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Grid Parity Summary for Response to Undertaking #94

Prepared by
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April 2014

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1 Studies and Research Papers

1.1 Review of Solar Photovoltaic Levelized Cost of Electricity

Published as**:** K. Branker, M. J.M. Pathak, J. M. Pearce, "A Review of Solar Photovoltaic Levelized Cost of Electricity"

Renewable & Sustainable Energy Reviews **15**, pp.4470-4482 (2011)
http://qspace.library.queensu.ca/bitstream/1974/6879/1/LCOE%20of%20PV%20pre-print.pdf

This paper reviews the methodology of properly calculating the LCOE for solar PV, correcting the misconceptions made in the assumptions found throughout the literature. Then a template is provided for better reporting of LCOE results for PV needed to influence policy mandates or make invest decisions

Given the state of the art in the technology and favourable financing terms it is clear that PV has already obtained grid parity in specific locations and as installed costs continues to decline, grid electricity prices continue to escalate, and industry experience increases, PV will become an increasingly economically advantageous source of electricity over expanding geographical regions.

1.2 Grid Parity: A potentially Misleading Concept?

Ben Elliston, *School of Electrical Engineering and Telecommunications*

Iain MacGill, *Centre for Energy and Environmental Markets*

Mark Diesendorf, *Institute of Environmental Studies University of New South Wales*

(2010)

http://www.ies.unsw.edu.au/sites/all/files/GridParity.pdf

It is difficult for PV to be competitive with a at retail tariff due to the varying time and location value of electricity. PV systems can supply power during periods of high demand and high costs, where it is easier to be cost competitive. In central California, very high peak pricing applies during the summer afternoon, allowing PV systems to be oriented in an optimal direction (i.e. more towards the west) to avoid high prices. Furthermore, inclining block tariff provide a strong financial incentive for high consumption customers to use PV to keep consumption below them high pricing tiers.

In a future absent of PV subsidies, a clear price signal that captures all of the relevant costs (and externalities) is essential to enable renewable generation to be invested in the most efficient manner.

The Californian situation shows that a price signal closely tied to demand encourages generators to supply at the times of highest demand. For as long as subsidies are required, policies are needed which direct PV deployment in a similar manner. Current versions of FiTs in Australia are structured to reward maximum energy yield and pay generators independent of the value of the PV system to the network. Some possible enhancements that vary FiTs with time and location have been proposed in this paper.

A simple notion of grid parity does not suffice when considering the dynamics of electricity pricing. The clearer the price signal for end users, the more PV systems will make economic sense on a case by case basis. The grid parity concept remains a useful benchmark for PV system manufacturers to drive towards; however as an indicator of market competitiveness, more complex definitions are needed. Further, the PV industry should address the barriers to adoption that will still exist even when PV systems are economically viable without subsidy.

1.3 Quantifying Rooftop Solar Photovoltaic Potential for Regional Renewable Energy Policy

Lindsay Wiginton, *Queen's University,* Ha Nguyen, *Queen's University,* Joshua M. Pearce, *Michigan Technological University, Queen's University (2010)*

http://www.academia.edu/1484567/Quantifying_rooftop_solar_photovoltaic_potential_for_regional_renewable_energy_policy

