



Emerging Technologies

How ISOs and RTOs can create a more nimble, robust bulk electricity system

March 2017

*Written by the IRC's Emerging Technologies Task Force and presented jointly
by the IRC's Operations and Communications Committees*

Contact:

Edward Arlitt, IESO

Chairman, IRC Emerging Technologies Task Force

Edward.Arlitt@ieso.ca | (905) 403-6918

Contents

Executive Summary.....	3
Analysis and Recommendations	5
Renewable Supply and Integration.....	5
IRC Positions: Renewable Supply and Integration:	6
Situational awareness.....	10
IRC Positions: Situational Awareness	11
Controlling an increasingly distributed electricity system.....	12
IRC Positions: A distributed electricity system	14
Context of the ETTF’s recommendations.....	15
Variable/Renewable generation growth	15
IRC Positions: Renewable Supply and Integration:	16
Recent events	16
Greater Situational Awareness	19
IRC Positions: Situational Awareness	19
Recent Events	20
Controlling an increasingly distributed electricity system.....	21
IRC Positions: A distributed electricity system	22
Recent Events	23
Summary: Technological maturity and other areas of attention	24
Appendix A: Assessment of Technology Deployment across IRC Organizations	26
Appendix B: Technology Status Summary Findings	30
Categories	30
Assessment Methodology	32
Summarized results from the Smart Grid Maturity Model.....	33
Requirements to Connect	36
Appendix C: The IRC Emerging Technologies Task Force and Acknowledgements	38
Acknowledgements:	38
Bibliography:.....	39

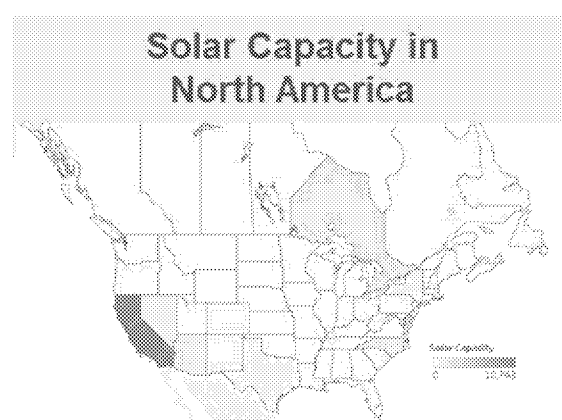
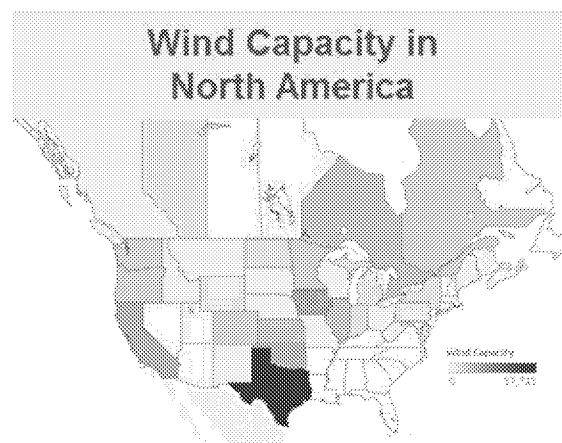
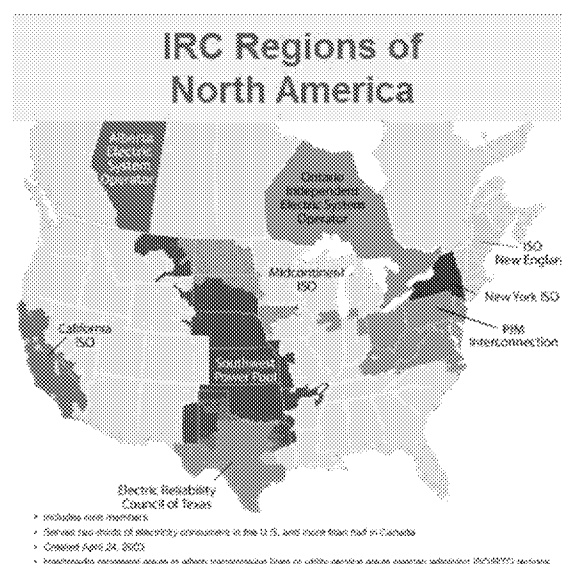
Executive Summary

Across North America, policies are transforming the electricity system, both in terms of supply mix and fundamental roles at every level of the production chain. The member organizations of North America's ISO/RTO Council (IRC) are at the forefront of these changes, and increasingly, a crucial success factor behind their implementation.

The IRC consists of nine Independent System Operators (ISO) and Regional Transmission Organizations (RTO) in North America and serves two thirds of electricity consumers in the United States and more than half in Canada. The IRC and its committees assemble representatives from each ISO/RTO to collaborate to match power generation instantaneously with demand to keep the lights on and ensure access to affordable, reliable and sustainable power via wholesale energy markets.

A simple inspection of a map of North America reveals a striking trend: 80.3 percent of all wind capacity on the continent is now located in IRC regions.¹ A similar trend is apparent for solar energy, with 81.1 percent of its capacity situated in regions served by IRC members.² The reasons for this may be varied, but the overall trend is undeniable: The reliable integration of renewables into North America's electricity system has, in no small part, depended on the efforts of the IRC membership. As this report shows however, the ongoing effectiveness of renewable technologies will depend directly on the electricity system's capacity to accommodate them.

In summer 2015, the Operations Committee of the ISO/RTO Council created the IRC Emerging Technologies Task Force (ETTF) to examine the deployment of emerging technologies across the IRC regions in North America.



¹ Data sources: Government of Alberta, International Energy Agency, IESO, United States Department of Energy, "Wind Technologies Market Report, 2015", Aug. 2016, U.S. Department of Energy, "WINDExchange" website: http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp accessed, October, 2016

² Data sources: U.S. Energy Information Administration, EIA - Electric Power Monthly, July, 2016, Government of Canada – Natural Resources Canada, "Photovoltaic Technology Status and Prospects - Canadian Annual Report", 2015, IESO

Specifically, the task force seeks to identify where technological deployment intersects with operational and policy considerations. This report is the culmination of that effort.

In the course of developing this report, three key priorities emerged as imperatives to continuously ensure the reliability and efficiency of the Bulk Electric System as the penetration of emerging technologies continue to expand. Those identified priorities are as follows:

1. **Renewable supply and integration:** Many breakthroughs are being made in individual technologies such as renewable generation, grid-scale energy storage and microgrids, for example. However, is there enough innovative activity happening cohesively to integrate all of these disparate components into the overall electricity system?
2. **Greater situational awareness:** Several technological options are presenting themselves, but are they being exploited to their maximum potential and will they be enough to maintain adequate awareness over a changing system?
3. **Controlling an increasingly distributed electricity system:** As Distributed Energy Resources (DER)³ increasingly connect to the distribution system, their aggregate impact on the bulk electricity system⁴ is already evident. To what extent should operation of DERs be ‘controlled’ or influenced by the bulk system operator and what should that relationship look like? What technologies will best assist that framework?

These issues are briefly discussed below and raised throughout this report. The IRC ETTF also circulated this report to several other IRC committees, each of which addressed a variety of topics ranging from regulatory matters to market design. The above three priorities have been confirmed through broad consultation with the IRC committees, some of who have already identified potential areas of mutual cooperation on these issues.

³ The Electric Power Research Institute defines distributed energy resources as “smaller power sources that can be aggregated to provide power necessary to meet regular demand. As the electricity grid continues to modernize, DER such as storage and advanced renewable technologies can help facilitate the transition to a smarter grid. Deploying DER in a widespread, efficient and cost-effective manner requires complex integration with the existing electricity grid. Research can identify and resolve the challenges of integration, facilitating a smoother transition for the electricity industry and their customers into the next age of electricity infrastructure.” (<http://www.epri.com/Our-Work/Pages/Distributed-Electricity-Resources.aspx>)

⁴ “The Federal Energy Regulatory Commission defines the bulk electric system as transmission elements operated at 100 kV and higher and Real Power and Reactive Power resources connected at 100 kV or higher.

Analysis and Recommendations

Renewable Supply and Integration

Throughout the world, solar energy capacity rose 28.1 percent in 2015.⁵ This has been the result of more than 40 years of scientific endeavor that has steadily improved this technology (see figure below). Now these advancements face a serious challenge – the electricity system itself. 2016 marked the midpoint of the U.S. Department of Energy’s “Sunshot” program with a goal of achieving a leveled cost of energy for solar power of 6 cents per kilowatt hour (kWh) by the year 2020. While the recent Sunshot midterm report noted the program has reached 70 percent of this goal, the report also noted a significant barrier. Specifically, the report noted solar curtailment could easily push this figure back up to 11 cents per kWh in some cases.⁶

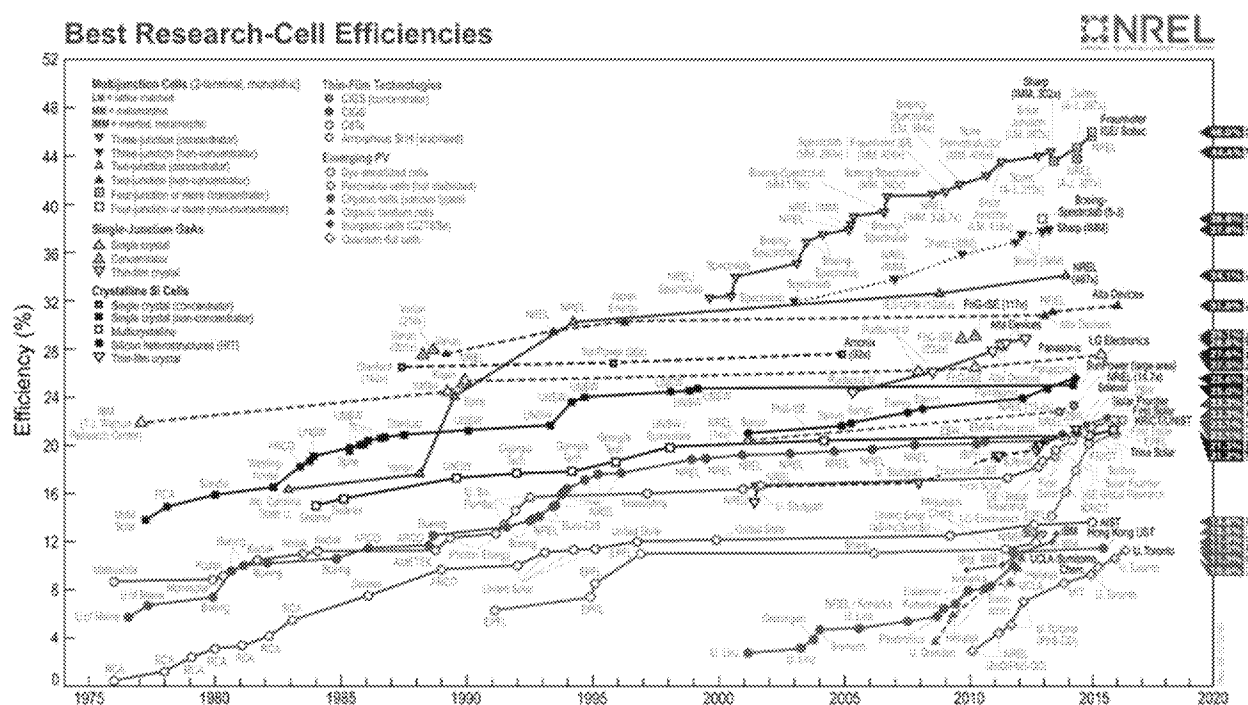


Figure: NREL labs solar module efficiency curves: 40 years of technological progress – but is North America’s electricity system adequately prepared to realize these gains?

