Clean Coalition
Making Clean Local Energy Accessible Now

Distributed Generation of Clean Energy (DG)
Catalog of Benefits

The DG Catalog of Benefits is a reference to technical reports and literature that have analyzed the numerous economic, environmental, and social benefits of the distributed generation of clean energy, as compared to conventional generation or remote, large-scale generation, renewable or otherwise.

Index of Materials by Benefits Category

Employment and Economic Benefits

Relative to large-scale renewables and conventional generation, DG can provide greater employment and economic benefits to a community.

Rocky Mountain Institute review of Solar PV Benefit and Cost studies (2013)

Hansen, Lena, Virginia Lacy, and Devi Glick. "A Review of Solar PV Benefit and Cost Studies" (2013). *Prepared by: Rocky Mountain Institute, Boulder, CO* (2013). *Available at* http://www.rmi.org/Content/Files/eLab-DER_cost_value_Deck_130722.pdf

- Social: Economic Development, pg. 41

"Many of the jobs created from PV, particularly those associated with installation, are local, so there can be **value to society and local communities from growth in quantity and quality of jobs available**. The locations where jobs are created are likely not the same as where jobs are lost. While there could be a net benefit to society, some regions could bear a net cost from the transition in the job market."

Updated Arizona PV Value report (2013)

2013 Updated Solar PV Value Report (2013)
(Arizona Public Service study—follow up to 2009 Distributed Renewable Energy Operating Impacts and Valuation Study led by R.W. Beck) *available at* http://www.solarfuturearizona.com/2013SolarValueStudy.pdf

- "Section 3: Value Assessment Update"

Conclusions:
"The primary element of the value for solar PV is the avoided energy related costs that are displaced by the incremental solar PV production (as indicated in Figure 3-1 for the Expected Penetration Case in 2025)."

Crossborder Energy study for Arizona Public Service (2013)

Beach, Thomas R., and Patrick G. McGuire. "The Benefits and Costs of Solar Distributed Generation for Arizona Public Service" (2013). *Provided by Crossborder Energy, Berkeley, CA* (2013).

- Introduction, pg. 2

"Our work concludes that the benefits of DG on the APS system exceed the cost, such that new DG resources will not impose a burden on APS's ratepayers. The following table summarizes our results. **The benefits exceed the costs by more than 50%, with a benefit / cost ratio of 1.54.**"

Clean Power Research report on DG value in NJ and PA (2012)

Perez, Richard, Benjamin L. Norris, and Thomas E. Hoff. "The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania" (2012). *Prepared by: Clean Power Research, Napa, CA* (2012). *Available at* http://www.solarfuturearizona.com/PVBenefitsReportNJ-PA2012-11-011.pdf

- Economic Development Value, pg. 45

  "The German and Ontario experiences as well as the experience in New Jersey, where fast PV growth is occurring, show that solar energy sustains more jobs per unit of energy generated than conventional energy. Job creation implies value to society in many ways, including increased tax revenues, reduced unemployment, and an increase in general confidence conducive to business development."

German paper on economic effects of renewable energy expansion (2011)

Blazejczak, Jürgen, et al. *Economic effects of renewable energy expansion: A model-based analysis for Germany*. No. 1156. Discussion Papers, German Institute for Economic Research, DIW Berlin, 2011, *available at* https://www.econstor.eu/dspace/bitstream/10419/61337/1/722208774.pdf

- Abstract

  "Our results show that renewable energy expansion can be achieved without compromising growth or employment. The analysis reveals a positive net effect on economic growth in Germany. Net employment effects are positive."

Berkeley RAEL paper on clean energy jobs (2010)

Wei, Max, Shana Patadia, and Daniel M. Kammen. "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy* 38.2 (2010): 919-931. Available at https://rael.berkeley.edu/sites/default/files/old-site-files/green_jobs_paper_Oct1809_0.pdf

- Introduction, pg. 4-5

  "Our modeling approach yields the following key conclusions:
  (1) The renewable energy and low carbon sectors generate ***more jobs per unit of energy delivered than the fossil fuel-based sector****.*
  (2) Among the common RPS technologies, solar photovoltaics (PV) create the most jobs per unit of electricity output.
  (3) Energy efficiency and renewable energy can contribute to much lower CO2 emissions and significant job creation. Cutting the annual rate of increase in electricity generation in half and targeting a 30% RPS in 2030 each generates about two million job-years through 2030.
  (4) A combination of renewable energy, EE, and low carbon approaches such as nuclear and CCS can yield over four million job-years through 2030 with over 50% of the electricity supply from non-fossil supply sources."

ClearSky report on Economic Impacts of Solar in Ontario (2010)

Louw, Brennan, Jon E. Worren, and Tim Wohlgemut. "Economic Impacts of Solar Energy in Ontario" (2010). *Prepared by: ClearSky Advisors Inc.* (2010).

- Executive Summary, Job Creation

"Installing 3 GW of solar PV capacity in Ontario from 2010-2015 will result in 72,429 person-years of employment in the province; **Solar PV in Ontario creates 12 times more jobs than nuclear and 15 times more jobs than natural gas or coal per unit of energy produced**."