Solar photovoltaic (PV) technology has matured to become a technically viable large-scale source of sustainable energy. Understanding the rooftop PV potential is critical for utility planning, accommodating grid capacity, deploying financing schemes and formulating future adaptive energy policies. This paper demonstrates techniques to merge the capabilities of geographic information systems and object-specific image recognition to determine the available rooftop area for PV deployment in an example large-scale region in south eastern Ontario. A five-step procedure has been developed for estimating total rooftop PV potential which involves geographical division of the region; sampling using the Feature Analyst extraction software; extrapolation using roof area-population relationships; reduction for shading, other uses and orientation; and conversion to power and energy outputs. Limitations faced in terms of the capabilities of the software and determining the appropriate fraction of roof area available are discussed. Because *this aspect of the analysis uses an integral approach, PV potential will not be dereferenced, but rather presented as an agglomerate value for use in regional policy making. A relationship across the region was found between total roof area and population of 70.0 m^2/capita ± 6.2%. With appropriate roof tops covered with commercial solar cells, the potential PV peak power output from the region considered is 5.74 GW (157% of the region's peak power demands) and the potential annual energy production is 6909 GWh (5% of Ontario's total annual demand). This suggests that 30% of Ontario's energy demand can be met with province-wide rooftop PV deployment. This new understanding of roof area distribution and potential PV outputs will guide energy policy formulation in Ontario and will inform future research in solar PV deployment and its geographical potential.*

1.4 FINANCIAL RETURN FOR GOVERNMENT SUPPORT OF LARGE-SCALE THIN-FILM SOLAR PHOTOVOLTAIC MANUFACTURING IN CANADA

K. Branker and J. M. Pearce, *Department of Mechanical and Materials Engineering, Queen's University (2010)*

http://qspace.library.queensu.ca/bitstream/1974/5682/1/Gov%20PV%20Qshare.pdf

Sustainable large scale manufacturing and achieving economies of scale with proper fiscal policy and government assistance will help solar PV reach grid parity. In order to accelerate the production of inexpensive renewable electricity governments in general and those of Ontario and

Canada in particular can support large-scale PV manufacturing through incentives. This paper provided a financial analysis of a 1 GW/year turnkey a-Si PV manufacturing plant, although the analysis could be replicated for other solar technology or RETs. The economic benefits for the provincial and federal governments were quantified for various levels of support of the PV manufacturing plant in Ontario from simple loan guarantees and tax holidays to more aggressive 100% subsidies. In all scenarios the governments enjoyed positive cash flows in less than 12 years and in many of the scenarios both governments earned IRRs well over 8% in short time periods. The results showed that it is in the financial best interest of both the Ontario and Canadian federal governments to implement aggressive policy to support PV manufacturing. Such policy would provide substantial economic, environmental and social benefits.

1.5 STUDY OF GRID-CONNECT PHOTOVOLTAIC SYSTEMS: BENEFITS, OPPORTUNITIES AND STRATEGIES

R. J. Passey, M. E. Watt, M. Snow, H. R. Outhred and T. Spooner

Centre for Energy and Environmental Markets (CEEM), University of New South Wales, Sydney, NSW 2052, Australia (2009)

http://onlinelibrary.wiley.com/doi/10.1002/pip.889/pdf

The present values earned by PV in offsetting conventional baseload and peaking generation are significant compared to its installed cost in WA. They are most strongly influenced by the insolation profile and largely independent of where the PV is located on the grid. In contrast, the present values earned by PV in deferring network augmentation and reducing line losses on the WA 'main grid' are very low compared to its installed cost and are very site specific.

The combined sum of these values, when converted to a per kWh value, is approximately equal to the value of the electricity tariff paid to residential end-users for generated electricity on a net metered basis. The discounted value paid to the end-user through the tariff is still insufficient to cover the installation cost of a PV system unless combined with the income available through the PVRP grant and from RECs.

For systems owned by commercial end-users, the combined sum of these values is greater than the available tariff. Since businesses are not eligible for the PVRP grant, PV systems are currently not a financially viable option, even if they were paid a full net metered export rate. Thus, a decision to install PV would depend on the recognition of other values provided by PV, such as improved corporate image or building aesthetics.

In regional areas, where the cost of conventional generation is high (especially where diesel is used), PV systems provide significantly more value than they currently receive for the electricity that they generate. Any FiT up to the cost of conventional generation would actually decrease costs for Horizon Power and so reduce the demand placed on the TEF. In some areas, this would more than cover the cost of PV installation and so likely drive significant uptake.

