Metric #7: Grid-Connected Distributed Generation and Storage

M.7.1.0 Introduction and Background

This metric measures the quantities and types of distributed-generation and energy-storage equipment that are connected to the grid. Distributed-generation systems are atypical compared to the large and centralized generators that provide most of the grid's power. Rather, DG systems are noted for their smaller-scale local power-generation (10 MVA or less) and distribution systems, and generally have low installation and maintenance costs.

This category includes power generators such as wind turbines connected at the distribution system level, micro hydro installations, solar panels, diesel, etc. These distributed generators produce power for onsite or adjacent consumption and sometimes sell surplus capacity back into the grid under an established feed-in tariff. This metric also covers energy-storage devices such as batteries and flywheels which could be used to store energy produced or purchased during off-peak hours and then sold or consumed during on-peak hours.

M.7.2.0 Description of Metric and Measurable Elements

Electricity sold or stored from DG will be classified into one of 6 categories: internal combustion, combustion turbine, steam turbine, hydroelectric, wind, and other. After recording the classification and the quantity (kW, MW…) of power, the following dimensions will be established. These metrics should not include DG and storage which is not grid-responsive or is available for emergency capacity only. Measures could separate out important new technologies as they help even-out required dispatchable generation. This would include storage that enables time-varying voltage regulation. At this time there are few storage options.

The following three metrics have been identified as important aspects to understanding and quantifying grid-connected distributed generation and storage.

(Metric7.a) Percentage of actively-managed fossil-fired, hydrogen, and biofuels distributed generation. This metric excludes DG whose operation does not respond to grid conditions and excludes emergency, backup generation capacity that is only operated when there is an outage. Must be connected to the distribution system or distribution substation to qualify. Both installed MW and supplied MWh are measured as a percentage of total DG and total grid generation capacity/supply.

(Metric7.b) Percentage of actively-managed batteries and flywheels, excluding transportation applications. Both MW and MWh would be measured as a percentage of total DG and total grid generation capacity/supply.

(Metric7.c) Percentage of non-dispatchable renewable generation. This includes such generation connected anywhere in the grid, though a distinction should be made between distribution- and transmission-connected generation. Both MW and MWh would be measured as a percentage of total DG and total grid generation capacity/supply.

M.7.3.0 Deployment Trends and Projections

Distributed generation capacity has been a small part of total power generation, with combined total distributed generation capacity ranging from 5,423 MW in 2004, to 12,702 MW in 2007.[1] See Figure M.7.1. Available U.S. generating capacity in 2007 comprised 915,292 MW, while summer peak demand reached 782,227 MW and winter peak demand was 637,905.[2] Thus, while grid-connected generation capacity increased 134 percent over three years it still only represented 1.4% of grid capacity, 1.6% of summer peak and 2.0% of winter peak demand.