Pew Trust on the Clean Energy Race (2010)

Trusts, PEW Charitable. "Who's Winning the Clean Energy Race? Growth, competition and opportunity in the world's largest economies." *Washington, DC: PEW Charitable Trusts. Concentrating Solar Power in Developing Countries* 139 (2010).

- Executive Summary

"Policy, investment and business experts alike have noted that the clean energy economy is emerging as one of the great global economic and environmental opportunities of the 21st century. **Local, state, and national leaders in the United States and around the world increasingly recognize that safe, reliable, clean energy—solar, wind, bioenergy and energy efficiency—can be harnessed to create jobs and businesses**, reduce dependence on foreign energy sources, enhance national security and reduce global warming pollution."

UC Berkeley RAEL analysis on REESA FIT (2010)

Daniel Kammen and Max Wei, Renewable and Appropriate Energy Laboratory, Energy Resources Group, University of California, Berkeley, "Economic Benefits of a Comprehensive Feed-in Tariff: An Analysis of the REESA in California," pg. 9-15, July 7, 2010, *available at* http://rael.berkeley.edu/sites/default/files/Kammen,%20FIT%20Study.pdf

- "Summary of Benefits," pg. 1

"**Will create 3 times the number of jobs from 2011-2020**; Increase direct state revenues by ~$1.7 billion from sales tax, use tax, and income taxes; Stimulate up to $50 billion in total new investment in the state which in turn is eligible for up to $15 billion in Federal tax benefits for project developers."

- Conclusions on pg. 19

"The REESA FIT can drive a massive volume of cost-effective renewable energy in the near-term. With virtually 100% of the deployments in-state, **the program will result in significant employment and tax revenue benefits to California, stimulate activity in the renewable energy industries, increase**

the ability to get federal dollars into California, and provide money to local economies and to employ workers in sustainable jobs."

NREL report on economic development impacts of community wind (2009)

Lantz, E., and S. Tegen, National Renewable Energy Laboratory, "Economic Development Impacts of Community Wind Projects: A Review and Empirical Evaluation," April 2009, *available at* http://www.nrel.gov/docs/fy09osti/45555.pdf.

- Section 1.1. Potential Attributes of Community Wind

"The increased economic impact of community wind projects is generally thought to result from three primary avenues. First, there is the **possibility for increased utilization of local labor and materials during project development and operations**. This potential attribute is more feasible in some regions than others, depending on the local labor pool, and it often depends on developer preferences. Second, **profitable projects with local ownership provide dividends to local shareholders**. Finally, community wind projects may also support **increased economic development impacts by relying on local banks** for construction financing and operating loans, if needed."

- Conclusions

"This analysis finds that **total employment impacts from completed community wind projects are on the order of four to six 1-year jobs per-MW during construction and 0.3 to 0.6 long-term jobs per-MW during operations.** Furthermore, when comparing community wind to hypothetical average absentee projects, construction-period employment impacts are 1.1 to 1.3 times higher and operations-period impacts are 1.1 to 2.8 times higher for community wind."

German ministry report on employment from Renewable Energy (2011)

O'Sullivan, M., et al. "Gross Employment From Renewable Energy in Germany in 2010-First Estimate." *Federal Ministry for the Environment Nature Conservation and Nuclear Safety* (2011).

- Background Information, pg. 10

"According to this first estimate, **gross employment in 2010 therefore totaled about 367,400, which represents a 129% increase over 2004**."

Locational Benefits

DG facilities are located on the distribution grid and can allow utilities to avoid many grid operation costs by producing and delivering power to loads without use of high voltage transmission facilities.

Updated Arizona PV Value report (2013)

2013 Updated Solar PV Value Report (2013)
(Arizona Public Service study—follow up to 2009 Distributed Renewable Energy Operating Impacts and Valuation Study led by R.W. Beck) *available at* http://www.solarfuturearizona.com/2013SolarValueStudy.pdf

- Conclusions

  "The remaining value categories determined for solar PV in 2025 include **avoided transmission capacity costs and fixed O&M costs**. The transmission capacity relates to the avoided or delayed transmission projects (associated with generation planning) due to the projected incremental solar PV penetration."

Clean Power Research paper on designing Austin Energy's Solar Tariff (2012)

Rábago, Karl R., Leslie Libby, and Tim Harvey. "Designing Austin Energy's Solar Tariff Using a Distributed PV Value Calculator." *Proceedings of World Renewable Energy Forum*. 2012, *available at* http://www.cleanpower.com/wp-content/uploads/090_DesigningAustinEnergysSolarTariff.pdf

- Distributed PV Value Calculator

  "Loss savings represent the benefits that distributed resources provide **by reducing system losses by producing power in the same location where it is used**. Loss savings increase the value of other benefits across generation, transmission, and distribution systems"

Natural Gas & Electricity article on the value of rooftop solar (2012)

Powers, Bill. "Alternate fuels: Calculating the value of rooftop solar." *Natural Gas & Electricity* 28.6 (2012): 8-12.

- Calculating What Distributed PV is Worth:

  "The generation of power at or near the point of use eliminates the transmission-line losses that would occur if the electricity is imported from more distant sources to serve the same load. **The value of the line losses avoided by use of distributed generation in PG&E territory is approximately $10 a megawatt-hour**.