“As the deployment of photovoltaics (PV) increases, it is possible that during some sunny midday periods due to limited flexibility of conventional generators, system operators would need to reduce (curtail) PV output in order to maintain the crucial balance between electric supply and demand. As a result, PV’s value and cost competitiveness would degrade.”

U.S. Department of Energy, *On the Path to Sunshot: Executive Summary*, May 2016

⁵ BP, *Statistical Review of World Energy* June 2016

⁶ U.S. Department of Energy, Solar Technologies Office, *“On the path to Sunshot: Executive Summary”*

A similar situation is also unfolding for wind technologies. In their *2015 Wind Technologies Report*, the U.S. Department of Energy noted wind constituted the single largest source of capacity additions in the United States in 2015. Moreover, the report noted the average wind turbine nameplate capacity has increased 180 percent since 1998-99.⁷ However, the operating characteristics of renewable resources are presenting a challenge to the electricity system's ability to accommodate increasing levels of intermittent generating capacity.

IRC member organizations have devoted an extensive effort to capitalize on emergent technologies to integrate renewable energy resources like wind and solar over the past several years. To manage the variability of supply and renewable integration enabled by emerging technologies, the IRC recommends the following:

"Wind power represented the largest source of U.S. electric-generating capacity additions in 2015. Wind power constituted 41 percent of all U.S. generation capacity additions in 2015, up sharply from its 24 percent market share the year before and close to its all-time high."

U.S. Department of Energy
"2015 Wind Technologies Report"
August 2016

IRC Positions: Renewable Supply and Integration:

The IRC:

- **Generally supports policies and positions** that recognize the electricity system's ability to reliably and efficiently accommodate large-scale amounts of renewables and realize their growing technological potential.
- **Is agnostic to specific technologies** that may be applied to the renewable integration problem while simultaneously ensuring that policies include the greatest possible optionality for new and emerging technologies to be applied to renewable integration.
- **Recommends approaches that avoid early technological lock-in:** Experiences catalogued in the IRC ETTF report show that a suitable policy environment is required to ensure that new technologies and approaches can continue to be developed, tested and applied to the renewable integration challenge. Several IRC member organizations are already piloting various "outlier" technologies that may someday overtake present day mechanisms if their effectiveness can be proven.
- **Supports discussions to achieve a continent-wide consensus** of the extent to which renewable integration will be achieved through regional or interregional trade. In both cases, emerging technologies may be applied to the problem, but potentially in different contexts depending on the degree of interregional trade that occurs over the coming decades (see also, diagrams on next three pages). This will assist IRC members plan for their future use of emerging technologies.

⁷ U.S. Department of Energy 2015 Wind Technologies Report, August 2016, pg. vii

Regional vs. Interregional Renewable Integration on the EASTERN Interconnection:

How and where will emerging technologies be applied?
...and which technologies will be most critical to IRC members?

Emerging technologies can assist all manner of renewable integration scenarios—but the usage context of each one can be vastly different. In a recent study conducted by the U.S. Department of Energy National Renewable Energy Laboratory, the outcomes of various renewable penetration scenarios on the Eastern Interconnection were modeled using high performance computing technologies at NREL. The potential outcomes for various IRC members are strikingly different...

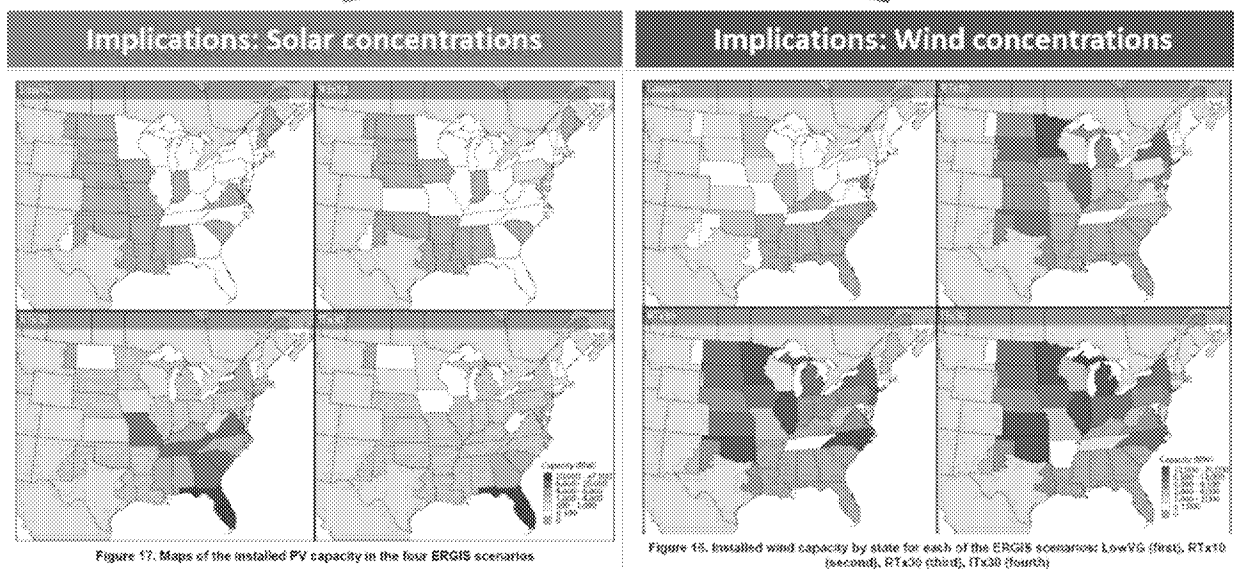
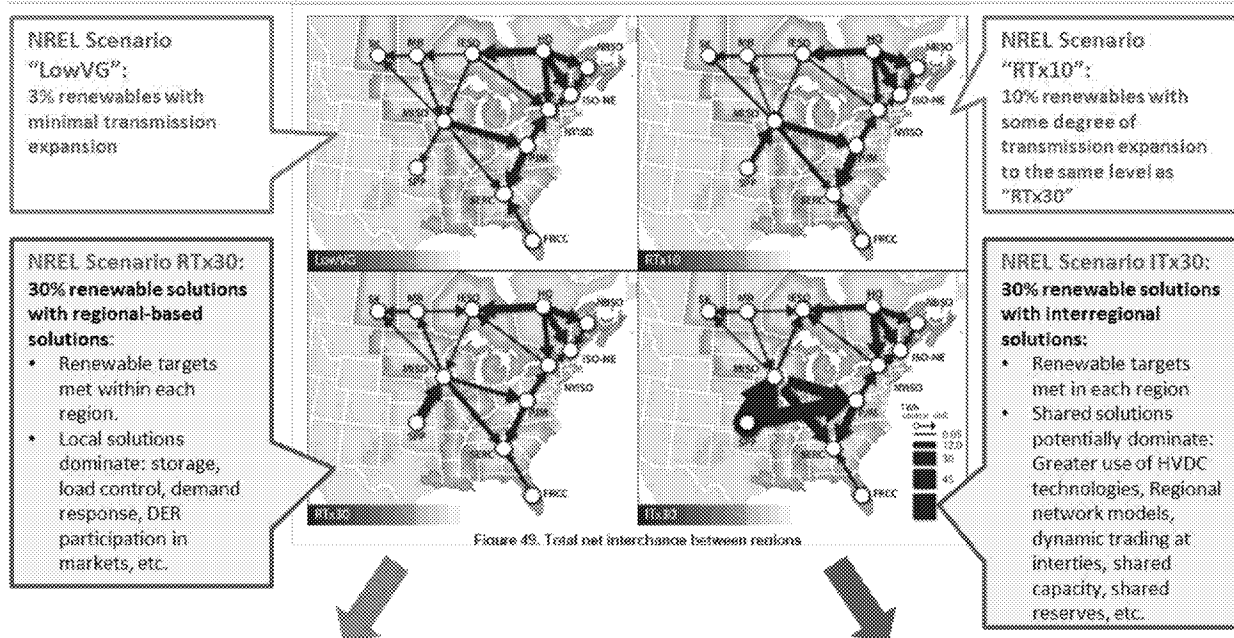