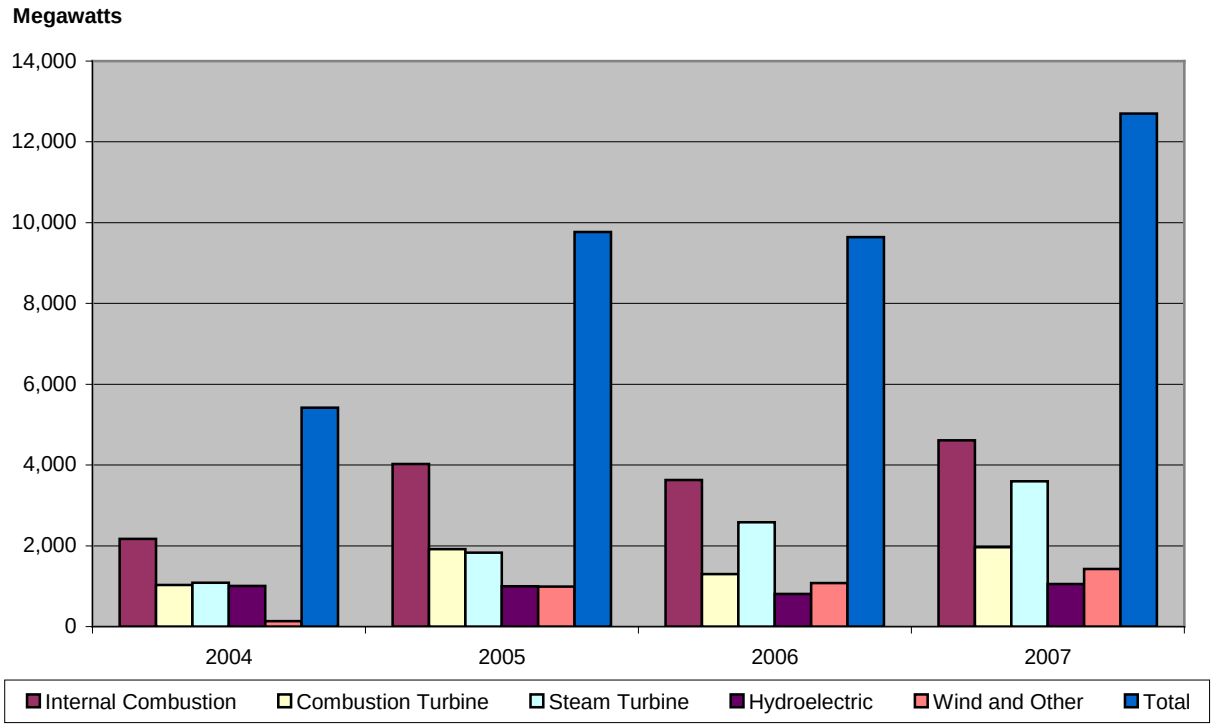

Figure M.7.1. Yearly installed DG capacity by technology type[3]

Actively-managed fossil-fired, hydrogen, and biofuels distributed generation capacity reached 10,173 MW in 2007, up 112% from 2004. This represented approximately 1.1% of total generating capacity and 80% of total DG. Wind and other renewable energy sources grew significantly between 2004 and 2007, increasing by 941%, yet they only represent 0.16% of total available generating capacity, 0.18% of summer peak capacity, and 0.22% of winter peak.[4] Intermittent renewable-energy resources such as wind may not be effective countermeasures for peak demand reduction, although solar has the potential to be more coincident with summer peak-demand periods.

[1] Energy Information Administration (EIA). 2009. *Capacity of Distributed Generators by Technology Type, 2004 through 2007*. Accessed January 30, 2009 at http://www.eia.doe.gov/cneaf/electricity/epa/epaxlfile2_7b.pdf
[2] EIA 2009.
[3] EIA 2009.
[4] EIA 2009.

Interviews conducted in support of this report (see Annex B) indicated the following about grid-connected DG:

- Grid connected DG was reported by only 0.69% of service provider customers.
- Storage capacity was indicated by 3 entities comprising about 0.3 percent of their total customers
- Non-dispatchable renewable generation was reported by only 1.4% of total customers.

Table M.7.1. Yearly Installed DG Capacity by Technology Type[5]

Capacity of Distributed Generators by Technology Type, 2005 and 2006 (Count, Megawatts)

	Internal Combustion	Combustion Turbine	Steam Turbine	Hydroelectric	Wind and Other	Total	
Period	**Capacity**	**Capacity**	**Capacity**	**Capacity**	**Capacity**	**Number of Units**	**Capacity**
2004	2,169	1,028	1,086	1,003	137	5,863	5,423
2005**	4,024	1,917	1,831	998	994	17,371	9,766
2006	3,625	1,299	2,580	806	1,078	5,044	9,641
2007	4,614	1,964	3,595	1,053	1,427	7,103	12,702

** Distributed generator data for 2005 includes a significant number of generators reported by one respondent that may be for residential applications.
Note: Distributed generators are commercial and industrial generators that are connected to the grid. They may be installed at or near a customer`s site, or elsewhere. They may be owned by either the customers of the distribution utility or by the utility. Other Technology includes generators for which technology is not specified.