  "The addition of local generation also relieves load on the local distribution substation and the transmission line(s) serving that distribution substation. This effect is more pronounced in areas with inadequate transmission, or distribution substations approaching their capacity at times of peak demand."

International Journal of Electrical Power & Energy Systems article on optimal sizing of DG (2012)

Rotaru, Florina, et al. "Two-stage distributed generation optimal sizing with clustering-based node selection." *International Journal of Electrical Power & Energy Systems* 40.1 (2012): 120-129.

- Introduction:

"The benefits brought by the DG introduction are numerous, and the reasons for implementing DG range from energy efficiency or rational use of energy, to liberalisation or competition policy, diversification of energy sources, ability to exploit renewable energy sources, availability of modular generating plants, ease of finding sites for smaller generators, shorter construction times, lower capital costs of smaller plants, network upgrade deferral, and **proximity of the generation plant to large loads, leading to transmission costs reduction**."

Energy Policy article on solar power costs (2011)

Perez, Richard, Ken Zweibel, and Thomas E. Hoff. "Solar power generation in the US: Too expensive, or a bargain?." *Energy Policy* 39.11 (2011): 7290-7297.

"The two primary factors that do determine value per kWh produced are (1) location and (2) solar penetration. **Location is important because the value delivered by solar generation in terms of transmission and distribution and capacity, as well as blackout protection is location-dependent**: a system in winter-peaking rural upstate New York will deliver less value than a system in a growing commercial sector of Long Island."

CA Energy Commission paper on transmission losses (2011)

Wong, Lana. "A Review of Transmission Losses in Planning Studies" (2011). California Energy Commission [staff paper]: CEC-200-2011-009.

- Abstract and Executive Summary

"California average system losses for transmission and distribution ranged from **5.4 percent to 6.9 percent during 2002 to 2008**, based on Energy Commission data."

2009 Distributed Renewable Energy study for Arizona Public Service (2009)

Distributed Renewable Energy Operating Impacts and Valuation Study (R.W. Beck, Inc., 2009) (Arizona Public Service study)

- Section 4 – Technical Value – Transmission System

"[Distributed Energy] reduces the line losses across the transmission system because less energy needs to be transmitted from large central station generation to the location of the demand.
It **reduces the burden on the transmission system at peak demands, possibly allowing deferral of transmission investments**."

Planning Benefits

The smaller size and more rapid development of distribution interconnected facilities can provide greater certainty, flexibility and responsiveness in grid investment and planning than central generation.

Clean Power Research paper on designing Austin Energy's Solar Tariff (2012)

Rábago, Karl R., Leslie Libby, and Tim Harvey. "Designing Austin Energy's Solar Tariff Using a Distributed PV Value Calculator." *Proceedings of World Renewable Energy Forum*. 2012, *available at* http://www.cleanpower.com/wp-content/uploads/090_DesigningAustinEnergysSolarTariff.pdf

- Distributed PV Value Calculator

  "T&D capacity savings are the benefits that distributed PV generation provides by reducing peak loading on the T&D system – delaying the need for capital investments in the T&D system."

Clean Power Research report on DG value in NJ and PA (2012)

Perez, Richard, Benjamin L. Norris, and Thomas E. Hoff. "The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania" (2012). *Prepared by: Clean Power Research, Napa, CA* (2012)*. Available at* http://www.solarfuturearizona.com/PVBenefitsReportNJ-PA2012-11-011.pdf

- T&D Capacity Value, pg. 8:

  "In addition to capital cost savings for generation, PV potentially provides utilities with capital cost savings on T&D infrastructure. In this case, PV is not assumed to displace capital costs but rather defer the need."

Lawrence Berkeley paper on solar valuation methods (2012)

Mills, Andrew, and Ryan Wiser. "An evaluation of solar valuation methods used in utility planning and procurement processes." *Lawrence Berkeley National Laboratory* (2012). Available at http://eetd.lbl.gov/sites/all/files/publications/lbnl-5933e.pdf

- Conclusions and Recommendations, pg. 45

  "**As renewable technologies mature, recognizing and evaluating their economic value will become increasingly important for justifying their expanded use.** We found that many LSEs have a framework to capture and evaluate solar's value, but approaches varied widely: only a few studies appeared to complement the framework with detailed analysis of key factors such as capacity credits, integration costs, and tradeoffs between distributed and utility-scale PV. Factors like the dispatchability benefits of CSP plants with thermal storage appear to be quantified only in terms of a higher capacity credit versus other solar technologies. **As the cost of building solar decreases, it will become increasingly important to refine estimates of these factors for all solar technologies, refine study methodologies, and communicate those methodologies to developers and generating equipment manufacturers**."

Grid Services and Reliability Benefits

If sufficient amount of DG is deployed in beneficial locations and managed well with the latest technology, it can enhance grid security, reliability, and resilience.

Clean Power Research report on DG value in NJ and PA (2012)

Perez, Richard, Benjamin L. Norris, and Thomas E. Hoff. "The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania" (2012). *Prepared by: Clean Power Research, Napa, CA* (2012)*. Available at* http://www.solarfuturearizona.com/PVBenefitsReportNJ-PA2012-11-011.pdf

- Security Enhancement Value, pg. 8

"The delivery of distributed PV energy correlated with load results in an improvement in overall system reliability. By reducing the risk of power outages and rolling blackouts, economic losses are reduced."