The methodology applied here could be applied to any location worldwide, and could be used to assess the level and nature of support most appropriate for PV, based purely on the potential benefits it provides to the conventional electricity supply system.

Reducing diesel use for electricity generation could have balance of trade benefits in WA because most of the diesel fuel comes from the refinery at Kwinana, and more than half the crude oil for that refinery comes from outside Australia. Similar *benefits would accrue in most countries given the geographical concentration of crude oil deposits. Increased deployment of PV systems in rural and remote areas worldwide will have greenhouse gas reduction benefits and should also result in local job creation, not only for installation but also for maintenance, while reduced electricity costs should also have economic benefits.*

1.6 RECONSIDERING SOLAR GRID PARITY

Chi-Jen Yang, *Technology Policy Analyst Center on Global Change Duke University, USA (2010)*

http://people.duke.edu/~cy42/PV.pdf

Grid parity–reducing the cost of solar energy to be competitive with conventional grid-supplied electricity–has long been hailed as the tipping point for solar dominance in the energy mix. Such expectations are likely to be overly optimistic. A realistic examination of grid parity suggests that the cost-effectiveness of distributed photovoltaic (PV) systems may be further away than many are hoping for. Furthermore, cost-effectiveness may not guarantee commercial competitiveness. Solar hot water technology is currently far more cost-effective than photovoltaic technology and has already reached grid parity in many places. Nevertheless, the market penetration of solar water heaters remains limited for reasons including unfamiliarity with the technologies and high upfront costs. These same barriers will likely hinder the adoption of distributed solar photovoltaic systems as well. The rapid growth in PV deployment in recent years is largely policy-driven and such rapid growth would not be sustainable unless governments continue to expand financial incentives and policy mandates, as well as address regulatory and market barriers.

1.7 THE PROSPECTS FOR COST COMPETITIVE SOLAR PV POWER

Stefan Reichelstein, Michael Yorston, *Graduate School of Business, Stanford University, USA (2012)*

http://www.law.stanford.edu/sites/default/files/publication/359530/doc/slspublic/prospects_for_cost_competitive_solar_pv_power.pdf

New solar Photovoltaic (PV) installations have grown globally at a rapid pace in recent years. We provide a comprehensive assessment of the cost competitiveness of this electric power source. Based on data available for the second half of 2011, we conclude that utility-scale PV installations are not yet cost competitive with fossil fuel power plants. In contrast, commercial-scale installations have already attained cost parity in the sense that the generating cost of power from solar PV is comparable to the retail electricity prices that commercial users pay, at least in certain parts of the U.S. This conclusion is shown to depend crucially on both the *current federal tax subsidies for solar power and an ideal geographic location for the solar installation. Projecting recent industry trends into the future, we estimate that utility-scale solar PV facilities are on track to become cost competitive by the end of this decade. Furthermore, commercial-scale installations could reach "grid parity" in about ten years, if the current federal tax incentives for solar power were to expire at that point.*

1.8 THE ECONOMIC INEFFICIENCY OF GRID PARITY: THE CASE OF GERMAN PHOTOVOLTAICS

Cosima Jägemann, Simeon Hagspiel, Dietmar Lindenberger, Institute of Energy Economics at the University of Cologne (EWI), December 2013

http://www.ewi.unikoeln.de/fileadmin/user_upload/Publikationen/Working_Paper/EWI_WP_13-19_The_economic_inefficiency_of_grid_parity.pdf

Since PV grid parity has already been achieved in Germany, households are given an indirect financial incentive to invest in PV and battery storage capacities. This paper analyzes the economic consequences of the household's optimization behavior induced by the indirect financial incentive for in-house PV electricity consumption by combining a household optimization model with an electricity system optimization model.