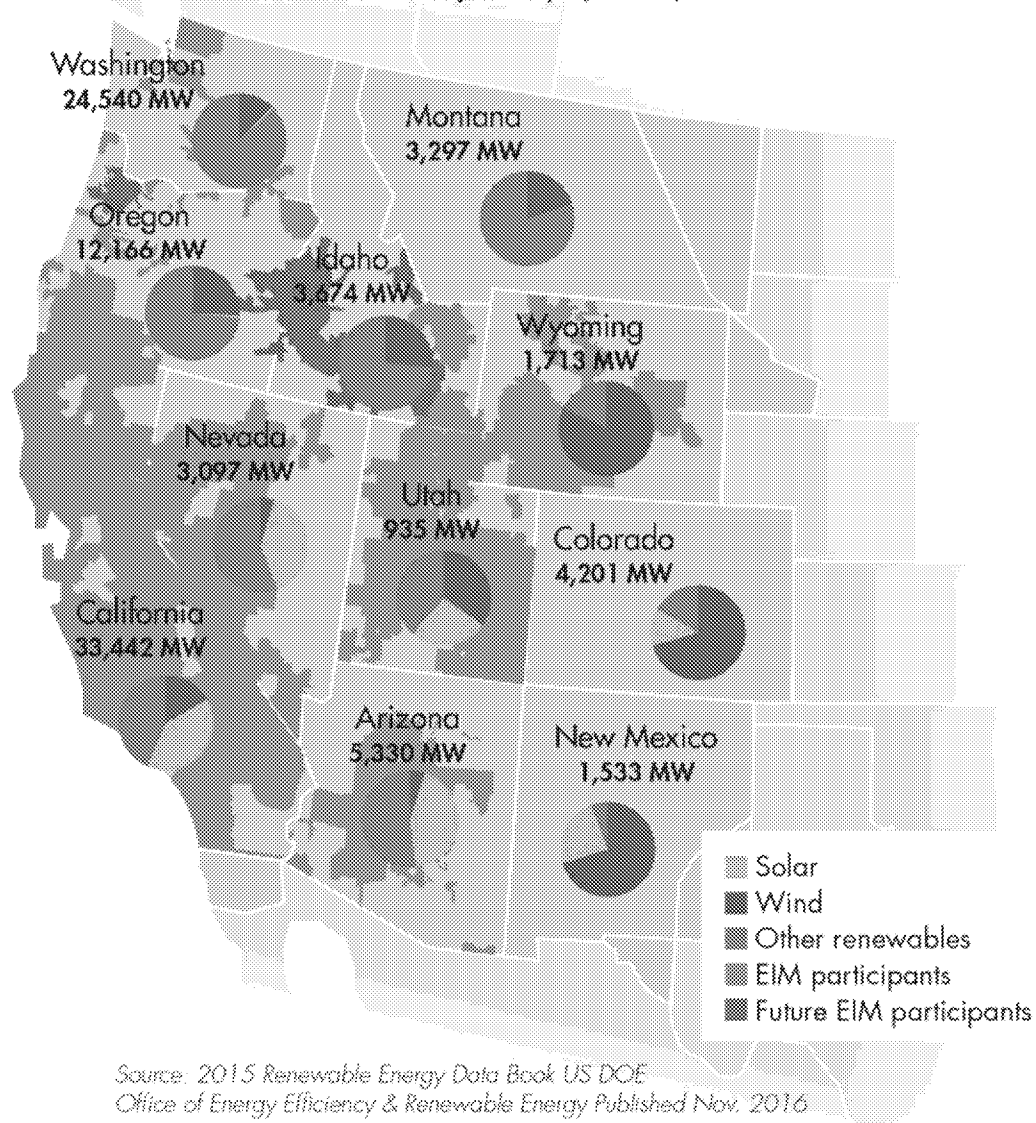
Image sources from: National Renewable Energy Laboratory (NREL) "Eastern Renewable Integration Study," August, 2016

Regional vs. Interregional Renewable Integration on the WESTERN Interconnection:

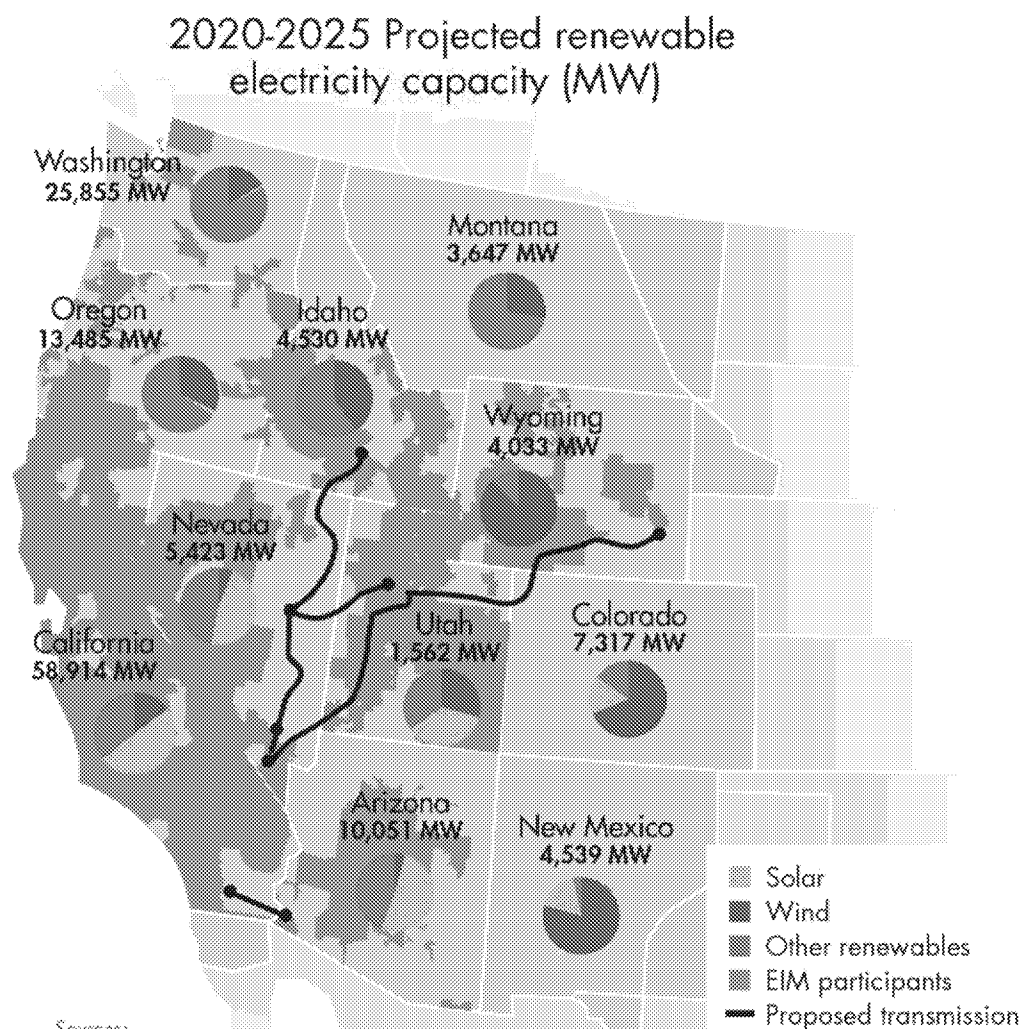
Renewable Capacity: 2015

As with the NREL's recent study of the Eastern Interconnection, recent data compiled by the CAISO illustrates the potential impact of various transmission investment scenarios across the Western interconnection in support of higher levels of renewables.

2015 Cumulative renewable electricity installed capacity (MW)



Regional vs. Interregional Renewable Integration on the WESTERN Interconnection: Renewable Capacity: 2020-2025 with transmission investment to support high renewable penetration



Sources:

Proposed transmission: 2016-2017 CAISO Transmission Planning Process Stakeholder Meeting, November 16, 2016 presentation, 50% RPS Special Study Update, Slide 60.
Projected Renewable Capacity: National Renewable Energy Laboratory (NREL) Technical Report (NREL/TP-6A20-53540) Western Region Renewable Energy Markets: Implications for the Bureau of Land Management, January 2012 plus 2015-16 Transmission Plan, dated March 28, 2016 and Board Approved, page 209, Table 3.4.2 for Wyoming and New Mexico wind additions.

Situational awareness

An electricity system that is more distributed and less predictable places a greater emphasis on data that ISOs and RTOs must obtain to meet their responsibilities. The need for situational awareness at all levels of bulk power system operations has been an issue of recent and growing prominence. In the past two decades since wholesale electricity markets have been established across North America, the situational awareness of IRC members has largely centered on the bulk electricity system. This is changing however, both in terms of data sources and the intensity of the data itself.

Regarding data intensity, IRC members have matured beyond the technological framework that existed at the time of market deregulation in the 1990s. For example, supervisory control and data acquisition (SCADA) systems typically provide data at the two-per-second resolution, but this has been supplemented with phasor measurement unit (PMU) data that provides a data at a time-synchronized sampling rate of many times per second. While PMU technology has been deployed in most IRC member organizations, the future use of this technology could continue to change drastically. Changing distribution sector load is another factor that is a result of a growing proliferation of distributed energy resources (see below).

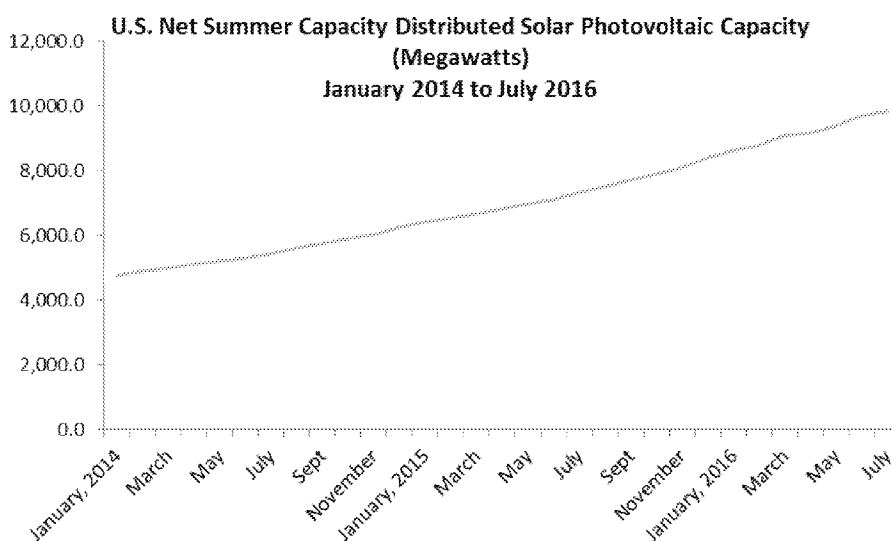


Illustration – DER growth is fueling the need for greater situational awareness.⁸

The IRC recognizes that the traditional monitoring and forecasting framework established in the 1990s may not accommodate the changing demands of an evolving electricity sector. Furthermore, the IRC recognizes that mass adoption of DERs and the ensuing data implications of these DERs will need to be addressed in order to maintain reliable bulk electric system operations. Consider for example a recent study of the California electricity system⁹ regarding the potential of achieving 50 percent renewable penetration. As the following illustration shows, the distribution system has the potential to become a net injector into the bulk electricity system. For ISOs and RTOs to ensure reliability going forward, such an arrangement, which

⁸ Sources: U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'

⁹ NREL, "Energy Storage Requirements for Achieving 50% Solar Photovoltaic Energy Penetration in California", Aug. 2016

challenges present conventions for serving distribution loads, begins with a comprehensive approach to using situational awareness technologies.

