatory incentives are enacted and demonstrations are conducted that show the value of DER in these applications and the regulations are in place to give utilities adequate return on investment. The hydrogen/electric economy is not expected to impact DER by 2015 unless there are significant technological breakthroughs or changes in policy.

Table 7-1
Scenarios and Impact to DER Pathways

Scenarios / Pathways	End-User	Grid Support	Energy Supply
Business as Usual—modest tech development, no policy changes	◒	○	○
Increased Environmental Regulations—carbon tax, strict emissions controls	●	◒	○
Issues with Reliability and Security—continuing grid failures, Homeland Security requirements	●	●	◒
Global Fuel Scarcity—gas and oil prices rise	◒	○	○
DER Technology Breakthroughs—achievements in cost reduction and efficiency	●	●	●
Hydrogen/Electric Economy—government support, transportation achievements	◒	◒	○

Key: ● High increase in DER. ◒ Moderate. ○ Low.

End-User Pathways

By far, end-users represent the primary pathway and application vector for DER systems, and they are likely to continue to be the chief area of application through 2015. End-users are seeking energy cost savings and higher reliability. They also desire turnkey energy solutions where a third party takes on the risks of the DER option and the energy offering. There is a current unrealized market potential of 30 GW of DER in this pathway, assuming current technology costs and current gas and electric rates. The market could increase to 60 GW with improvements in technology. The following are a number of possible end-use pathways for DER.

- Replacement of existing backup power systems with cleaner dispatchable options.
- Expanded use of CHP and other heat recovery/cooling applications.
- New use of UPS's as a demand response tool involving joint end-user and utility dispatch arrangements.
- Trends toward higher efficiency DER systems especially in CHP and cooling.
- Solutions for emissions reduction credits and renewables quotas.
- Dispatchable small energy storage systems for load management
- Emerging residential and other mass-market applications.

Utility Grid-Support Pathways

While DER has been claimed to offer the potential to avoid T&D infrastructure investments and provide other grid-support benefits, in practice these applications are very limited, primarily due to cost-effectiveness considerations and existing regulatory models. Utilities who have delayed infrastructure investments and who have now experienced load growth due to the rebounding economy are applying mobile DER (diesel gen sets) in critical areas, especially during the hot summer months. In some locales, utilities have been precluded from owning and operating DER and are required to contract for this option; in other cases, the cost of DER is still too high compared to costs of distribution investments. The awareness of DER as a grid support option has increased, and some utilities have adopted the practice of evaluating DER options as part of their distribution planning process. Some of these efforts have been mandated by the public utility commission.

Absent better clarity on regulatory policy, DER options are likely to be introduced only incrementally for grid support and in new infrastructure redesign and implementation. Because some DER technologies have low emissions, they may be employed in the near term in targeted applications to support the grid today. However, with the growing awareness of the aging infrastructure, incremental applications of DER might evolve in combination with advanced distribution automation and monitoring technologies and new active demand-side management technologies to achieve a more robust and reliable grid.

Electric Distribution Pathways

The following are a number of possible pathways for DER in electric distribution systems:

- Strategically located DER systems to provide peaking solutions and to meet demand response.
- DER options used to avoid or defer utility infrastructure capital investment.
- DER technologies employed as components, together with automated communications and control technologies, in advanced distribution initiatives to provide self-healing capabilities of the grid.
- DER use in microgrids and new infrastructure developments as part of build-out in new commercial/industrial parks and communities.

Electric Transmission Pathways

The following are a number of pathways for DER in electric transmission systems:

- DER systems used in constrained areas to improve reliability.
- Larger DER systems used to support power transfer and relieve transmission bottlenecks.