Up to 2050, we find that households save 10 % - 18 % of their accumulated electricity costs by covering 38 - 57 % of their annual electricity demand with self-produced PV electricity. Overall, cost savings on the household level amount to more than 47 bn e2011 up to 2050. However, while the consumption of self-produced electricity is beneficial from the single household's perspective, it is inefficient from the total system perspective. The single household's optimization behavior is found to cause excess costs of 116 bn e2011 accumulated until 2050. Moreover, it leads to significant redistributional effects by raising the financial burden for (residual) electricity consumers by more than 35 bn e2011 up to 2050. In addition, it yields massive revenue losses on the side of the public sector and network operators of more than 77 and 69 bn e2011 by 2050, respectively. In order to enhance the overall economic efficiency, we argue that the financial incentive for in-house PV electricity consumption should be abolished and that energy-related network tariffs should be replaced by tariffs which reflect the costs of grid connection.

1.9 A REVIEW OF SOLAR ENERGY MARKETS, ECONOMICS AND POLICIES

Govinda R. Timilsina, Lado Kurdgelashvili, Patrick A. Narbel, *The World Bank Development Research Group, Environment and Energy Team* (2011)
http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-5845

Physically, solar energy constitutes the most abundant renewable energy resource available and, in most regions of the world, its theoretical potential is far in excess of the current total primary energy supply in those regions. Solar energy technologies could help address energy access to rural and remote communities help improve long-term energy security and help greenhouse gas mitigation.

The market for technologies to harness solar energy has seen dramatic expansion over the past decade – in particular the expansion of the market for grid-connected distributed PV systems and solar hot water systems have been remarkable. Notably, centralized utility scale PV applications have grown strongly in the recent years; off-grid applications are now dominant only in developing markets. Moreover, the market for larger solar thermal technologies that first emerged in the early 1980s is now gathering momentum with a number of new installations as well as projects in the planning stages.

While the costs of solar energy technologies have exhibited rapid declines in the recent past and the potential for significant declines in the near future, the minimum values of levelized cost of any solar technologies, including tower type CSP, which is currently the least costly solar technology, would be higher than the maximum values of levelized costs of conventional technologies for power generation (e.g., nuclear, coal IGCC, coal supercritical, hydro, gas CC) even if capital costs of solar energy technologies were reduced by 25%. Currently, this is the primary barrier to the large-scale deployment of solar energy technologies. Moreover, the scaling-up of solar energy technologies is also constrained by financial, technical and institutional barriers.

Various fiscal and regulatory instruments have been used to increase output of solar energy. These instruments include tax incentives, preferential interest rates, direct incentives, loan programs, construction mandates, renewable portfolio standards, voluntary green power programs, net metering, interconnection standards and demonstration projects. However, the level of incentives provided through these instruments has not been enough to substantially increase the penetration of solar energy in the global energy supply mix. Moreover, these policy instruments can create market inefficiencies in addition to the direct costs of requiring more-39 costly electricity supplies to be used. While not discussed in this paper, these indirect impacts need to be considered in assessing the full opportunity cost of policies to expand solar power production.

Carbon finance mechanisms, in particular the CDM, could potentially support expansion of the solar energy market. While some changes in the operation of the CDM could increase solar investment, the price of carbon credits required to make solar energy technologies economically competitive with other technologies to reduce GHG emissions would be high.

The fundamental barrier to increasing market-driven utilization of solar technologies continues to be their cost. The current growth of solar energy is mainly driven by policy supports. Continuation and expansion of costly existing supports would be necessary for several decades to enhance the further deployment of solar energy in both developed and developing countries, given current technologies and projections of their further improvements over the near to medium term. Overcoming current technical and economic barriers will require substantial further outlays to finance applied research and development, and to cover anticipated costs of initial investments in commercial-scale improved-technology production capacity.