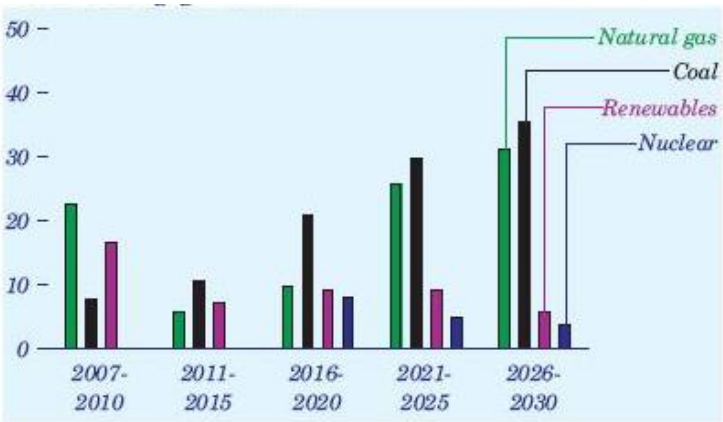

Figure M.7 2. Electricity Generation Capacity Additions by Fuel Type, 2007-2030 (gigawatts)[6]

While DG systems have large startup costs for customers, some technologies, such as solar panels, can be easily installed on rooftops by homeowners and safely generate power for years. Solar power

[5]DOE/EIA. 2009. Form EIA-861, *Electric Power Annual*. Table 2.7.B. Accessed January 30, 2009 at http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html
[6]DOE/EIA 2007. *Energy Market Impacts of a Clean Energy Portfolio Standard – Follow-up.*

installed in this way has a cost of $10 to $12 per watt,[7] although in the future these costs could become much lower.[8] These costs and the costs for other DG technology are expected to fall by 10% for the first three capacity doublings, then fall to 5% for the next 5 doublings. After this point, projected costs fall by 2.5% for all following capacity doublings.[9] Given cost decreases and advancements in other technologies, it is projected that DG generational capacity will reach 5.1 GW by 2010 and 7.5 GW over the next 5 years (see Figure M.7.3).[10] Note, that DG capacity discrepancy between these numbers and those reported early is mainly due to the fact that only grid-connected DG is reported in Table M.7.1.

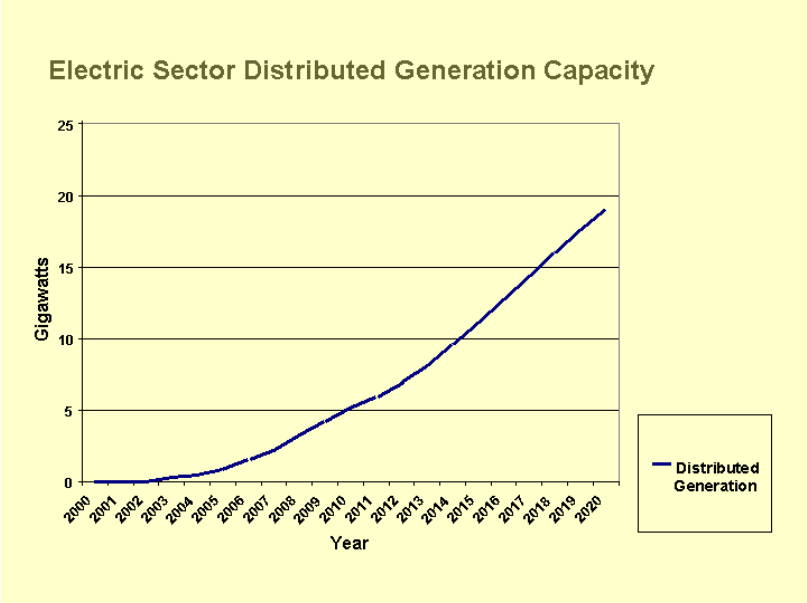

Figure M.7.3. Projected DG Capacity in GW[11]