Journal of Economic Perspectives article on smarter US grid (2012)

Joskow, Paul L. "Creating a smarter US electricity grid." *The Journal of Economic Perspectives* 26.1 (2012): 29-47.

- Enhancing High Voltage Transmission Systems

"…building major new transmission lines is extremely difficult. The U.S. transmission system was not built to facilitate large movements between interconnected control areas or over long distances; rather, it was built to balance supply and demand reliably within individual utility (or holding company) service areas."

- Conclusions

"The existing electricity distribution system is very old in many areas, and investments to replace key components will have to accelerate just to maintain the reliability of the system. These replacement programs should be consistent with longer-term strategies for modernizing the distribution system."

Energy Conversion and Management article on minizing voltage sag (2012)

Biswas, Soma, Swapan Kumar Goswami, and Amitava Chatterjee. "Optimum distributed generation placement with voltage sag effect minimization." *Energy Conversion and Management* 53.1 (2012): 163-174.

- Introduction

"The technical benefits include improvement of voltage, loss reduction, relieved transmission and distribution congestion, improved utility system reliability and power quality. All these benefits are achieved by installing DG at proper location with proper size."

Applied Energy article on paradigm shift in urban energy systems (2011)

Manfren, Massimiliano, Paola Caputo, and Gaia Costa. "Paradigm shift in urban energy systems through distributed generation: Methods and models." *Applied Energy* 88.4 (2011): 1032-1048.

- Introduction

"Beyond efficiency and carbon reduction, distributed generation (DG) can contribute to the deferral of transmission lines upgrades and expansions (investments in such facilities are constrained by several factors) and **may ensure a better reliability** for users that require uninterrupted service. **Security of supply** is an important issue too that can be addressed within this paradigm. In particular, the main strengths of DG paradigm can be summarized as follows:
1. Power generation from a large variety of distributed resources together with the exploitation of local micro-sources with benefits in term of **decreasing fossil fuels dependence** and protection against electric system's failure (lower risk than in the case of centralized generation);
2. Optimal generation, distribution and storage management to meet specific needs in the built environment;
3. Market accessibility for small investors;
4. Direct customers' involvement in energy demand and peak power reduction programs."

Rocky Mountain Institute review of Solar PV Benefit and Cost studies (2013)

Hansen, Lena, Virginia Lacy, and Devi Glick. "A Review of Solar PV Benefit and Cost Studies" (2013). *Prepared by: Rocky Mountain Institute, Boulder, CO* (2013). *Available at* http://www.rmi.org/Content/Files/eLab-DER_cost_value_Deck_130722.pdf

- Security: Reliability and Resilience, pg. 37

"**Any distributed resources that can be installed near the end user to reduce use of, and congestion along, the T&D network could potentially reduce transmission stress**. This includes technologies that allow energy to be used more efficiently or at different times, reducing the quantity of electricity traveling through the T&D network (especially during peak hours). Any distributed technologies with the capability to be islanded from the grid could also play a role."

CALSEIA paper on implementing the CA SB 32 FIT (2009)

Schell, Lori. "Implementing the Feed In Tariff for Small-Scale Solar Photovoltaics in California as Authorized by SB 32" (2009, Negrete-McLeod, D-Chino). *Provided by California Solar Energy Industries Association* (2009).

- Conclusions:

  "Solar PV systems in California provide significant value to Californians above and beyond the threshold costs of the natural gas-fired proxy plant that are quantified in the 2009 MPR. This analysis has identified and quantified as a PV Adder those components of above-MPR value attributable to electricity generated by a representative PV system using California's bountiful and indigenous solar resource. These components of the PV Adder include the **value of avoided T&D, the value of increased reliability, blackout avoidance and power quality,** as well as the above-MPR value of incremental avoided air emissions associated with natural gas combustion and the associated health benefits."

Environmental Benefits

DG can provide greater **environmental** benefits than other types of generation, including reduced land impacts, pollution and emissions. A "full-cost accounting" of the environmental costs of conventional generation can show that DG costs less than fossil fuel generation.

Environment California Research & Policy Center article on benefits of solar (2013)

Kinman, Michelle (2013). Solar in the Southland: The Benefits of Achieving 20 Percent Local Solar Power in Los Angeles by 2020. Released by *Environment California Research & Policy Center.*

- Solar power saves water, p. 10:
  "Given that water is a scarce, valuable resource in Los Angeles, it is critical to consider how power generation impacts water availability. **Solar panels generate electricity without using any water beyond that needed for occasional washing**. As a result, solar technology can be a smart alternative to traditional fossil fuel plants. Traditional fossil fuel plants use vast amounts of water, constituting almost 50 percent of all water withdrawals in the country. In California, groundwater accounts for approximately one-third to two-thirds of the water consumed by power plants, which can threaten the long-term sustainability of water supplies. **If 1,200 MW of rooftop solar displaced electricity generated from natural gas power plants, it would save an estimated 435 million gallons of water per year**."