2 PUBLICATIONS, PRESENTATIONS AND RESEARCH REPORTS

2.1 TECHNOLOGY ROADMAP

International Energy Agency, October 2010

https://www.iea.org/publications/freepublications/publication/pv_roadmap.pdf

While its use is small today, solar photovoltaic (PV) power has a particularly promising future. Global PV capacity has been increasing at an average annual growth rate of more than 40% since 2000 and it has significant potential for long-term growth over the next decades. This roadmap envisions that by 2050, PV will provide 11% of global electricity production (4 500 TWh per year), corresponding to 3 000 gigawatts of cumulative installed PV capacity. In addition to contributing to significant greenhouse gas emission reductions, this level of PV will deliver substantial benefits in terms of the security of energy supply and socio-economic development. Achieving this target will require a strong and balanced policy effort in the next decade to allow for optimal technology progress, cost reduction and ramp-up of industrial manufacturing. This roadmap also identifies technology goals and milestones that must be undertaken by different stakeholders to enable the most cost-efficient expansion of PV. As the recommendations of the roadmaps are implemented, and as technology and policy frameworks evolve, the potential for different technologies may increase. In response, the IEA will continue to update its analysis of future potentials, and welcomes stakeholder input as the roadmaps are taken forward.

2.2 GRID PARITY FOR RESIDENTIAL PHOTOVOLTAIC IN THE UNITED STATES: KEY DRIVERS AND SENSITIVITIES

S.Ong,P.Denham, and N.Clark, *Presented at the 2012 World Renewable Energy Forum Denver, Colorado*

http://www.nrel.gov/docs/fy12osti/54527.pdf

> *We evaluate the break-even price for residential PV customers in the United States and find that the current break-even price varies more than a factor of 10 even though the solar resource varies by less than a factor of two. This difference is largely driven by electricity prices, which can vary by a factor of eight (or more when considering the range of tiered rates in California). Large variations in break-even cost also result from the range of financing options and other non-technical factors.*
>
> *The general trend observed in this analysis is that break-even conditions appear first in the Southwest where they are driven by resource and in the Northeast where they are driven by high electricity prices. As PV system prices continue to decline, break-even conditions begin to occur in the Southeast and Midwest. Very low electricity prices will preclude break-even conditions in certain areas in the Northwest and Midwest even with PV prices at $3.5/W and continuation of the federal investment tax credit.*
>
> *Overall, the scenarios evaluated represent a market entry point for solar PV. However, the scenarios do not consider the potential for a deep, sustained market. PV breakeven does not imply that customers will necessarily adopt PV, and only a fraction of customers in each utility will have the necessary combination of good solar access and attractive financing options to consider a PV system. A true depth of market analysis is required to determine a "demand curve" for PV at various price points.*

2.3 SOLAR PV MARKET FORECASTS

Navigant Research, Published 3Q 2013

http://www.navigantresearch.com/wp-assets/uploads/2013/07/MD-SMF-13-Executive-Summary.pdf

> *Following years of solar PV module oversupply and unsustainable, often artificially low pricing, 2013 is expected to be the year that the global solar PV market begins to stabilize.*
>
> *Navigant Research's forecast is based on the assumption that PV module prices and installation costs will continue to decline at a much more conservative range of 3% to 8% per year from 2013 to 2020, compared to the drastic price declines in previous years. By 2020, solar PV systems will be installed in the range of $1.50*

per watt to $2.19 per watt throughout the world. If this price range is realized, solar PV will largely be at grid parity, without subsidies, in all but the least expensive retail electricity markets.

2.4 Current Status and Future Trends of Solar Cell Technologies

Rafael Kleiman, *Nova Scotia Energy Research & Development Forum 2012*

http://www.oera.ca/wp-content/uploads/2013/04/Rafael-Kleiman-McMaster-University.pdf

- Solar is largest available energy resource
- Grid parity for solar inevitable
- Arrival time depends on jurisdiction and external factors, 2019-2023
- Canada on *lagging* edge of grid parity
    - Nova Scotia on *leading* edge in Canada
- Silicon technology leading in near and medium term
- Long term
    - higher efficiency technologies likely to prevail, since Si cell limits ~ 25%

2.5 Photovoltaics Business Models

L.Frantzis, S. Graham, R. Katofsky, and H. Sawyer, *NREL, Navigant Consulting Inc*., *February 2008*

http://www.nrel.gov/docs/fy08osti/42304.pdf

Currently, PV business models revolve around access to lower-cost financing, increasing the efficiency of the supply chain, and reducing hassles and complexity for the customer. These types of incremental improvements will occur naturally as 0 and 1st Generation business models continue to evolve.