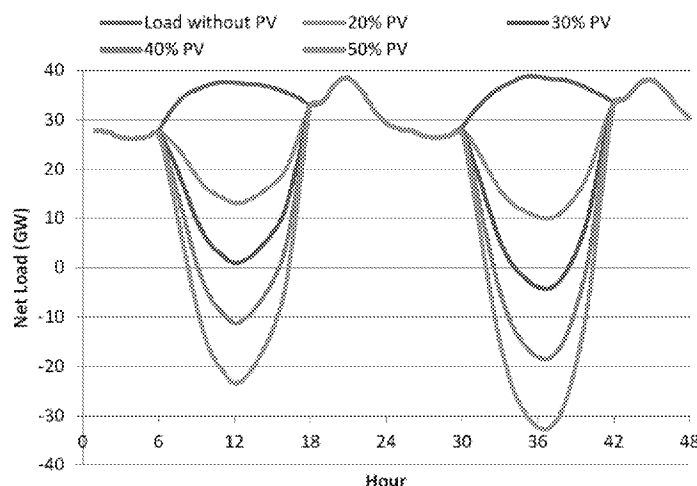


Illustration – hypothetical computer models of the load profile of the CAISO service territory under various future scenarios of 20-50 percent PV penetration.¹⁰

Data is a common theme running through the DER issue. Traditionally, the electricity system was segmented into production, transmission and distribution. While much has been written about the new model for the electricity industry, traditional boundaries still persist – particularly in regard to data. Even at the most basic level, IRC members have been hard-pressed to find consistent and reliable data series cataloguing the growth of DERs within their respective service territories. This is now becoming a serious concern and forms the basis of the IRC ETTC recommendations in this area.

IRC Positions: Situational Awareness

The IRC believes:

- Data should no longer be treated as the constraining factor with respect to situational awareness arrangements across the transmission/distribution interface – particularly in regard to data transfers.
- At a minimum, North American ISOs and RTOs should have access to basic static data series about DERs in their respective service territories. Location, size and technological capabilities are just a few examples of critical and reliable data that IRC members need to formulate a comprehensive strategy for managing an increasingly distributed electricity system.
- A general operational data framework should be developed, where increasingly comprehensive operational data from the distribution system is provided as DER penetrations reach different thresholds. This framework should be flexible enough to accommodate local differences in policy, roles and structural arrangements across North America.

¹⁰ Image Source: NREL, “Energy Storage Requirements for Achieving 50% Solar Photovoltaic Energy Penetration in California”, Aug. 2016

Controlling an increasingly distributed electricity system

On Nov. 17, 2016, the U.S. Federal Energy Regulatory Commission (FERC) issued a Notice of Proposed Rulemaking (NOPR), which may require wholesale markets to accommodate energy storage and Distributed Energy Resources (DER).¹¹ This potentially significant regulatory development could set the stage for a more formalized framework to address a challenge that IRC members have recognized for some time: How will system operators harness the capabilities and manage the risks that intermittent DER growth presents?

Figure: Lawrence Berkeley National Labs, Kristov, L. (CAISO), et. al., “Distribution Systems in a High Distributed Energy Resources Future.” December, 2015

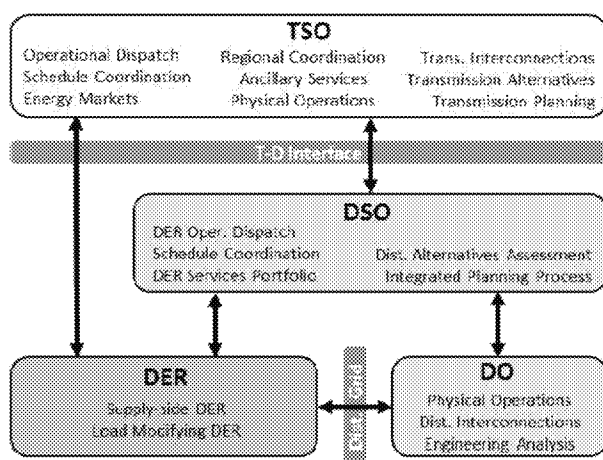


Figure: IN VARIOUS JURISDICTIONS ACROSS NORTH AMERICA, THE ROLE OF AN ISO OR TSO CAN ENCOMPASS DIFFERENT COMBINATIONS OF FUNCTIONS REPRESENTED IN THE “TSO” BOX IN THIS DIAGRAM.

“Specifically, we propose to require each RTO and ISO to revise its tariff to:

(1) Establish a participation model consisting of market rules that, recognizing the physical and operational characteristics of electric storage resources, accommodates their participation in the organized wholesale electric markets and

(2) Define distributed energy resource aggregators as a type of market participant that can participate in the organized wholesale electric markets under the participation model that best accommodates the physical and operational characteristics of its distributed energy resource aggregation.”

U.S. Department of Energy, Federal Energy Regulatory Commission, “Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators;” [Docket Nos. RM16-23-000; AD16-20-000] November 17, 2016

Because of emerging technologies, North America’s electricity systems are moving toward a more distributed arrangement. Since the beginning of 2015, the U.S. Energy Information Administration (US EIA) has been tracking the growth of Distributed Energy Resources as part of its regular data series. In several North American jurisdictions, a debate has emerged regarding the future of the distribution sector. The prevalence

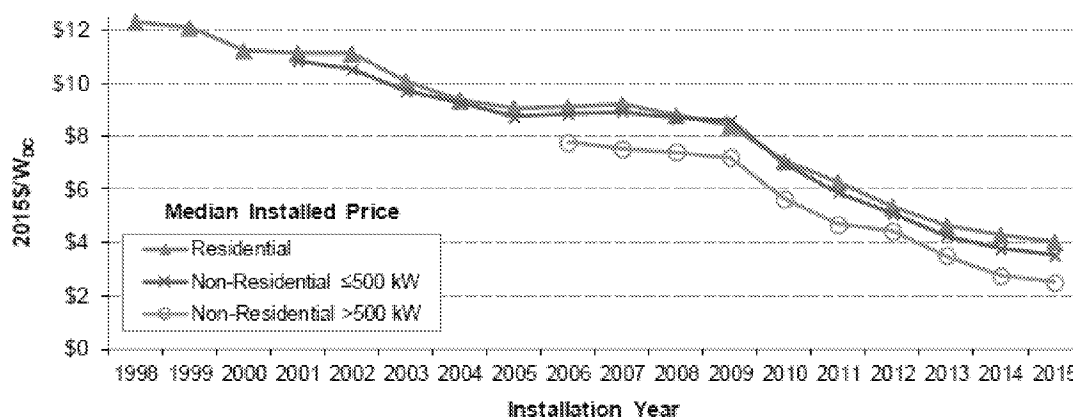
¹¹ U.S. Department of Energy, Federal Energy Regulatory Commission, “Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators;” [Docket Nos. RM16-23-000; AD16-20-000] Nov. 17, 2016

of DER's has affected the overall operability of the system, challenged a century-old regulatory model of electricity distribution and led to the emergence of new concepts such as distribution system "platforms" to allow for the two-way transaction of electricity. Some of the fastest-growing impacts to the bulk electricity system are happening outside of the traditional purview of ISOs and RTOs. Implications for IRC members include:

- Decreasing technology costs
- DER growth
- Declining electricity demand growth rates
- Changing distribution sector structures and policies
- Emergence of third party, non-utility entities

Emerging technologies form **part** of the solution to providing a system capable of enabling a future with a high penetration of DERs, but often these technologies need policies to enable their full potential. Perhaps the most pressing part of this discussion has been the governance of the interface between the transmission and distribution systems.

Illustration – The sustained, falling cost of solar modules in every retail customer class. Figure source: Lawrence Berkeley National Labs, "SunShot: Tracking the Sun IX" pg. 14



IRC Positions: A distributed electricity system

The IRC:

- Recognizes that there must be some form of coordinating influence in a high-DER future to help ensure reliability.
- Will continue to facilitate a continent-wide dialogue on the appropriate means by which mass DERs and the bulk electricity system can mutually benefit each other. This dialogue should focus on effective transfer of data across the transmission/distribution system interface while allowing maximum flexibility for suitable local policies and market mechanisms to develop.
- Believes due consideration should be given by jurisdictions in which Distribution System Operators (DSO) are implemented and require such entities to conform to a sufficiently rigorous set of standards that allows for the safe interaction between DSOs, non-utility actors and the bulk electricity system.
- Supports policies to ensure that if variability at the distribution level results in a risk to system reliability ISO/RTOs have appropriate authority over DERs — or otherwise isolate their impact from the bulk electricity system.

Top Four Reasons ISOs/RTOs are Good for North America (from ISO-RTO.org)

1. *Reliability: keeping the lights on*
 2. *Efficiency: leading the way to tomorrow's grid operations and diverse energy network*
 3. *Transparent, open markets: dispelling the mystery of electricity, while promoting innovation, wise investment and least cost for consumers*
 4. *Fostering innovation: moving forward with advanced grid technologies: Whether working to make electric vehicle or plug-in hybrid EV technology more widely available or advancing the deployment of smart meters and demand response programs, ISO/RTO innovations support technological advancements to enable a more sustainable and efficient grid."*
-

Context of the ETTF's recommendations

There appear to be several trends universally affecting or driving the use of emerging technologies across IRC member organizations. Over the course of this section, we will discuss some of the principal drivers behind each of the ETTF's recommended priority areas for the IRC and some of the recent developments across the North American continent that warrant particular attention by the IRC:

1. **Renewable Supply and Integration**
2. **Greater situational awareness**
3. **Control over an increasingly distributed electricity system**

Variable/Renewable generation growth

Worldwide, non-hydro renewable energy production rose by 15.8 percent in 2015, the highest ever recorded in a year.¹² The aggregated impacts of non-hydro renewables are now becoming a material challenge for all IRC members. In 2016 a significant volume of literature was published highlighting the economic imperative of policies to facilitate the proper integration of renewables into the electricity system. IRC members have been focused on this topic for quite some time now, but this is now becoming part of the mainstream dialogue in North American energy policy. Do we have an electricity system that will utilize renewable energy sources to their fullest technical potential? Can emerging technologies be applied to this problem? Will that be enough to solve the problem?

¹² BP, *Statistical Review of World Energy*, June 2016

IRC Positions: Renewable Supply and Integration:

The IRC:

- **Generally supports policies and positions** that recognize the electricity system's ability to reliably and efficiently accommodate large-scale amounts of renewables and realize their growing technological potential.
- **Is agnostic to specific technologies** that may be applied to the renewable integration problem while simultaneously ensuring that policies include the greatest possible optionality for new and emerging technologies to be applied to renewable integration.
- **Recommends approaches that avoid early technological lock-in:** Experiences catalogued in the IRC ETTF report show that a suitable policy environment is required to ensure that new technologies and approaches can continue to be developed, tested and applied to the renewable integration challenge. Several IRC member organizations are already piloting various "outlier" technologies that may someday overtake present day mechanisms if their effectiveness can be proven.
- **Supports discussions to achieve a continent-wide consensus** of the extent to which renewable integration will be achieved through regional or interregional trade. In both cases, emerging technologies may be applied to the problem but potentially in different contexts depending on the degree of interregional trade that occurs over the coming decades. This will assist IRC members to plan for their future use of emerging technologies.