Clean Power Research report on DG value in NJ and PA (2012)

Perez, Richard, Benjamin L. Norris, and Thomas E. Hoff. "The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania" (2012). *Prepared by: Clean Power Research, Napa, CA* (2012). *Available at*
http://www.solarfuturearizona.com/PVBenefitsReportNJ-PA2012-11-011.pdf

- Environmental Value, pg. 9

"One of the primary motives for PV and other renewable energy sources is to **reduce the environmental impact of power generation**. Environmental benefits covered in this analysis represent future savings for mitigating environmental damage (sulfur dioxide emissions, water contamination, soil erosion, etc.)."

Synapse Energy Economics paper on hidden costs of electricity (2012)

Keith, Geoff, Sarah Jackson, Alice Napoleon, Tyler Comings, and Jean Ann Ramey. "The Hidden Costs of Electricity: Comparing the Hidden Costs of Power Generation Fuels" (2012). *Provided by Synapse Energy Economics Inc. (2012).*

- Table 3. Climate Change Impacts

"Solar and Wind—Direct emissions from plant operation are negligible."

- Section 4.3. Climate Change Impacts of Coal Power

"Coal-fired generation is one of the largest sources of CO_2 in the U.S., emitting approximately 2 billion tons nationwide in 2010 (EPA 2010a). Coal-fired plants emit CO_2 at a rate between 795 and 1,040 g/kWh (1,750 and 2,300 lb/MWh), depending on the type of coal burned and the plant efficiency."

Clean Power Research paper on Austin Energy's Solar Tariff (2012)

Rábago, Karl R., Leslie Libby, and Tim Harvey. "Designing Austin Energy's Solar Tariff Using a Distributed PV Value Calculator." *Proceedings of World Renewable Energy Forum*. 2012, *available at* http://www.cleanpower.com/wp-content/uploads/090_DesigningAustinEnergysSolarTariff.pdf

- Distributed PV Value Calculator

"**Environmental benefits** recognize the fact that the environmental footprint of PV is considerably smaller than that of fossil-based generation. Environmental value equals PV output times REC price—the incremental cost of offsetting a unit of conventional generation."

Annals of NY Academy of Sciences article on full cost accounting of coal (2011)

Epstein, Paul R., et al. "Full cost accounting for the life cycle of coal." *Annals of the New York Academy of Sciences* 1219.1 (2011): 73-98. Available at http://www.nexteraenergycanada.com/pdf/bluewater/Consultation_01f_App_A7_Part1.pdf

- Abstract

"Each stage in the life cycle of coal—extraction, transport, processing, and combustion—generates a waste stream and carries multiple hazards for health and the environment. These costs are external to the coal industry and are thus often considered "externalities." We estimate that the life cycle effects of coal and the waste stream generated are costing the U.S. public a third to over one-half of a trillion dollars annually. Many of these so-called externalities are, moreover, cumulative. **Accounting for the damages conservatively doubles to triples the price of electricity from coal per kWh generated, making wind, solar, and other forms of nonfossil fuel power generation, along with investments in efficiency and electricity conservation methods, economically competitive**. We focus on Appalachia, though coal is mined in other regions of the United States and is burned throughout the world."

National Bureau of Economic Research article on economics of renewables (2011)

Borenstein, Severin. *The private and public economics of renewable electricity generation*. No. w17695. National Bureau of Economic Research, 2011. Available at http://www.uce3.berkeley.edu/WP_017.pdf

- Introduction:
"**The primary public policy argument for promoting electricity generation from solar, wind, and other renewable sources is the unpriced pollution externalities from burning fossil fuels**. Some parties advocate for renewable electricity generation to improve energy security, price stability, or job creation as well, but these arguments are more difficult to support in a careful analysis, as I discuss later. Even comparing the higher costs of renewables with the environmental benefits, however, is not straightforward. This is because the market value of electricity generation is very dependent on its timing, location and other characteristics, and because quantification of the non-market value from reduced emissions is difficult and controversial."

Renewable and Sustainable Energy Reviews life cycle case study (2010)

Amor, Mourad Ben, et al. "Can distributed generation offer substantial benefits in a Northeastern American context? A case study of small-scale renewable technologies using a life cycle methodology." *Renewable and Sustainable Energy Reviews* 14.9 (2010): 2885-2895.

- Abstract:
"DG utilization will represent an improvement over centralized electricity production in a Northeastern American context, with respect to the environmental, energy and economic indicators assessed, and under the appropriate conditions discussed (i.e., geographical locations and affected centralized electricity production scenarios)."

Renewable and Sustainable Energy Reviews article on benefits to the environment (2010)

Akorede, Mudathir Funsho, Hashim Hizam, and Edris Pouresmaeil. "Distributed energy resources and benefits to the environment." *Renewable and Sustainable Energy Reviews* 14.2 (2010): 724-734. *Available at* http://www.unilorin.edu.ng/publications/akoredef/DER.pdf

- Conclusion
"An overview of distributed energy resources (DER) technologies has been presented in detail in this paper. The study examined the environmental impacts of the conventional power generation method feeding on fossil fuels to the detriment of our environment. It thereafter **identified four areas where DG could be of significant use in mitigating these environmental problems, thereby improving the air quality**. The areas are: reduction in GHG emissions,

higher energy efficiencies, reduced damages to human health, and conservation of resources for additional use."

Energy article on future of electricity systems (2009)

Bayod-Rújula, Angel A. "Future development of the electricity systems with distributed generation." *Energy* 34.3 (2009): 377-383.