Energy-Supply Pathways

Central-station plants will continue to be the least-cost energy supply options for most utilities. Over the next 10 years, however, generating companies will be undertaking a key transition of the current fleet to a new, more advanced fleet of supply-side generation options, and the cost structure to generate power is expected to increase considerably due to rising fuel costs, and environmental and security costs. Utilities face the issues of how best to make the transition, how best to retire plants, and how to determine if there is a role for larger DER systems. The pathways of DER into the future will build on past trends in the development of renewable and certain "in-city" generation assets. Future pathways will be driven by scenarios of increasing central-station power production costs, transmission constraints, and breakthroughs in advanced generation or storage technologies. Pathways could involve implementation of advanced, modular, clean generation options operating initially on natural gas, alternate fossil fuels, renewables, and later on bio-gas and eventually clean coal. The following are a number of possible energy-supply pathways for DER:

- Partial requirements for cities and communities
- Support for transmission-line bottlenecks
- DER as part of integrated strategy and plan in meeting state renewable portfolio standards
- Low-cost, high-efficiency, fossil-fueled DER

Joint Pathways

Figure 7-1 illustrates how the grid-support pathway is seen as complementary to both the end-use and energy supply pathways. DER can be placed at strategic locations within the utility distribution system that can serve both end-use needs as well as offer support to the grid when it approaches its system's limits. If incentives are offered to the end-user to install and operate the DER for grid support, then grid support applications have the potential to increase the market for end-use applications by helping defray capital or operating cost. Currently, incentives for DER in distribution system grid support applications are being explored in New York and are being planned for California.

Similarly, larger DER systems intended to provide energy supply at strategic locations such as bottlenecks or load pockets can also provide grid support to the transmission system when it approaches its capacity limits. Again, with incentives for proper placement of DER that provides valued grid support, these applications could improve the market prospects for DER to serve energy supply needs and enhance its competitiveness with central-station generation.

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CONCLUSIONS

- **Markets.** End-users will continue to be the largest market for DER options in our "business-as-usual" base case with federal and state DER incentive programs providing most of the current market momentum. Recip engines used for emergency standby dominate the market, with more than 80% of current applications. The un-realized end-user market potential in the U.S. is significant—estimated at 30 GW based on today's high natural gas costs and utility rate structures. However, policy actions are needed to fully capture this potential.
- **Technologies.** Technology advances are linear and incremental, and continue to evolve toward decreasing costs, increasing efficiency, and lowering of emissions. A technology breakthrough in modular generation and/or energy storage is necessary to significantly impact the market.
- **Costs and Benefits of DER.** Some DER can be cost-effective, compared to the delivered cost of energy to end-users, depending on rate structure and level and customer load factor. Also, given the fact that future central-station costs are likely to increase, the gap may be closing. Current high natural gas prices point to the need for DER options to have ultra-high fuel efficiencies and fuel flexibility and to use alternative fuels. Combustion turbines and natural gas engines used in CHP applications offer potentially mutual benefits to both customers and utilities. For utility-side applications, the system benefits of DER are highly area- and time-specific, and in practice, monetization of these values has been very limited. Applications that capture both the private owner and utility owner benefits for DER hold the most promise for a "win-win."
- **DER Business Models.** End-users are driving the markets for DER, and solutions are being provided by numerous consultants and small engineering firms. Utilities and grid system operations and planning are not integrated with these external market actions. Most regulated utilities are taking a "wait-and-see" approach to DER, but are monitoring technology developments. A number of non-regulated companies and new entrants are succeeding with packaged systems for targeted customer applications. Deregulation has impacted the way in which integrated resource plans are conducted.
- **Current Regulatory Trends.** The policy landscape across the country is an inconsistent patchwork of differing utility and state requirements.
- **Pathways to the Future.** End-use pathways are likely to continue to be the chief area of application through 2015. In the grid-support pathway, without better clarity on regulatory policy, DER options are likely to be introduced only incrementally and in new infrastructure redesign and implementation. For energy supply, future pathways will be driven by scenarios of increasing central-station power production costs, transmission constraints, state renewable portfolio targets, and breakthroughs in advanced generation or storage

technologies. In many cases, opportunities exist for joint applications—to meet both end-use and grid support needs, or for both energy supply and grid support.

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RECOMMENDATIONS

The following actions should be considered to close the technological and policy gaps to achieve the future pathways.

DER Technology

- **R&D.** Continued R&D is needed to lower the total capital installed cost, improve efficiency and reliability, and enable fuel flexibility.
- **Waste Heat Utilization.** Advances are needed to improve integrated packages, such as chillers associated with waste heat utilization.
- **Energy Storage.** Advances are needed to improve the cost-effectiveness and capability of energy storage options for end-users, grid support, and leveraging energy supply. Of key interest are electric storage systems in the 10 kWh to 4,000 kWh size range for DER applications.
- **Hydrogen.** Considerable R&D is needed to lower the cost of hydrogen production and cost-effective hydrogen storage. High-pressure, low-cost electrolyzers are needed to best leverage the electric system. Early hydrogen-refueling station pilot demonstrations (anticipated by 2015) should be configured with DER prime movers to enable peak shaving and utility grid support values to be realized in addition to vehicle-refueling roles.