M.7.3.1 Associated Stakeholders

Associated stakeholders include:

- End-users (customers). Distributed-generation technology allows customers to act as both buyers and sellers in the energy market. Customers can save money by substituting their own generational capacity for expensive on-peak electricity or temporarily reduce their household consumption and sell their electricity back into the market at high peak prices.[12] Further, DG technology allows customers

[7]The Solar Guide. *Solar Cost FAQ*. Moxy Media, Guelph, Ontario. Accessed November 7, 2008 at http://www.thesolarguide.com/solar-power-uses/cost-faq.aspx .

[8]*Next Energy News*. December 19, 2007. "Nano Solar Begins Production of $1 per watt Thin-Film Panels." Accessed November 7, 2008 at http://www.nextenergynews.com/news1/next-energy-news12.19d.html

[9]Eynon RT. ca 2007. *The Role of Distributed Generation in U.S. Energy Markets.* U.S. Department of Energy, Energy Information Administration, (DOE/EIA) Washington, D.C. Accessed November 7, 2008 at http://www.eia.doe.gov/oiaf/speeches/dist_generation.html

[10]U.S. Department of Energy, Energy Information Administration. 2007. *Energy Market Impacts of a Clean Energy Portfolio Standard – Follow-up*. SR/OIAF/2007-02, DOE/EIA, Washington, D.C. Accessed November 24, 2008 at http://www.eia.doe.gov/oiaf/servicerpt/portfolio/index.html

[11]Eynon 2007.

[12] Construction WebLink. 2005. *"Distributed Generation: The Benefits Companies Can Reap y Generating Their Own Power" Accessed on August 28, 2008 at*

to contribute or draw electricity based on environmental standards that they choose. On shorter time scales, storage can assist with balancing and ramping of environmentally friendly, but intermittent, energy resources. If energy deposited into the grid is tracked by source type, consumers can choose to purchase more environmentally friendly energy sources such as wind or solar power, or supply their own "green" power into the market. Additionally, should the grid experience technical problems or an emergency occurrence, customers can disconnect from the grid and generate their own power and/or draw from battery-stored reserves.[13]

- Distribution service providers or utility companies. Utility companies, on the other hand, face a different set of risks. While DG offers the grid access to quick and cheap resources which expand grid flexibility and capacity,[14] DG will also require a significant investment of resources to manage the quality of the power being supplied, as well as the purchase of new infrastructure to dispatch DG resources;
- Distributed-generation and storage-device manufacturers: Suppliers will have a stake in developing lower-cost technologies and making those devices more cost effective;
- Balancing authorities. Balancing authorities are important stakeholders as non-dispatchable renewable generation grows as a proportion of total grid generation capacity;
- Transmission providers. Transmission providers will also have a stake as distributed generation grows to be a larger proportion of the total generation capacity and they need control for power quality issues;
- Local, state and federal energy policy makers may need to develop policies on DG cutoff standards;
- Standards organizations and their developers will need to respond to policy makers on DG cut-off standards.

M.7.3.2 Regional Influences

Different states and regions may have regulations for the quality of the power being sold or how the power is produced. Some states may value DG capacity differently from others and offer different subsidies and/or taxes based on those values. For example, Oregon state law has specific plant site-emissions standards for minor sources emitting pollutants such as NOx, SO_2, CO, particulate matter (PM), etc., whereas Ohio relies on the Best Available Technology (BAT) standard with specific limitations for PM and SO_2 based on location, generator type, and size.[15] Please see Metric 3 on DG Interconnection for more details on state interconnection differences. Additionally, in accordance with

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http://www.constructionweblinks.com/Resources/Industry_Reports__Newsletters/Sep_19_2005/dist.html. September 19th 2005

[13] Construction WebLink. 2005.