- Section 3, DG technologies and applications

"Power generation systems that use renewable resources—the sun, wind, organic matter, and geothermal energy—have some advantages over traditional fossil-fuelled generation systems. For example, **most renewable power technologies do not produce greenhouse gases and emit far less pollution compared to burning oil, coal, or natural gas to generate electricity**. It is widely recognised than the greenhouse gas intensity in hydroelectrical systems is about 15 g CO2/kWhe on average, 20 g CO2/kWhe in the case of wind turbines, and 100 g CO2/kWhe for photovoltaics, whereas in classical thermal systems burning natural gas it is around 577 g CO2/kWhe (combined cycle) or 750 g CO2/kWhe (open cycle) and in burning black coal the values are greater than 860 g CO2/kWhe."

- Section 4, Benefits and problems associated with DG

"Wide-scale use of RES will reduce fossil fuel consumption and greenhouse gas emissions as well as noxious emissions such as oxides of sulphur and nitrogen (SO_x/NO_x), therefore benefiting the environment."

German Federal Ministry paper on renewable energy costs (2009)

Van Mark, Michael and Wolfhart Durrschmidt. "Electricity from Renewable Energy Sources: What Does it Cost?" (2009). *Published by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Berlin, Germany* (2009).

- Why EEG Costs are only Half the Truth, pg. 34

"…the external costs of electricity generation from fossil fuels that are avoided by using renewable energy sources are particularly important from a macro-economic point of view: If these costs were allocated in strict accordance with the 'polluter pays' principle, the price of electricity from non-renewable energy sources would be much higher."

Speed to Deploy and Reduced Risks

DG can generally be deployed much more quickly than larger scale, remote generation. Also DG will typically have lower risks in deployment on a per project basis, and a portfolio of many smaller DG facilities will have a lower portfolio risk than one consisting of a few large facilities. These factors can be beneficial in a variety of program and planning objectives (e.g. timing, planning & investment flexibility, energy & community/external benefits). Finally, "free" renewable resources such as solar and wind provide a cost hedge against the risk of fossil fuel price volatility and future carbon pricing.

Energy Policy article on Ontario feed-in tariff (2013)

Stokes, Leah C. "The politics of renewable energy policies: The case of feed-in tariffs in Ontario, Canada." *Energy Policy* (2013). Available at http://web.mit.edu/lstokes/www/docs/Stokes_2013_Politicsofrenewableenergypolicy.pdf

- Introduction
"While governments have adopted a range of policies aimed at increasing investments in renewable energy, **policy experts consistently characterize feed-in tariff (FIT) policies as the most effective instrument to support large-scale, rapid renewable energy deployment**."

- Section 3.4. Period IV. Fit implementation
"The Green Energy and Green Economy Act removed many barriers to entry, including grid connection problems and lack of cooperation by local distribution companies. The government created a Renewable Energy Facilitation Office to work with project proponents to speed FIT contract approval and grid connection. Further, the Act removed municipal jurisdiction, making it mandatory to connect feed-in tariff contracted projects ("take or pay") into the local distribution system. Essentially, this regulatory change limited a municipality's ability to block projects locally. In addition, the program allowed projects to connect directly to the transmission system, with grid expansion paid for by ratepayers rather than project proponents (Yatchew and Baziliauskas, 2011). Overall, **addressing these non-economic barriers was critical to speeding up project deployment**."

German paper on evolution of the German FIT (2013)

Hoppmann, Joern, Joern Huenteler, and Bastien Girod. "Compulsive Policy-Making–The Evolution of the German Feed-in Tariff System for Solar Photovoltaic Power." *The Role of Deployment Policies in Fostering Innovation for Clean Energy Technologies–Insights from the Solar Photovoltaic Industry* (2013): 141. Available at http://e-collection.library.ethz.ch/eserv/eth:6987/eth-6987-02.pdf?pid=eth:6987&dsID=eth-6987-02.pdf#page=152

- Section 6.2 Policy-Induced Technological Change as a Driver of Issues, p. 162
"…while fostering the deployment of PV was the explicit goal of the policy scheme, **in the case of the German FIT for PV the speed of deployment was continuously higher than what policy makers had expected**."

Crossborder Energy study for Arizona Public Service (2013)

Beach, Thomas R., and Patrick G. McGuire. "The Benefits and Costs of Solar Distributed Generation for Arizona Public Service" (2013). *Provided by Crossborder Energy, Berkeley, CA* (2013).

- Avoided Renewables Costs, pgs. 13-14
"In addition to further reductions in emissions of greenhouse gases and criteria air pollutants, there are economic reasons to procure additional renewables. For example, the 2012 IRP notes that, in both the intermediate- and long-terms, '**renewable resources have the ability to diversify the overall portfolio of resources and provide mitigation against the inherent price volatility risks associated with a natural gas-dominated energy mix**'."

Synapse Energy Economics paper on hidden costs of electricity (2012)

Keith, Geoff, Sarah Jackson, Alice Napoleon, Tyler Comings, and Jean Ann Ramey. "The Hidden Costs of Electricity: Comparing the Hidden Costs of Power Generation Fuels" (2012). *Provided by Synapse Energy Economics Inc. (2012).*

- Table 1. Planning and Cost Risk
"Distributed PV projects have very short lead times, well under a year for residential projects."