Up until this point, there has been little reason to address system control or consider PV aggregation as an explicit policy matter, given the limited number of PV systems installed on the distribution grid. However, a time will come—in some areas of the country much sooner than others—when the sheer number of installed distributed PV systems becomes a material and operational concern—or opportunity—for utilities. Policy and regulatory considerations will then be paramount.

The most significant finding in this study to date is that the full benefits of an extensive distributed PV resource are not likely to be realized without some degree of utility control and ownership. The need to have active management and control of an increasingly large number of distributed PV systems implies that utilities will most likely become more involved in one way or another. As market penetration increases, distributed generation will reach a scale (i.e., generally greater than 100 MW) that could translate to significant value. For example, utility involvement could *help optimize distributed PV assets by incorporating them into grid and generation planning. This is likely to reduce new peaking power requirements, distribution substation upgrades, and other system investments, thus unlocking latent value in the electric grid as a whole.*

The results of the analyses performed in this series of DOE studies show that the real value of PV lies in its potential to offset generation, capacity, and T&D investment. Such value greatly outweighs the value PV has for providing ancillary services on the distribution grid. Therefore, business model development will not be driven by the potential for ancillary grid services. It is the possibility that a large quantity of distributed PV systems will be installed that provides the greatest potential benefit to the nation's energy infrastructure, as these systems in aggregate could actually offset significant investment requirements in new generation, transmission, and distribution capacity.

Aside from the technological changes that will be required to accommodate a large capacity of PV on the grid, the organizational structure of today's utilities does not facilitate the adoption of the new business models discussed in this report. For example, current grid planning and operation practices do not explicitly take into account the potential value from PV, and these functions are largely separate within utility organizations, which hampers inclusion of PV and other distributed resources in system.

2.6 Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business

Edison Electric Institute, January 2013

http://www.eei.org/ourissues/finance/documents/disruptivechallenges.pdf

While the threat of disruptive forces on the utility industry has been limited to date, economic fundamentals and public policies in place are likely to encourage significant future disruption to the utility business model. Technology innovation and rate structures that encourage cross subsidization of DER and/or behavioral modification by customers must be addressed quickly to mitigate further damage to the utility franchise and to better align interests of all stakeholders.

Utility investors seek a return on investment that depends on the increase in the value of their investment through growth in earnings and dividends. When customers have the opportunity to reduce their use of a product or find another provider of such service, utility earnings growth is threatened. As this threat to growth becomes more evident, investors will become less attracted to investments in the utility sector. This will be manifested via a higher cost of capital and less capital available to be allocated to the sector.

Investors today appear confident in the utility regulatory model since the threat of disruptive forces has been modest to date. However, the competitive economics of distributed energy resources, such as PV solar, have improved significantly based on technology innovation and government incentives and subsidies, including tax and tariff-shifting incentives. But with policies in place that encourage cross subsidization of proactive customers, those not able or willing to respond to change will not be able to bear the responsibility left behind by proactive DER participating customers. It should not be left to the utility investor to bear the cost of these subsidies and the threat to their investment value.

This paper encourages an immediate focus on revising state and federal policies that do not align the interests of customers and investors, particularly revising utility tariff structures in order to eliminate cross subsidies (by non-DER participants) and utility investor cost-recovery uncertainties. In addition, utilities and stakeholders must develop policies and strategies to reduce the risk of ongoing customer disruption, including assessing business models where utilities can add value to customers and investors by providing new services.