Recent events

In 2016, the ETTF observed the following efforts that continue to shape and define this challenge and its potential solutions:

- **Quantifying the electricity system's capacity to accommodate new renewables:** Over the course of 2016, the U.S. Department of Energy has conducted useful studies, delving into the system's capacity to accommodate renewable sources of energy and frame the challenge for system operators and other electricity sector entities.¹³
- **Quantifying the pace of technological change in renewables:** Comprehensive studies were completed in 2016 regarding both the scale of renewable deployment and the growing production efficiency of these technologies.¹⁴ These works are already lending further insight

¹³ Citations include: i. National Renewable Energy Laboratory (NREL) "Eastern Renewable Integration Study," Aug. 2016; and ii. National Renewable Energy Laboratory (NREL) "Energy Storage Requirements for Achieving 50% Solar Photovoltaic Energy Penetration in California ", Aug. 2016

¹⁴ Examples include: i. United States Department of Energy, "Wind Technologies Market Report, 2015", Aug. 2016 and, ii. Lawrence Berkeley National Labs, "SunShot: Tracking the Sun IX", Aug. 2016

into to the magnitude of the issue and the level of investment that may be needed at various levels of the system.

- Further studies into interregional integration:** Interregional integration could drastically affect the renewable deployment landscape over the coming years, and commensurately, the types of emerging technologies that might be applied to this challenge. As this report was being finalized, organizations from Canada, the United States and Mexico were in the process of establishing the Pan North American Renewable Integration Study (PARIS) – one of the largest studies of its kind.¹⁵
- Valuing flexibility in wholesale markets:** Several IRC member organizations are initiating or refining market rules around various mechanisms to value sources of flexibility. Such mechanisms may affect the composition of emerging technologies that are applied to the renewable integration question. As noted earlier, in 2016 NREL published a study analyzing the interplay between emerging technologies such as energy storage and other sources of flexibility in various potential future scenarios.¹⁶
- Electricity/Gas system coordination:** Recent events involving the Aliso Canyon natural gas storage facility have highlighted a need for intensified coordination between the gas and electricity systems – particularly as the balance of the supply mix contains a larger proportion of variable sources. This has been a topic of extensive conversation within the ETTF, and the issue continues to unfold. Again, emerging technologies have a role to play in providing both systems with greater operational certainty through intensified data exchange.

¹⁵ U.S Department of Energy Grid Modernization Laboratory Consortium (GMLC) – Awards: <http://energy.gov/under-secretary-science-and-energy/doe-grid-modernization-laboratory-consortium-gmlc-awards> - accessed on November 28, 2016

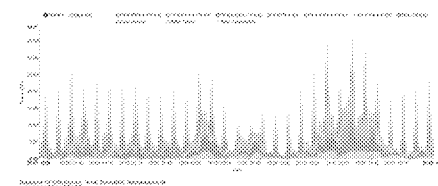
¹⁶ National Renewable Energy Laboratory (NREL) “Energy Storage Requirements for Achieving 50% Solar Photovoltaic Energy Penetration in California”, Aug. 2016

Wind and Solar on the German Power Grid: August 2015

As of the end of 2015, Germany had 39.6 GW of installed solar PV capacity. Renewables in general constituted approximately 35 percent of German domestic energy production.

Midday solar peaks are having a significant impact on import/export markets and eroding peak demand so that the Fraunhofer Institute recently observed, “*PV is already noticeably reducing the midday electricity demand and the associated price peak on the energy exchange, gas-fired plants do not currently constitute a worthwhile investment.*”

What lessons do the German experiences hold for North American system operators? As new supply brings along new operating characteristics, it of course raises questions as to how such resources will be integrated into the system and to what extent emerging technologies might be brought to bear on this challenge.



“ISOs/RTOs are also utilizing forecast data in new or upgraded operational and market tools, including real-time visualization capabilities that will help system operators develop situational awareness, and probabilistic ramp forecasting that may increasingly inform unit commitment and dispatch over time.”

ISO/RTO Council Briefing Paper: *Variable Energy Resources, System Operations and Wholesale Markets* (August 2011)

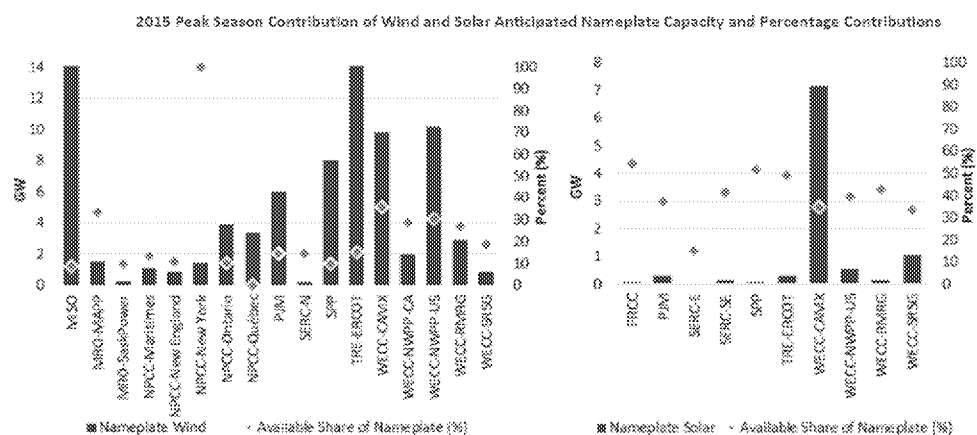


Figure: Growing contributions of Wind and Solar capacity in North American jurisdictions.¹⁷

As noted earlier, the growth of variable energy resources has driven all of the IRC member organizations toward a high degree of engagement (level 4 on the Smart Grid Maturity Model) in the “renewable integration” category with each organization. Not surprisingly, the application of emerging technologies was the highest ranked priority issue on average among ETTF member organizations, according to the straw poll referenced in the Executive Summary.

There is a high-degree of overlap between the “renewable integration” category and other categories such as energy storage, distributed energy resources and requirements to connect. Across these other categories, there is a much lower degree of convergence on a particular stage of the Smart Grid Maturity Model and a high degree of diversity in terms of the approaches taken. This may reflect a wide array of new technologies emerging in this area that have not yet reached a level of maturity for IRC member organizations to develop a uniform approach. The reasons for this may warrant further investigation.

¹⁷ Image Source: NERC, “Long-Term Reliability Assessment 2015” pg. 14, December 2015

Greater Situational Awareness

Five years after producing a public report on the integration of variable energy resources, situational awareness remains a vitally important issue for the IRC community. Early on, the ETTF identified this as a key clustering of emerging technologies that will continue to play a crucial role in the success of each IRC member. However, some of the context of this enduring priority lies increasingly within the distribution system. In many respects the drivers behind the ETTF recommendations for “Situational Awareness” and “Level of control over an increasingly distributed electricity system” are closely intertwined. They are both in part driven by a changing distribution sector, changing customer behaviors and a host of new technologies giving rise to a more complex electricity system overall. All of these pressures are contributing to an increasingly focused discussion of the data flows across the transmission/distribution interface.

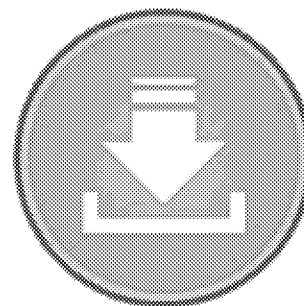
IRC Positions: Situational Awareness

The IRC believes:

- Data should no longer be treated as the constraining factor with respect to situational awareness arrangements across the transmission/distribution interface – particularly in regard to data transfers.
- At a minimum, North American ISOs and RTOs should have access to basic static data series about DERs in their respective service territories. Location, size and technological capabilities are just a few examples of critical and reliable data that IRC members need to formulate a comprehensive strategy for managing an increasingly distributed electricity system.
- A general operational data framework should be developed, where increasingly comprehensive operational data from the distribution system is provided as DER penetrations reach different thresholds. This framework should be flexible enough to accommodate local differences in policy, roles and structural arrangements across North America.

Recent Events

- **An increasing focus on the Transmission/Distribution Interface:** A recent report co-authored by CAISO and Lawrence Berkeley National Laboratories poses a number of crucial questions regarding the developmental path of a distribution system as distributed energy resources reach higher penetration levels.¹⁸ The report considers several new roles at the distribution level, including that of a Distribution System Operator (DSO) with duties similar to those of a system operator at the bulk-electricity system level. Such concepts are also prompting system operators to think about the data flows and market interactions across the transmission/distribution interface – and the technological resources required to accommodate them. Such factors have fueled the ETTF’s choice of situational awareness and level of control over a distributed system as two of its highest priority.
- **Regulatory impetus:** As noted earlier, FERC’s Nov. 17, 2016 Notice of Proposed Rulemaking¹⁹ takes the United States a step closer to formalizing the relationship between aggregations of Distributed Energy Resources and wholesale markets. If such a ruling comes to pass, it too will place a greater emphasis on the situational awareness recommendations contained in this report.
- **Coordinated efforts to standardize and exchange DER data series:** In 2016, the U.S. Department of Energy initiated the **Orange Button initiative**. As part of the U.S. Department of Energy’s broader **SunShot Initiative** to drive down the levelized cost of solar energy by 2020, the Orange Button focuses on reducing the “Soft Costs” component of solar via standardized data platform reaching at least 60 percent of solar industry.²⁰ Orange Button is seeking to achieve this by the following steps:
 - Identify inefficiencies in data exchanges that lead to reduced soft costs associated with solar projects
 - Develop open, easy-to-adopt solar data architecture and standards
 - Develop a data format translation software tool
 - Convert paper-based solar records to machine readable formats and establish a marketplace for standardized solar datasets.



Orange Button is an example of efforts to consolidate data at the distribution level of the system and is directly in line with one of the key recommendation in this section, to create an opportunity

¹⁸ Lawrence Berkeley National Labs, Kristov, L. (CAISO), et. al., “Distribution Systems in a High Distributed Energy Resources Future.” December, 2015

¹⁹ U.S. Department of Energy, Federal Energy Regulatory Commission, “Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators,” [Docket Nos. RM16-23-000; AD16-20-000] November 17, 2016

²⁰ Source: U.S. Department of Energy - <http://energy.gov/eere/sunshot/orange-button-solar-bankability-data-advance-transactions-and-access-sb-data>

whereby IRC members will have access to standardized, reliable, static information about DER growth in their respective service territories.

Controlling an increasingly distributed electricity system

Across North America, the majority of utility executives expect to see a significant transformation of the distribution sector over the next 15 years.²¹ Distributed generation growth, erosion of revenue, microgrids and greater system resiliency are just a few of the areas that are driving change in this segment of the sector. These issues are transforming discussions regarding the role of the distribution company, the emergence of a Distribution System Operator (DSO) function and local pricing of the distribution value of electricity within those systems. New York and California are two examples of jurisdictions where these discussions are in advanced stages at the regulatory level. These developments might greatly affect the way in which the IRC ETTF organizations engage distributed energy resources, demand response, microgrids and other emerging technologies issues. More recently, this issue has come into sharper focus with FERC's Notice of Proposed Rulemaking on electric storage.