The Electricity Journal article on designing FIT policies in the US (2011)

Bull, Pierre, Noah Long, and Cai Steger. "Designing feed-in tariff policies to scale clean distributed generation in the US." *The Electricity Journal* 24.3 (2011): 52-58.

- Conclusion
"**FITs and other standard contract mechanisms can reduce transactional costs and promote rapid development of distributed projects—**with all the associated local and environmental benefits. These policies can be highly effective if they are scaled and staged to avoid the excessive rate impacts seen in Europe, while meeting the unique needs of the U.S. market."

Civil Society Institute paper on a sustainable future for US Power (2011)

Toward a Sustainable Future for the U.S. Power Sector: Beyond Business as Usual 2011. Prepared for the Civil Society Institute, November 16, 2011. Available at http://www.civilsocietyinstitute.org/media/pdfs/Toward%20a%20Sustainable%20Future%2011-16-11.pdf

- Introduction and Summary, pg. 1

"…information has emerged over the past year suggesting that the cost of replacing coal with clean energy is falling. The current and projected price of coal has increased, and the price of photovoltaic (PV) systems has fallen sharply since 2009, a result of unprecedented growth in this sector globally. Further, **the financial sector is increasingly placing risk premiums on technologies with carbon emissions, making renewable energy and efficiency more attractive in comparison**."

NREL analysis on photovoltaic value (2008)

Frantzis, L., et al. *Photovoltaics value analysis*. National Renewable Energy Laboratory, 2008. Available at http://www.midwestsolartraining.org/wiki/images/9/94/PVvalue_NREL.pdf

- Hedge value
  "Current electricity generation is heavily dependant on natural gas and coal. Recent environmental constraints suggest that utilities will become more dependent on natural gas. **PV lessens the exposure of the utility to volatile fuel prices and provides stable and predictable electricity prices**."

Report to Austin Energy on the value of distributed PV (2006)

Hoff, Thomas E., et al. "The Value of Distributed Photovoltaics to Austin Energy and the City of Austin." *Final Report to Austin Energy (SL04300013)* (2006).

- Discussion—Energy Production

"PV systems produce electricity at a stable price. PV cost is almost entirely capital related, with nearly negligible O&M costs and no fuel costs. **PV energy prices are therefore fixed and known over the life of the system. In contrast, electricity prices from fossil-based generation are subject to potentially large fuel price fluctuations**. Just as insurance or certain financial products provide "hedge" value against undesirable outcomes under uncertain future conditions, PV provides a hedge against natural gas price uncertainty."

Energy Policy article on risk reduction in European renewables policies (2006)

Mitchell, Catherine, Dierk Bauknecht, and Peter M. Connor. "Effectiveness through risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany." *Energy Policy* 34.3 (2006): 297-305.

- Section 5.1 Price Risk

  "…the guaranteed feed-in tariff gives generators not just a price that lies above the market price. It also **provides a hedge against price volatility, thereby saving them money they would otherwise have to spend on hedging their price risk.** The higher the price volatility, the higher the value of a guaranteed feed-in tariff."

- Section 5.4 Conclusion

  "The current German feed-in system for renewables has **a number of advantages for renewable generators in terms of reducing their risk**. The effect of this reduced risk is an increased ability for renewable generators to finance their investment through the capital market."

Community and Public Health Benefits

Renewable and Sustainable Energy Reviews article on social acceptance of DG (2012)

Wolsink, Maarten. "The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources." *Renewable and Sustainable Energy Reviews* 16.1 (2012): 822-835.

- Section 4. Community Perspective
  "(a) Collaborative decision-making on wind power schemes, which employs effective forms of community involvement, has proven to be crucial for successful deployment.
  (b) **Successful projects are usually those the community can strongly identify with, as a result of effective involvement and participation in the siting process or due to high community involvement in the management and/or ownership**."

The Lancet article on public health benefits of reducing GHG (2010)

Haines, Andy, et al. "Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers." *The Lancet* 374.9707 (2010): 2104-2114.

- Policy Implications
  "The finding of generally positive health effects of mitigation shows that **strategies promoting a low greenhouse-gas emission economy can also have potential to improve public health**. It also provides a rationale to reduce greenhouse-gas emissions that is not wholly confined to the achievement of climate change mitigation."

Renewable and Sustainable Energy Reviews article on benefits to the environment (2010)

Akorede, Mudathir Funsho, Hashim Hizam, and Edris Pouresmaeil. "Distributed energy resources and benefits to the environment." *Renewable and Sustainable Energy Reviews* 14.2 (2010): 724-734. *Available at* http://www.unilorin.edu.ng/publications/akoredef/DER.pdf

- Section 4.3. Minimizes Damage to Health
  "**Distributed generation technologies are able to mitigate climate change and consequently reduce health risks to the society**. DG is capable of achieving this goal in two ways. One, the value of reducing the reliance on the central grid enables less power losses, and hence less power is produced from the conventional plants. Two, the pattern of emissions from outdoor or airborne pollutants such as NOx, SO2, and others from clean DG units are less hazardous than emissions of the conventional plants that DG replaces. **Due to these two**

factors, the quality of air is being conserved from man-made pollutants, which in turn means reduction in health damage. In addition, since less power would be transported over transmission lines when DG is fully adopted, there is a reduced public concerns over health risks such as leukaemia and brain cancer [33,34] caused by electromagnetic radiation."