While the pace of disruption cannot be predicted, the mere fact that we are seeing the beginning of customer disruption and that there is a large universe of companies pursuing this opportunity highlight the importance of proactive and timely planning to address these challenges early on so that uneconomic disruption does not proceed further. Ultimately, all stakeholders must embrace change in technology and business models in order to maintain a viable utility industry.

2.7 An Inexpensive Fuel-Cell Generator

Kevin Bullis, *MIT Technology Review, August 2013*

http://www.technologyreview.com/news/518516/an-inexpensive-fuel-cell-generator/

People could soon get cleaner energy from a compact fuel-cell generator in their backyards, at costs cheaper than power from the grid. At least, that's the hope of Redox Power Systems, a startup based in Fulton, Maryland, which plans to offer a substantially cheaper fuel cell next year.

2.8 Going with the Flow

The Economist, January, 2014

http://www.economist.com/blogs/babbage/2014/01/giant-batteries

If battery-makers have to use metals, they are restricted to what the periodic table offers them. If they can use quinones, then they can tweak their materials by adding and subtracting atoms until they get the properties they want.

That, plus the low cost (Dr Huskinson and Dr Marshak estimate $21 per kilowatt-hour of storage capacity for the AQDS and a further $6 for the bromine and hydrobromic acid, as against $81 for a vanadium-based system even before any platinum electrodes used are taken into account), means the future looks bright for quinone-based flow batteries—and thus, by extension, for renewable energy

3 MICROGRIDS

3.1 ARE SMART MICROGRIDS IN YOUR FUTURE? EXPLORING CHALLENGES AND OPPORTUNITIES FOR STATE PUBLIC UTILITY REGULATORS

Tom Stanton, Principal Researcher, National Regulatory Research Institute, October 2012

http://www.secs.oakland.edu/~frick/Smart_Grid/Leidel_OU/Are%20Smart%20Microgrids%20in%20Your%20Future_Stanton_2012_NRRI-12-15.pdf

As Grünewald, Cockerill, et al. (in press) observe, new technologies and services can result in pressure for regime change in current markets and institutions. Microgrid service represents this kind of potentially disruptive technology.

That there is growing interest in microgrids is indisputable. So is the fact that microgrid development raises issues that can be addressed only by state public utility commissions.

The current status of microgrids in the U.S. is that a small number of case studies are starting to provide preliminary proof that microgrids can provide many important benefits for customers, the electric grid, and society as a whole. Though many important benefits from microgrids are possible, those benefits are conditional, depending on the specific combinations of components included, the capabilities embodied in controls and management protocols, grid locations, and size in terms of electric capacity. In many ways, state public utility regulations will ultimately determine the details about whether, how, and where microgrids can be built, what customers they can serve, what services they can provide, and thus what benefits microgrids can produce.

At present, the policy arena for microgrids is uncertain in most jurisdictions; that uncertainty has a chilling effect on both companies interested in providing and customers interested in obtaining microgrid services. As a starting point for addressing microgrids, current policies will need to be reviewed and clarified. Once the current policy environment is clearly understood, then all interested parties can begin to identify possible future policy changes to enable one or more business models for microgrid development.

The three major policy approaches this paper recommends are that commissions

(1) provide leadership for the process of reviewing and clarifying present rules and regulations;

(2) review rate structures for full- and partial-requirements service customers to align them as much as practical with the costs and benefits of DER; and then (3) take modest, incremental steps to begin opening one or more opportunities for microgrids, at least for additional demonstrations, experiments, or pilot projects.

3.2 MICROGRIDS: POWER SYSTEMS FOR THE 21ST CENTURY

Tom Markvart and Ray Arnold, *University of Southampton, September 2005*

http://www.science.smith.edu/~jcardell/Courses/EGR325/Readings/Microgrid_UK.pdf

Almost all the electricity currently produced in the UK is generated from a centralised power system designed around large fossil fuel or nuclear power stations. This power system is robust and reliable but the efficiency of power generation is low, resulting in large quantities (around 60%) of primary energy being wasted as heat. Tom Markvart and Ray Arnold argue that smaller scale power supply networks could deliver substantial environmental benefits via higher energy efficiency and by facilitating the integration of renewable sources.