End-Use Applications

- **Standardized Packages.** Standardized energy solution packages are needed for CHP, back-up power, peak shaving, and UPS markets. Also, a standardized and open communication interface compatible with the electric system is needed.
- **Interconnection Device.** Research is needed to develop a low-cost meter, and a low-cost plug-and-play interconnection device for larger kVA DER options, especially for CHP and peak-shaving applications.

Grid-Support Applications

- **T&D Planning.** Engineering and economic tools and best practices are needed to help justify the technical and economic feasibility of incorporating DER into the T&D planning process.
- **Networks.** Research is needed to address and resolve electrical interconnection of DER within electric distribution networks.

- **Business Models for Grid Management.** Business models are needed for dispatching, managing, and controlling DER systems in ways that provide justifiable value to both end-users and to the electric system.
- **Communications and Control.** More robust, sophisticated communications and control infrastructure and protocols are needed to ensure control of DER devices, and to provide grid operators with a comprehensive view of system operation.
- **Regional Planning.** Market-based regional planning is needed to optimize the portfolio of available supply-side, grid investments, and energy efficiency options.
- **Reliability.** The reliability of DER devices needs to be validated to address issues associated with physical assurance.
- **Deferring Investments.** Assessments are needed to establish the technical/economic issues of using large DER to help defer high-voltage transmission investments.
- **Grid Infrastructure Redesign.** Research is needed, for the long term, to investigate the potential role and fit of DER in the redesign strategy and implementation of advanced electric distribution systems including the necessary protection schemes to allow two-directional radial flow of power. Including:
  - – Designs to accommodate DER at customer sites.
  - – Designs with standardized and embedded DER to maximize value.
  - – Designs of new micro-grids with standardized DER options that maximize value.
- **Demonstrations and Pilots.** State-level regional pilots are needed to demonstrate the value and use of DER technologies coupled with innovations in grid design, and automation. The pilots will establish a baseline to encourage follow-on investments in DER enabled grid infrastructure and give utilities a basis for receiving adequate regulatory treatment and returns for such investments.

Energy-Supply Applications

- **High Efficiency and Modularity.** Development is needed of advanced DER systems that are low cost, efficient, and capable of being quickly deployed.
- **Availability.** Standardization of products and pre-certification of systems are needed to verify the reliability of DER technologies.
- **Fuel Diversity.** Vendors need to develop DER options that have the flexibility to burn alternative fuels.

DER Policy Considerations

- **Utility Ownership.** The issue of utility ownership of DER assets needs to be re-examined and resolved by regulatory bodies in some regions.
- **Utility Rate Structures.** Utility rate structures, including standby charges, should be evaluated to determine if redesigned rates might provide win-win opportunities—with

- customer incentives to DER deployment and utility deferment of grid upgrades or other system values monetized as incentives or other considerations.
- **Siting.** Local codes and permits should be assessed to determine if revisions are necessary to facilitate DER siting.
- **Emission Rules.** Differentiated emission rules for DER devices should be evaluated.
- **Reliability Indices.** Enforceable electricity reliability standards that anticipate the needs of the 21st century should be defined and legislated. In addition, the possible use of regulatory incentives should be evaluated to incent utilities to use DER options to improve performance in reliability indices.
- **Federal Policy.** Encouragement should be given to market-based regional planning that recognizes the diversity of DER options and the need for a more flexible and dynamic grid.
- **State and Regional Planning.** Regional market-based integrated resource planning should be explored to enable optimization of supply-side resources, renewables, DER, T&D investments, energy efficiency, and the environmental trade-offs. Better transparency of locational marginal pricing (LMP) could make DER options more cost competitive in some congested areas and help to drive applications.
- **Federal and State Planning.** Jurisdictional disputes between federal and state agencies should be resolved, in order to encourage investor confidence

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