"Specifically, we propose to require each RTO and ISO to revise its tariff to

{...}

(2) Define distributed energy resource aggregators as a type of market participant that can participate in the organized wholesale electric markets under the participation model that best accommodates the physical and operational characteristics of its distributed energy resource aggregation."

U.S. Department of Energy, Federal Energy Regulatory Commission,
"Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators"
[Docket Nos. RM16-23-000; AD16-20-000], (Nov. 17, 2016)

²¹ Data source: PwC, "14th PwC Power and Global Utilities Survey."

IRC Positions: A distributed electricity system

The IRC:

- Recognizes that there must be some form of coordinating influence in a high-DER future to help ensure reliability.
- Will continue to facilitate a continent-wide dialogue on the appropriate means by which mass DERs and the bulk electricity system can mutually benefit each other. This dialogue should focus on effective transfer of data across the transmission/distribution system interface while allowing maximum flexibility for suitable local policies and market mechanisms to develop.
- Believes due consideration should be given by jurisdictions in which Distribution System Operators (DSO) are implemented and require such entities to conform to a sufficiently rigorous set of standards that allows for the safe interaction between DSOs, non-utility actors and the bulk electricity system.
- Supports policies to ensure that if variability at the distribution level results in a risk to system reliability ISO/RTOs have appropriate authority over DERs — or otherwise isolate their impact from the bulk electricity system.

Recent Events

- Policy uncertainty and DER growth:** There is still uncertainty over the drivers, growth rates and policies surrounding the prospective growth of Distributed Energy Resources. FERC's NOPR could further tie wholesale markets to the changing distribution landscape. In addition to the NOPR, the extension of policies across North America to subsidize or encourage the growth of DERs remains uncertain. As noted in the recent projections for residential DER growth from the U.S. Energy Information Administration (below) the continuance or cancellation of certain policies could affect the rate of DER growth over the coming decades, though DERs are expected to increase significantly by 2040 in either case.

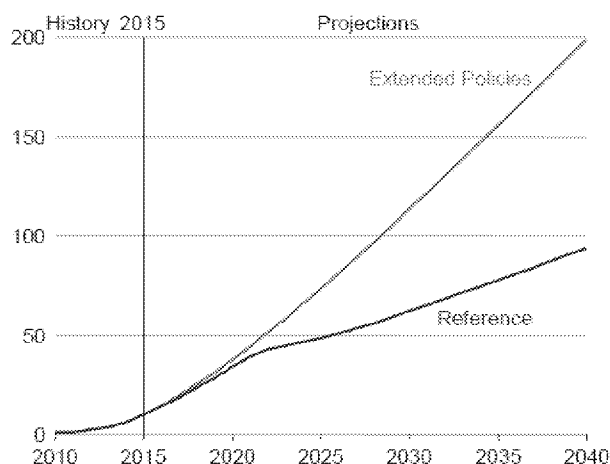


Figure- US Energy Information Administration Projections Residential distributed electricity generation in two cases, 2010–40 (billion kilowatt-hours)²²

- Technological maturation and market share:** Renewables, distributed energy resources and energy storage are all exhibiting characteristics of technological maturation as they move down the cost curve. Some of these technologies are beginning to reach significant scale of deployment. For example, on Dec. 2, 2015, the U.S. Energy Administration announced it is now tracking distributed solar generation growth in its official data series.²³
- Continuance of falling price trends:** Setting the background to this development has been years of technological improvement and falling costs of solar modules – as evidenced in the recent compilation in cost data by Lawrence Berkeley National Laboratories.

²² U.S. Energy Information Administration, *Annual Energy Outlook, 2016*, figure MT-13

²³ U.S. Energy Information Administration, TODAY IN ENERGY: Wednesday, December 2, 2015 "EIA electricity data now include estimated small-scale solar PV capacity and generation"

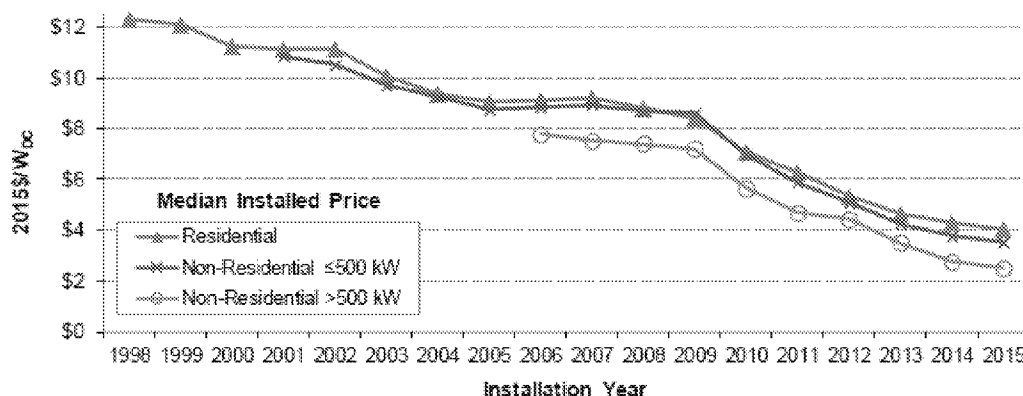


Figure PV Installed Price Trends: U.S. 1998 - 2015²⁴

Many ETTF members are still developing an understanding of how best to harness the capabilities of the rapidly growing distributed energy resources segment of the market (see Appendix). Many IRC members do not have any compulsory registration requirements for facilities below 500 kW in size, and yet falling technology costs may drive this segment to become the fastest growing area of the marketplace in coming years.

Summary: Technological maturity and other areas of attention

As noted in the summarized results section of this report, the various members of the ETTF have clustered around common stages of the Smart Grid Maturity Model in some technology areas (such as HVDC and synchrophasors). In other technological areas, however, (e.g. Distributed Energy Resources, energy storage, and dynamic ratings), there is wider disparity among ETTF members, which is likely reflective of the relative immaturity of these technologies. These technologies may warrant further attention to better understand the reasons for these differences across the membership and if there is common ground to be established and leveraged in the future.

Over the course of the past year, ETTF members discussed other potential priorities that have emerged and may merit further discussion and examination. Some of the priority issues raised during these discussions include:

- Fostering innovation in areas of importance to system operators, such as reliability, open markets and informational transparency to better harness the potential of distributed resources.
- Leveraging emerging technologies for greater situational awareness. Here, several members cited examples including Geomagnetic Disturbance (GMD) monitoring, Phasor Measurement

²⁴ Data source: Lawrence Berkeley National Laboratory, "SunShot: Tracking the Sun IX" August, 2016 pg. 14

Unit (PMU) data, Advanced Metering Infrastructure (AMI) data and applying data analytics to turn data into useful information.

- Forecasting challenges related to variable and distributed energy resources.
- Falling technology costs and accelerating growth of distributed generation, energy storage and microgrids.
- Integrating new technologies into operations to address less direct control over the electricity system such as data analytics and new sources of data from Distribution System Operators.
- Local policies regarding energy storage and the extent to which they may hamper growth in this area of the market.
- Gas/electric interface technology.
- Third Party (non-utility) Control Centers where control of distributed energy resources is aggregated to points outside the traditional, regulated utility.

Each ETTF member organization is already immersed in the various technological categories that intersect with the above issues and the three main priority areas identified in the Executive Summary.

Appendix A: Assessment of Technology Deployment across IRC Organizations

This report has been prepared by the ISO/RTO Council (IRC) Emerging Technologies Task Force (ETTF), which reports to the Operations Committee of the IRC under its *Terms of Reference*.

The IRC ETTF member organizations (see Appendix C) compiled data concerning the current state of operational deployment of various emerging technologies within their respective organizations. Initially, this began with a freeform accumulation of significant activities under the following general technological categories:

- Synchrophasors and other system-wide monitoring
- Microgrids and Distributed Resources
- Energy Storage
- Dynamic ratings (transmission)
- Staff and resources to Support Emerging Technologies
- Smart Grid Devices

Over the course of this investigation, several of these categories have further divided into various subcategories. In other cases, new additions have been made, such as “renewable integration” and “requirements to connect to the grid” for example.²⁵ While this interim report was being prepared, the ETTF has continued to discover new issue areas that may be of mutual importance to all of the IRC member organizations. The main purpose of this interim report is to provide a snapshot of the data accumulated so far so the Operations Committee might consider where the future focus and attention of the ETTF’s work might be directed.

This investigation has revealed strong commonality across the member organizations in some categories, and wide divergence in others. The IRC-ETTF is continuing to investigate the reasons for this. In some cases, this may be a reflection of the relative maturity of the underlying technology itself. In other cases, matters of local and regional policy may affect the relative priorities given to various technological areas. In addition, several “outlier” categories have been identified where a small number of member organizations are forging ahead with unique technological concepts.

²⁵ See also, “*Technology Status Summary findings*” section for a description of all categories included in this study.

Main Technology Categories Summarized

The ETTF used an adapted version of the Software Engineering Institute's five-stage "Smart Grid Maturity Model" to normalize the data collected from each ETTF organization for each technology category (see also, "Assessment Methodology"). The chart below indicates the various stages that each ETTF organization assessed themselves at across each technology category. A high degree of clustering of responses around a particular stage of the maturity model is likely indicative that the underlying technology is at a higher maturity stage.

Capability and Maturity Model level:		0	1	2	3 to 4	4	5	
		Default/no activity	Initiating	Enabling	Integrating/Optimizing	Optimizing	Pioneering	
Category								
Microgrids	0		5	5	3	1	3	Low degree of clustering indicating relatively immature technology categories
Distributed Energy Resources (DERs)	0		5	5	6	4	3	
Energy Storage	0		2	5	7	5	3	
Dynamic Ratings (transmission)	0		4	6	6	5	1	
Applying Emerging Technologies to Renewable Integration	0		1	0	0	9	3	High degree of clustering indicating relatively mature technology categories
Synchrophasors and other system wide monitoring	0		2	2	7	9	7	
Staff & Resources to Support Emerging Technologies	0		1	3	8	8.5	7	
Flexible AC Transmission System (FACTS)	0		0	0	9	5	5	
Using Emerging Technologies to address threats from GMDs and artificial electromagnetic pulses (EMPs)	0		1	0	9	9	1	
High Voltage Direct Current (HVDC)	0		0	0	9	9	5	

Note 1: In many cases, ETTF members noted that they were simultaneously spanning several stages of the Smart Grid Maturity Model. Therefore, in many categories the total scores for each row add up to more than the nine member organizations of the ETTF.