[14] Thelen LLP. September 19, 2005." Distributed Generation: The Benefits Companies Can Reap by Generating Their Own Power." *Construction WebLinks.* Accessed November 7, 2008 at http://www.constructionweblinks.com/Resources/Industry_Reports__Newsletters/Sep_19_2005/dist.html.

[15] Energy and Environmental Analysis, Inc. 2004. *Economic Incentives for Distributed Generation*. Accessed November 7, 2008 at http://www.eea-inc.com/rrdb/DGRegProject/Incentives.html

the U.S. Federal Government's Green Power Purchasing Goal, states tend to offer the most incentives for distributed generation projects that use recognized renewable energy sources.[16]

M.7.4.0 Challenges to Deployment

Distributed generation produces significant technical, business and legal challenges for the grid. The technical challenges include integrating DG resources while maintaining the level and quality of voltage and workable protection coordination. Business and financial challenges include the costs to utilities of integrating DG resources and ensuring a flexible enough system that consumers can afford to recover investments in DG resources.

M.7.4.1 Technical Challenges

Technical challenges to deployment include,

- standardization of the DG system interface with the grid (see Metric 3),
- operation and control of the distributed generation; DG may also make fault detection more difficult,[17]
- planning and design,
- voltage regulation.[18]

Of course, both the DG and storage resources being considered here share similar monitoring and control challenges identified for demand-response metrics (Metrics 3 and 5).

The system interfaces associated with incorporating DG resources widen significantly from the traditional grid interface. Internal combustion engines, combustion turbines and small hydropower generation require synchronous or induction generators to convert to the prime source and power frequency. Fuel cells, wind turbines, photovoltaics and batteries require inverters. The challenge is to bring the sources online and maintain system voltage and frequency. In addition, the inverters used to transform DC power generation units to AC power can increase harmonics in the grid.[19]

Voltage-regulation challenges are greater than just changing the transformer. The problem will include overvoltage issues which can arise due to ungrounded DG connected generation.[20] Driesen and Belmans (2006) point out that DG will present technical hurdles in terms of frequency, voltage level, reactive power and power conditioning.

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[16]Database of State Incentives for Renewables & Efficiency (DSIRE). 2008. *Federal Incentives for Renewable Energy: U.S. Federal Government - Green Power Purchasing Goal*. Accessed November 8, 2008 at http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US01R&State=Federal&currentpageid=1

[17]Driesen, J and R Belmans. 2006. "Distributed Generation: Challenges and Possible Solutions. In *2006 IEEE Power Engineering Society General Meeting*. I nstitute of Electrical and Electronics Engineers, Piscataway, New Jersey.

[18]Pai MA. 2002. *Challenges in System Integration of Distributed Generation with the Grid*. Presented at Power Electronics and Fuel Cells Component System Integration Workshop, University of Illinois, Urbana, Illinois. Accessed November 7, 2008 at http://www.nfcrc.uci.edu/2/UfFC/PowerElectronics/PDFs/04_Pai_Challenge_Part1.pdf

[19]Eynon 2007.

[20]Eynon 2007.

Fault detection and protection may become more difficult with increased distributed generation. As electricity usually flows from areas of high voltage to low voltage, it may become more difficult to detect with fault current coming from both the main power system and from the DG unit.[21] This technical challenge means that in case of fault detection DG units usually are removed from the grid first, which could have business impacts as discussed in the next section.

Electricity storage technical challenges include short lifetimes and environmental issues for batteries and materials properties for flywheels. Flow batteries do have long lifetimes but they have only seen field trials. Nickel metal hybrid batteries also have long lifetimes but have lower energy density.