Other Avoided Costs-based Analyses

AESC paper on avoided energy supply costs in New England (2013)

Hornby, R. et al. (Synapse) July 12, 2013. Avoided Energy Supply Costs in New England: 2013 Report Executive Summary. Prepared for Avoided Energy Supply Component (AESC) Study Group. Available at http://www.synapse-energy.com/Downloads/SynapseReport.2013-07.AESC.AESC-2013.13-029-Executive%20Summary.pdf

- Ch. 1 Executive Summary
- Section 1.2. Avoided Costs of Electricity

Black & Veatch PV Impact study for San Diego (2013 Draft)

San Diego Distributed Solar PV Impact Study (2013 Draft report). B&V Project No. 176941. Prepared by Black & Veatch and Clean Power Research (2013).

- 4.1.1 Net Cost of Distributed PV Customers:

  "In addition to identifying and quantifying the cost of each service, one of the study objectives was to compare total utility costs and distributed PV value to calculate the "net cost" of customer PV for the utility. Based on this analysis, **the marginal value of distributed PV to the utility is less than the marginal utility cost to serve the loads covered by customer PV generation**. Figure 17 shows the comparison in each year; the "net cost" is the difference between the two bars, which **varies between $0.03/kWh and $0.04/kWh** throughout the study period. Utility costs in this chart are shown with interconnection costs levelized, since this gives a more representative result in terms of the net cost in each year.

California case study on economic value of variable generation (2013)

Mills, Andrew. "Changes in the economic value of variable generation at high penetration levels: A pilot case study of California." (2013).

- Executive Summary—Results and Conclusion, pg. 5

  "The first key conclusion from this analysis is that the marginal economic value of all three solar options considered here is high, higher than the marginal economic value of a flat block of power, in California at low levels of solar penetration. **This high value at low penetration is largely due to the ability of solar resources to reduce the amount of new non-renewable capacity that is built, leading to a high capacity value.** The magnitude of the capacity value of solar resources depends on the coincidence of solar generation with times of high system need, the cost of generation resources that would otherwise be built, and decisions regarding the retirement of older, less efficient conventional generation."

E3 Assessment on technical potential for distributed PV in CA (2012)

CPUC "Technical Potential for Local Distributed Photovoltaics in California" Preliminary Assessment. *Provided by Energy and Environmental Economics, Inc., San Francisco, CA* (2012).

- Section 3.3.2. Avoided Cost, pgs 56-59

Table 15: Components of Avoided Cost

  - *Generation Energy: Estimate of hourly wholesale value of energy adjusted for losses between the point of the wholesale transaction and the point of delivery*
  - *System Capacity: The costs of building new generation capacity to meet system peak loads*
  - *Ancillary Services: The marginal costs of providing system operations and reserves for electricity grid reliability*
  - *Transmission and Distribution (T&D) Capacity: The costs of expanding transmission and distribution capacity to meet peak loads*
  - *Environment: The cost of carbon dioxide emissions associated with the marginal generating resource*
  - *Line Losses: The loss in energy from transmission and distribution across distance*

- pg. 63

"**For most substations, avoided costs are similar – roughly $0.10/kWh - $0.11/kWh**. For a small number of substations in areas with large planned capacity investments, avoided costs are much higher, up to $0.25/kWh."

Natural Gas & Electricity article on the value of rooftop solar (2012)

Powers, Bill. "Alternate fuels: Calculating the value of rooftop solar." *Natural Gas & Electricity* 28.6 (2012): 8-12.

- Abstract:

"As a result, the projected cost of energy from these new natural gas—fired plants, combined with an adjustment for the time of delivery and the transmission and distribution (T&D) costs avoided by reliance on a distributed generation resource, represents the value of rooftop solar electricity in California. **This rooftop solar value is in the range of $0.22—$0.24 a kilowatt-hour (kWh) in Pacific Gas & Electric (PG&E) service territory**."

Clean Coalition paper on Locational Benefits filed in California 2009 Integrated Energy Policy Report (2009)

Clean Coalition Locational Benefits paper from 2009 (filed in 2009 IEPR). Docket No. 09-IEP-1G/03-RPS-1078, available at http://www.clean-coalition.org/site/wp-content/uploads/2012/11/CEC-FIT-jun112009.pdf

- "We describe four major methods by which the FIT program will reduce costs in energy production and thus provide savings to ratepayers. These factors more than offset any price premiums that could exist in early FIT rates. As the analysis clearly shows, the worst-case scenario is that the program would take a few years to yield a net savings to ratepayers."

- *Substitution Effect*: "**In preempting the use of natural gas to generate electricity, the FIT Program will reduce the overall demand for natural gas, driving the price of natural gas downward**. The substitution effect from a comprehensive FIT in California was quantified to be worth between 1 and 2 cents/kWh in the UC Berkeley memo to the CEC dated 10 December 2008. This 1 to 2 cents reduces the effective price for each kWh delivered by renewables under the FIT. The substitution effect is therefore a significant second order effect that persuasively argues for scaling up the FIT program quickly."