Note 2: In some cases for certain categories a maturity stage had multiple columns, and the scores were therefore normalized to an average score out of 9, hence the appearance of some fractional scores in this table.

Included in this report, is an examination of:

1. The summarized results of the “Technology Status Summary” that the ETTF has been accumulating since summer 2015 (see also, “Technology Status Summary findings”).
2. The various contextual factors that are fueling the use of emerging technologies across the IRC member organizations (see also, “Context” section).
3. The relative level of technological adoption of each different type of technology across the ETTF member organizations

Identifying the priorities:

Perhaps most importantly, the ETTF group has identified emerging policy issues that may be of interest to the IRC organization as a whole. Over the course of the group’s investigation, a set of screening criteria for such issues was employed to identify prominent, technology-driven challenges that had the following characteristics:

- Affecting most/all of the IRC member organizations
- Technology-driven
- Common regulatory/policy issues that span national or subnational boundaries
- Expected to have a material, near-term impact on the IRC community
- Either not being addressed or not being addressed to the satisfaction of the IRC community.

Several important issue areas have emerged from this screening exercise. In the interests of focusing the ETTF’s future work, the group elected to identify what it considers to be three of the highest priority issues that are generally affected by emerging technologies and meet the above-mentioned criteria. In addition, it was important for the ETTF to be able to relate these three issues to the various technology areas it is monitoring. A cross-reference between the high-level issue area and the various technology categories explored in the next section of this report are provided in the table that follows on the next page.

In a straw poll conducted during the preparation of this report, each of the ETTF member organizations was asked to rank the **relative** priority of each of the three issue areas listed in the table that follows. It should be noted that the overall results of this straw poll were very close — particularly between the top-ranked priority and the second-ranked priority. Each of these issues are listed in relative order of priority as per the results of that straw poll.

Table 1: Three priority issues identified by the ETTF, ranked by relative order or priority as per a recent straw poll of group members:

Relative priority ranking	Issue description	Related topic areas from the “Technology Summary” document (see also “Technology Status Summary Findings” section of this report)	Key Reasons why this may be a priority issue for the IRC as a whole (see also “Context” section of this report)
1	Renewable Supply and Integration: Many breakthroughs are being made in individual technologies such as renewable generation, grid-scale energy storage and microgrids for example. However, is there enough innovative activity happening to cohesively integrate all of these disparate components into the overall electricity system? More specifically, are emerging technologies being used to their fullest potential to help integrate renewables into the grid?	• Requirements to Connect • Renewable Integration • Energy Storage • Microgrids • Distributed Energy Resources • FACTS • HVDC	• The whole North American supply mix is undergoing a significant shift towards more renewables • Several technological options are more mature than others (findings section) • Policies and approaches vary widely across the IRC
2	Leveraging emerging technologies for greater situational awareness: Several technological options are presenting themselves, but are they being exploited to their maximum potential and will they be enough to maintain adequate awareness over a changing system?	• PMUs • Renewable Integration • AMI/Smart meters • GMD monitoring • Transactive Energy	• Volume and pace of DER growth • Most connection requirements of ISOs don’t apply to facilities below 500 kW in size, leaving a potential informational gap. • Emerging cyber threats
3	Level of control over an increasingly distributed electricity system: As Distributed Energy Resources (DER) increasingly connect to the distribution system, their aggregate impact on the bulk electricity system is already beginning to be felt. To what extent should operations be ‘controlled’ or influenced by the bulk system operator and what should that relationship look like? What technologies will best assist that framework?	• Requirements to Connect • Renewable Integration • Microgrids • Microgrid controllers • Distributed Energy Resources • FACTS • HVDC • Topology Control • Smart wires • Smart inverters • Dynamic ratings • Vehicle-to-Grid Integration	• The distribution sector is changing • Various system operators in North America and Europe are already coping with the effects of increasingly unpredictable impacts from large numbers of DERs • DERs costs are rapidly falling – accelerating the pace of change.

Appendix B: Technology Status Summary Findings

Categories

As noted in the Executive Summary, the ETTF has had to amend and expand upon the various information categories contained in its Technology Status Summary. Over the course of this work, the ETTF has further developed its “main categories” to capture areas of extensive common activity across the various organizations. It has also discovered several “outlier” categories where one or a small number of ETTF member organizations are forging ahead with unique technologies or policy approaches to emerging technologies that were not apparent across the entire group. These categories, insofar as they stand at the end of 2015 are listed below:

Main categories:

A note regarding the descriptions below: In many cases, various categories pertain to emerging technologies where each IRC member organization may employ a different definition. The definitions provided below are meant to be generally descriptive and not to be construed as a formalized definition employed by the ETTF as a whole.

- **Synchrophasors and other System-Wide Monitoring:** Synchrophasor devices (and related equipment) provide near instantaneous, time-synchronized information on the state of an electricity system, which can be used in a real-time operational context and/or for after-the-fact analysis. In addition, a number of other emerging technologies to support situational awareness are beginning to present themselves – including gauging the behaviors and operational impact of distributed energy resources for example.
- **Microgrids:** Self-contained energy systems (often containing various combinations of distributed generation, energy storage and controllable load assets) that have the capability to connect and disconnect from the utility power grid, and provide energy and ancillary services back to the grid.
- **Distributed Energy Resources (DERs):** Assets that connect to the distribution system or may be embedded within a customer site connected to a distribution system and may include generation, energy storage and controllable loads. These assets may also be embedded within a microgrid.
- **Energy Storage:** There are numerous definitions of energy storage – but in the context of this paper, such devices generally have the ability to consume, store and deliver electrical energy back to the electricity system to which they are connected. For the purposes of this paper, references to “energy storage” may variously apply to assets connected to the bulk electricity system or the distribution system.
- **Dynamic Ratings (Transmission):** A family of technologies allowing system operators to dynamically adjust line ratings as system conditions change in real-time or near real-time.

- **Applying Emerging Technologies to Renewable Integration:** This category examines the various methods employed by ETTF members to integrate renewable generation technologies into the broader electricity system – either at the bulk electricity system level or aggregations of distribution-connected assets (e.g. distributed solar, electric vehicles, small-scale storage, etc.). The underlying technologies employed in this category may have some degree of overlap with the other technology categories listed here.
- **Smart Grid Devices – two subcategories:**
 - a. **Flexible AC Transmission System (FACTS):** This subcategory encompasses an array of interrelated technologies that provide greater control over power flows across specific segments of an interconnected, alternating current transmission system.
 - b. **High-Voltage Direct Current (HVDC):** This subcategory encompasses an array of interrelated technologies that enable power conversion and transmission of high-voltage direct current (DC) in a manner that is integrated with the operations of the alternating current (AC) bulk power system.
- **Requirements to Connect – two subcategories:**
 - a. **Requirements to connect Variable/Renewable Generation, Microgrids and Energy Storage:** This subcategory catalogues the degree to which each ETTF member organization has requirements in place for each type of asset across different connection arrangements at the bulk electricity system and distribution level.
 - b. **Methods employed to connect Variable/Renewable Generation, Microgrids and Energy Storage:** This subcategory catalogues the various requirements and connection thresholds for each type of asset across different connection arrangements at the bulk electricity system and distribution level.
- **Using Emerging Technologies to address threats from natural geomagnetic disturbances (GMDs) and artificial electromagnetic pulses (EMPs):** This category tracks the relative level of engagement on two important issues that may affect the reliability of emerging technologies due to natural hazards (GMDs) and artificial sources (EMPs).
- **Staff and Resources to Support Emerging Technologies:** This category assesses the level of staff resources and funding that each ETTF member organization devotes to analyzing, utilizing and developing emerging technologies.

Outlier categories:

These categories encompass emerging technology areas where one or a small number of ETTF member organizations are forging ahead with various activities ranging from preliminary investigation to pilot projects and, in some cases, mainstream use. A description of these technologies may be found in **Table 4**.

Assessment Methodology

Synthesizing a significant amount of freeform data on the use of emerging technologies in each member organization has been a significant challenge for the ETTF. Each organization takes its own approach to utilizing emerging technologies and harnessing their capabilities. In most cases local differences to policies and strategic imperatives have often caused each organization to take a different approach to the technology in question. To make matters more complicated, assessing the relatively “maturity” of each type of technology and the extent to which it is employed is a somewhat subjective task.

Nonetheless, the purpose of this study is to determine the relative level of engagement each organization has in various emerging technologies. A standardized assessment model needed to be applied to such an effort. To accomplish this, the ETTF group has employed an assessment methodology developed by the **Software Engineering Institute (SEI)** known as the **Smart Grid Maturity Model**. Similar to its more famous counterpart, the software “Capability and Maturity Model (CMM)” developed by the U.S. Department of Defense and the SEI in the late 1980s, the Smart Grid Maturity Model follows five stages of organizational capability in a wide range areas including Strategy, Management, Regulatory activity, Organization and Structure, Grid operations, and asset management.²⁶ In addition, each technology category also has specific tasks or activities associated with each maturity stage.

For the purposes of this study, the ETTF utilized the notion of the Smart Grid Maturity Model’s five stages of development and adapted them to the context of using emerging technologies in a grid operations role. The table below illustrates the basic characteristics of these five stages:

Table 2 – the five developmental stages of the Smart Grid Maturity Model:

0	1	2	3	4	5
0 - Default	Initiating	Enabling	Integrating	Optimizing	Pioneering
Not engaged on the emerging technology.	The organization is gathering data about the emerging technology and developing a long-term vision.	Initial planning, resourcing and pilot projects are developed at this stage.	The organization moves the technology into mainstream use outside the context of a pilot project.	The organization is adapting its rules, procedures and market structures to optimize the use of the underlying technology.	The organization is allocating resources to further develop or enhance the technology and surrounding policies.

²⁶ Software Engineering Institute “*Smart Grid Maturity Model Update*,” Volume 3, page 7-10 Other areas also include Customer management, Value Chain Integration, Societal and Environmental issues.

Summarized results from the Smart Grid Maturity Model

Together, the Smart Grid Maturity Model coupled with each technology-specific adaptation allowed each ETTF member organization to conduct a self-assessment of their stage of development in each major category. In each column where an ETTF member assessed themselves as reaching a specific maturity stage in each category, a score of 1 was assigned.²⁷ In many cases, ETTF members noted that they were simultaneously spanning several stages of the Smart Grid Maturity Model. Therefore in the table below, you will see that in many categories the total scores for each row add up to more than the nine member organizations of the ETTF.