Sodium-sulfur batteries have shown promise in utility applications but currently too costly. Additionally, the cycle efficiencies of batteries are in the range of 70% to 85% indicating that 15% to 30% percent of energy stored is lost.[22]

M.7.4.2 Business and Financial Challenges

Making the grid compatible with DG systems could be expensive for utilities. There will be a need for instrumentation and communication to make the DG resources dispatchable so that utilities and transmission operators can deal with all the technical issues discussed in the previous subsection. These costs could vary from utility to utility.[23] Please see Metric 3 for a discussion of the Business and Financial challenges presented by a lack of standard interconnection agreements.

Another financial problem posed by storing energy generated by DG resources is that batteries require a large degree of maintenance, which adds significantly to the overall costs of building DG systems, and thus increases the payback period.[24] Unless and until the marginal cost of a battery is less than or equal to the marginal cost of its time-of-use price, viable payback strategies, such as storing power during off-peak periods and selling energy back during high-priced peak periods, will not be feasible and could reduce DG penetration. This is especially true for green power such as wind and solar generation, which can vary during the day.

Distributed generation can be brought online much more quickly than more traditional utility-sized generation, with lower total capital costs. However, the costs per kW are higher and the overall costs of a kilowatt-hour (kWh) produced are usually higher than grid-supplied base-load power. In addition, with the greater flexibility associated with DG comes the risk of less grid stability. When DG is a relatively small amount of the grid, DG's impact is relatively small, but as DG penetration increases, the reliability of the grid could potentially degrade due to voltage fluctuations and reactive-power issues. However, other studies show that when DG is set up properly, greater grid reliability can be achieved since pockets of a smart grid can operate as "islands" in the event of a total grid collapse. Firms may need to take these

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[21] DOE/EIA 2007. *Energy Market Impacts of a Clean Energy Portfolio Standard – Follow-up.*

[22] American Physical Society. 2007. *Challenges of Electricity Storage Technologies.* APS Panel on Public Affairs, Committee on Energy and Environment. American Physical Society, College Park, Maryland. Accessed November 7, 2008 at http://www.aps.org/policy/reports/popa-reports/upload/Energy-2007-Report-ElectricityStorageReport.pdf

[23] U.S. Department of Energy (DOE). 2008. *Metrics for Measuring Progress Toward Implementation of the Smart Grid: Results of the Breakout Session Discussions at the Smart Grid Implementation Workshop, June 19-20, 2008* Office of Electricity Delivery and Energy Reliability. Prepared by Energetics Incorporated. Washington, D.C.

[24] Foote, C.E.T., A.J. Roscoe, R.A.F. Currier, G.W. Ault, J.R. MacDonald. November 18, 2005. "Ubiquitous Energy Storage." 2005 International Conference on Future Power Systems.

considerations into account when evaluating the costs/benefits of buying and providing electricity to their businesses.[25] For example, DG generation may serve as a hedge against grid price fluctuations or power-quality uncertainty: as prices fluctuate upward with tightening supply-demand balances or if power quality begins to fall, DG owners may opt to produce their own electricity.[26]

The use of DG will depend upon the supply and price of alternative fuels. Increasing fuel prices for small combustion generators or the intermittent nature of some renewable energy sources may make the economic feasibility of DG fluctuate and it may not be available to meet short-term needs. However, with flexible pricing schemes, shortfalls in grid-supplied capacity can be mitigated by rising prices.

M.7.5.0 Metric Recommendations

No data were found on the kWh of grid-connected distributed generation. The value may not currently be available, but should be with more advanced metering. In addition, the EIA electric power production information could be improved with an indication of the portion of power production that is dispatchable as opposed to variable resources.

[25] Driesen, J and R Belmans. 2006.

[26] LeMaire, Xavier, July 6, 2007. "Regulation and Distributed Generation." Presented at the Sustainable Energy Regulation Network/REEEP ERRA Integration Workshop, Budapest, Hungary. Accessed January 13, 2009 at http://www.rec.org/REEEP/workshops/distributed_generation/lemaire_regulation_and_distributed_generation.pdf