3.3 MICROGRIDS – BENEFITS, MODELS, BARRIERS AND SUGGESTED POLICY INITIATIVES FOR THE COMMONWEALTH OF MASSACHUSETTS

Massachusetts Clean Energy Center, February 2014

http://images.masscec.com/uploads/attachments/2014/03/Microgrids%20-%20Benefits,%20Models,%20Barriers%20and%20Suggested%20Policy%20Initiatives%20for%20the%20Commonwealth%20of%20Massachusetts.pdf

The report focuses on the benefits of microgrids and articulates the value of microgrids, as opposed to stand-alone distributed energy resources, whose operations are not necessarily coordinated. We identified the primary benefits as: the ability to economically provide electricity to critical loads within the microgrid, and to improve power quality, flexibility and reliability by integrating and optimizing various sources of energy. Therefore, microgrids represent coordinated control of DERs to maximize economics, reliability and clean energy (if feasible), and to stabilize electric loads and generation while operating independently of the macrogrid.

As an emerging field that has coincided with the development of distributed generation and advances in controls and communication systems, this report provides information on the wide variety of activities occurring in the United States *and European countries, including activities to pilot microgrids in developing markets, while evaluating their various advantages. To address potential conflicts with traditional distribution utility business models, this report examined four microgrid ownership/business model concepts, some of which are currently in use or are being piloted.*

4 STATEMENTS

4.1 COMMERCIAL MICROGRIDS: THE NEXT BIG THING?

Panel, June 2013

http://www.chadbourne.com/files/publication/fd811eb0-fd67-4dc2-b8b5-c5207648fc24/presentation/publicationattachment/f7a019c3-8e5c-40df-8235-c95bb7f74f58/CommercialMicrogrids_pfnJun13.pdf

How widespread are microgrids? How great a threat are they to traditional utilities? A group of panelists talked about these and other issues at an Infocast conference on commercial microgrids in Washington.

The panelists are Mark Crowdis, president of Think Energy Inc., Michael Kornitas, energy conservation manager for Rutgers University, Brian Patterson, chairman of Emerge Alliance, Jeff Seidel, director of capital expenditures for the Mohegan Tribal Gaming Community Authority, Dr. Mohammad Shahidehpour, professor and director of the Robert W. Galvin Center for Electricity Innovation at the Illinois Institute of Technology, and Phil Smith, director of federal project development for Honeywell Building Solutions. The moderator is Keith Martin with Chadbourne in Washington*.*

4.2 MICROGRIDS: THINKING OUTSIDE THE GRID

Clarke Bruno, Senior Vice President, Anabaric Transmission, *DNVL GL's 6th Annual Utility of the Future Leadership Forum, June 2013*

http://www.dnvkema.com/innovations/utility-future/books/panel-summaries.aspx#prettyPhoto/27/

"Microgrids are threat and I think they are threat in at least two areas. I think it is important to focus first, in terms of the franchise right. Microgrids begin to undermine the exclusive franchise. Second, because they do that they can cannibalize sales".

4.3 INTERVIEW: ORIGIN ENERGY CEO GRANT KING

New Economy, August 2013

http://reneweconomy.com.au/2013/interview-origin-energy-ceo-grant-king-61027

Grant King is the CEO of Origin Energy, the largest utility in the country, which is also a major shareholder in the $24 billion LNG project in Queensland.

King is influential in Coalition circles – to the point where some joke that he could be acting as a de-facto energy minister in an Abbott government – and his views carry great weight in the debate about energy policies in Australia.

In this interview with RenewEconomy, King address a range of issues, from carbon pricing, the renewable energy target, the threat of solar PV and distributed generation, the future of centralised vs local grids, and the impact of gas.