Table 3 – Summarized results of each IRC member organization self-assessed stage of engagement on various emerging technologies (dark green areas with a score close to 9 indicates a high degree of convergence across the IRC ETTF member organizations)

Capabitliy and Maturity Model level:		0	1	2	3 to 4	4	5
		Default/no activity	Initiating	Enabling	Integrating/Optimizing	Optimizing	Pioneering
Category							
Microgrids	0		5	5	3	1	3
Distributed Energy Resources (DERs)	0		5	5	6	4	3
Energy Storage	0		2	5	7	5	3
Dynamic Ratings (transmission)	0		3	6	6	5	1
Applying Emerging Technologies to Renewable Integration	0		1	0	0	9	3
Synchrophasors and other system wide monitoring	0		2	2	7	9	7
Staff & Resources to Support Emerging Technologies	0		1	3	8	8.5	7
Flexible AC Transmission System (FACTS)	0		0	0	9	5	5
Using Emerging Technologies to address threats from GMDs and artificial electromagnetic pulses (EMPs)	0		1	0	9	9	1
High Voltage Direct Current (HVDC)	0		0	0	9	9	5

²⁷ In some cases for certain categories a maturity stage had multiple columns, and the scores were therefore normalized to an average score out of 9, hence the appearance of some fractional scores in this table.

The previous table highlights several important trends. For example in every category, every IRC member has at least some level of engagement on the technology issue in question. Other notable trends emerge from the high-level results include:

- **A wide variance between the maturity levels of the various technologies themselves.** This is illustrated by the extent to which the various ETTF members are spread out across the five Smart Grid Maturity Model levels on the previous table. Areas shaded in dark green (e.g. synchrophasors and HVDC) indicate a high degree of clustering around a particular maturity stage, which in turn suggests the technology has reached the point where most IRC members have reached a similar usage level. In other areas of the table, one can see that the opposite is also true in some areas: Microgrids and Distributed Energy Resources are two examples where the IRC community has not yet appeared to have converged on a specific level of engagement on these emerging technology areas.
- **A high degree of organizational commitment.** Under the category of “Staff and Resources to Support Emerging Technologies,” every ETTF member assessed themselves as having at least reached level 4 on the maturity model with, “Staff and resources devoted to changing and/or developing markets and operating procedures to optimize new technologies.” In many cases, ETTF members assessed themselves at level 5 on the model.
- **Renewable Integration stands out with the highest degree of clustering at level 4 of the maturity model.** As noted in the “Context” section of this report, North America’s accelerating shift toward distributed renewable resources have prompted all of the IRC member organizations to become deeply engaged on this topic. However, the approaches and policies to this topic vary widely across the member organizations. ETTF members carved this out as a special topic of their study to catalogue the various requirements to connect microgrids, DER’s and Energy Storage assets and harness their respective capabilities. The results of this analysis are examined further on in this section.
- **IRC members are pushing out the knowledge envelope in every category.** In virtually every category examined by the ETTF, one will find evidence of one or more member organizations at level 5 of the maturity model, going well beyond simply adopting a new technology into their operations. In each category, various member organizations are assisting/funding, research and development and/or developing new approaches, techniques and rules regarding the use of emerging technologies that may be of future importance to the entire IRC community.
- **Outlier categories:** The ETTF group has identified several “outlier categories” where promising new technologies and approaches are being explored by various organizations. **Because only a small number of ETTF members are involved in these categories they are separately displayed on the next page.** In many cases, IRC members are at a level 5 (“Pioneering level”) in the Smart Grid Maturity Model with respect to these categories, as they fund and facilitate research in these areas.

Table 4 – Outlier Technology categories being explored or developed by various ETTF member organizations.

Outlier Technology Category	Description
Transactive Energy	An emerging concept to allow automated electricity trading between devices at all levels of the electricity system. Transactive Energy holds the potential to harness the capabilities of mass quantities of controllable assets and allow them to respond to market-based signals to varying degrees based on the asset owners' preferences.
Microgrid Controllers	This family of technologies help govern the interface between a microgrid and the broader electricity system. As microgrids become a more prevalent feature on the landscape these devices could be a crucial component to enabling aggregated microgrid capability to offer various services into electricity markets.
Vehicle to Grid integration	This category encompasses various concepts and technologies to allow mass numbers of electric vehicles to respond to market price signals and provide a host of services back to the electricity grid, ranging from load management to ancillary services.
Smart Inverters	Smart inverters provide power conversion capabilities to a wide range of distributed energy resources (DERs) and capabilities and can also be configured to provide specific responses and voltage stabilization services to the electricity system.
AMI/Smart meters	Smart meters can provide a range of benefits to the broader electricity system, including time-based price response, critical peak pricing and situational awareness. When coupled with advanced data analytics technologies and other datasets, AMI data may also provide operational insights and forecasting improvements to system operators at all levels of the electricity system.
Topology Control	A concept whereby a system operator dynamically reconfigures the topology of the electricity system as an integral part of the dispatch scheduling and optimization process in order to minimize congestion on the system.
Smart Wires	A collection of technologies that allow changes to the resistivity of individual circuit paths in order to selectively control power flows over an electricity system.
New Sources of Regulation Services	The category captures various investigations into new sources of frequency regulation services that can be provided to the electricity system.
Virtual Power Plants	This concept involves the integration of various combinations of energy storage, generation and load control across a number of customer sites to create a controllable resource with sufficient capacity as to provide a number of services to the electricity system.

Requirements to Connect

During the course of its work, the ETTF discovered that the, “requirements to connect” category deserves both special treatment and attention. This category concerns itself with the methods by which each organization uses to connect various types of resources that fall within the emerging technologies subcategories of:

1. Microgrids
2. Energy storage devices
3. Variable/Renewable generation

In addition, the manner by which these devices are connected to the broader “electricity system” (be it at the wholesale or distribution level) also affects the outcomes and approaches to be deployed. The ETTF therefore broke out its analysis across four major subcategory subtypes as follows:

1. Directly connected to bulk electricity system
2. Embedded in a wholesale market participant site
3. Connected to distribution system
4. Embedded in a distribution system customer site

In total, three subcategories of technologies and four subcategories of connection types yielded 12 different permutations of approaches for each organization.

Requirements to Connect – summary observations:

The ETTF applied the Smart Grid Maturity Model to each of the 12 permutations of technologies and connection arrangements and catalogued the various techniques employed by each organization to harness the capabilities of these resources. In terms of assessing the level of engagement in each of these areas the use of the Smart Grid Maturity Model was modified so each of the five stages would be applied as follows:

0	1	2	3 to 4	4	5
0 - Default	Initiating	Enabling	Integrating/ Optimizing	Optimizing	Pioneering
No specific rules or guidance in place	Organization is examining requirements in the context of new facilities	Specific pilot projects to test new connection concepts	New technologies are being incorporated to maintain participation	Connection requirements optimize participation of new technologies to assist power system needs	Leading or supporting research into new policies and approaches to connecting new resources

Some important findings can be surmised from this effort:

- Across the three technology categories (i.e. microgrids, energy storage devices and variable/renewable generation) most member organizations are most highly engaged with variable/renewable generation.
- Microgrids lag furthest behind in terms of ETTF organizations having well-defined connection requirements for them (including direct-connected microgrids).

- While most ETTF member organizations have rules in place for direct-connected energy storage devices, few have a well-established means to allow aggregated participation of large numbers of small-scale (i.e. somewhere below 0.1 to 0.5 MW) energy storage devices. This presents a future challenge as more and more small-scale storage capacity becomes embedded in distribution-connected customer sites.

Appendix C: The IRC Emerging Technologies Task Force and Acknowledgements

This report was prepared by the ISO/RTO Council (IRC) Emerging Technologies Task Force (ETTF), which reports to the IRC Operations Committee and consists of the organizations and representatives listed at right.

Acknowledgements:

The IRC ETTF wishes to thank the IRC Committees for their review of this report and in particular, the assistance of the IRC Communications Committee during the preparation of this report.

IRC-ETTF member organizations and representatives:

Alberta Electricity System Operator
AESO

Arman Kiani, Cam Bush

California Independent System Operator
CAISO

Brad Bouillon, Bob Kott, Ali Mirejadi

Electric Reliability Council of Texas
ERCOT

Bill Blevins, Pengwei Du, Clayton Stice

Independent Electricity System Operator
IESO

Edward Arlitt, ETTF Chair
Karen Backman

Independent System Operator of New England
ISONE

David Bertagnolli (ret.), Michael Gilmore

Midcontinent Independent System Operator
MISO

Kevin Frankeny, Beibei Li

New York Independent System Operator
NYISO

Brad Garrison

PJM Interconnection
Chantal Hendrzak

Southwest Power Pool
SPP

Casey Cathey, Derek Hawkins

Bibliography:

1. Government of Canada, Natural Resources Canada, *"Photovoltaic Technology Status and Prospects - Canadian Annual Report"*, 2015, IESO
2. Independent Electricity System Operator, energy capacity statistics, accessed at: www.ieso.ca
3. United States Department of Energy, "Wind Technologies Market Report, 2015", Aug. 2016, U.S. Department of Energy, "WINDExchange" website:
http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp accessed, October, 2016
4. BP, *Statistical Review of World Energy* June 2016
5. Lawrence Berkeley National Laboratory, *"SunShot: Tracking the Sun IX"* August, 2016
6. Lawrence Berkeley National Labs, Kristov, L. (CAISIO), et. al., *"Distribution Systems in a High Distributed Energy Resources Future."* December, 2015
7. National Renewable Energy Laboratory (NREL) *"Energy Storage Requirements for Achieving 50% Solar Photovoltaic Energy Penetration in California"*, Aug. 2016
8. National Renewable Energy Laboratory (NREL) *"Eastern Renewable Integration Study"* Aug. 2016;
9. PwC, *"14th PwC Power and Global Utilities Survey."*
10. Software Engineering Institute *"Smart Grid Maturity Model Update,"* Volume 3,
11. U.S. Department of Energy Grid Modernization Laboratory Consortium (GMLC) – Awards:
<http://energy.gov/under-secretary-science-and-energy/doe-grid-modernization-laboratory-consortium-gmlc-awards> - accessed on November 28, 2016
12. U.S. Department of Energy - <http://energy.gov/eere/sunshot/orange-button-solar-bankability-data-advance-transactions-and-access-sb-data>
13. U.S. Department of Energy *2015 Wind Technologies Report*, August 2016
14. U.S. Department of Energy, Federal Energy Regulatory Commission, *"Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators;"* [Docket Nos. RM16-23-000; AD16-20-000] Nov. 17, 2016
15. U.S. Department of Energy, Solar Technologies Office, *"On the path to Sunshot: Executive Summary"*
16. U.S. Energy Information Administration, *Annual Energy Outlook, 2016*, figure MT-13
17. U.S. Energy Information Administration, EIA - *Electric Power Monthly*, July, 2016
18. U.S. Energy Information Administration, TODAY IN ENERGY: Wednesday, December 2, 2015 *"EIA electricity data now include estimated small-scale solar PV capacity and generation"*