

Category 1 (Foundational/Regional) Project Final Report

Report Completion Date: 8/4/2020

Section 1: Project Information

Project Information	
Control #: Title:	1.1
Project Title:	1.1 Foundational Metrics Analysis for GMLC
Project PI Name and Lab Affiliation: Project Co-PI (plus-one) and Lab Affiliation:	Michael Kintner-Meyer (PNNL) Joe Eto (LBNL)
DOE Project Manager(s):	Joe Paladino (OE), Guohui Yuan (EERE)
Period of Performance:	6/1/2016 – 6/30/2020
Date Closed:	2/24/2020

Section 2: Project Assessment and Checklist

Project Assessment and Checklist	Y/N	Confirmation Date	Comments
Have all quarterly reports been submitted?	Y		
Have all milestones have been delivered?	Y		
Are all products finalized (e.g. technical reports, journal articles)?	Y		
Have all project products been finalized and presented/submitted to DOE Project Manager(s) and/or GMI Leadership?	Y		Several reports are still under DOE review
Have all potential sensitivities been identified and addressed with DOE Project Managers and/or GMI Leadership?	Y		
Has the project team received feedback from Project Stakeholders (e.g. advisory group)?	Y		
Are there any open or pending costs?	N		

Section 3: Outcomes, Deliverables, Publications

Provide the following:

**In addition to titles, provide links to any websites or other repositories where deliverables and/or other information will be available after the project has been completed*

**Publications available for public release, URLs, etc. listed here should be uploaded to GMLC Open Point*

1. List of Outcomes:

- a. Engaged with stakeholders to assess need for enhancement/revision of existing metrics and/or development of new metrics for various grid attributes
- b. Developed year 1 interim report on the state of the metrics for various grid attributes (e.g. reliability, resilience, flexibility, sustainability, affordability, physical security)
- c. Developed comprehensive 8 volume final report

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2. List of Deliverables:

- a. David Anderson, Annika Eberle, Thomas Edmunds, Joseph Eto, Steven Folga, Stan Hadley, Garvin Heath, Michael Kintner-Meyer, Julia Phillips, Gian Porro, Monisha Shah, Cesar Silva-Monroy, Eric Vugrin, Angeli Tompkins, Meng Yue. June 2016. *Grid Modernization: Metrics Analysis: Reference Document*, PNNL-26541. PNNL, Richland, WA.
- b. Andrew Mills. *Grid Modernization: Metrics Analysis: Characterizing Grid Operations Using New Metrics*. May 2017. PNNL-26541. PNNL, Richland, WA.
- c. Joseph Eto, Michael Kintner-Meyer, Andrew Mills, David Anderson, Annika Eberle, Gian Porro, Paul Denholm, Maninder Thind, Thomas Edmunds, Steven Folga, Frederic Petit, Julia Phillips, Jessica Trail, Cesar Silva-Monroy, Vanessa Vargas, Kristina Hamachi LaCommare, Sumittra Gunguli, Garvin Heath, Monisha Shah, Jordan Macknick, Rob Bickhart, Pedro Sotorrio, Angeli Tompkins, James Kavicky, Shabbir Shamsuddin, Debra Frederick, Eric Vugrin, Meng Yue. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Executive Summary Reference Document, Volume 1*. PNNL-28570. PNNL, Richland, WA.
- d. Joseph Eto, Kristina Hamachi LaCommare, Meng Yue. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Reliability Reference Document, Volume 2*. PNNL-28566. PNNL, Richland, WA.
- e. Frederic Petit, Vanessa Vargas, James Kavicky. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Resilience Reference Document, Volume 3*. PNNL-28567. PNNL, Richland, WA.
- f. Thomas Edmunds, Andrew Mills, Paul Denholm, Petro Satorrio, Thomas Jenkins. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Flexibility Reference Document, Volume 4*. PNNL-28563. PNNL, Richland, WA.
- g. Garvin Heath, Jordan Macknick, Annika Eberle, Monisha Shah, Gian Porro, Rob Bickhart, Maninder Thind, Ariel Miara. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Sustainability Reference Document, Volume 5*. PNNL-28561. PNNL, Richland, WA.

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- h. David Anderson, Sumittra Ganguli, Madison Moore, Alan Cooke. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Affordability Reference Document, Volume 6*. PNNL-28562. PNNL, Richland, WA.
- i. Steven Folga, Angeli Tompkins, Jessica Trail, Shabbir Shamsuddin, Debra Fredrick. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Physical Security Reference Document, Volume 7*. PNNL-28576. PNNL, Richland, WA.
- j. Gian Porro, Monisha Shah, Emily Chen, David Hurlbut, Jeffrey Cook. April 2020. Final report: *Grid Modernization: Metrics Analysis (GMLC1.1) – Selective Literature Review and Mapping Reference Document, Volume 8*. PNNL-28609. PNNL, Richland, WA.

3. List of Publications:

- Eberle, Annika L. & Heath, Garvin A., 2020. "**Estimating carbon dioxide emissions from electricity generation in the United States: How sectoral allocation may shift as the grid modernizes,**" *Energy Policy*, Elsevier, vol. 140(C).
- Conference presentation (Eberle and Heath. "Projected Growth in Small-scale, Fossil-fueled Distributed Generation: Potential implications for the U.S. Greenhouse Gas Inventory." Session 7: Emissions Inventory Preparation for Air Quality Modeling, U.S. Environmental Protection Agency 2017 International Emission Inventory Conference, 17 Aug. 2017, Hyatt Regency Baltimore on the Inner Harbor, Baltimore, MD. Program with presentation abstract available at: https://www.epa.gov/sites/production/files/2017-09/documents/final_program_2017.pdf)
- Edmunds, Thomas, Omar Alzaabi, and Andrew Mills, Flexibility Metrics to Support Grid Planning and Operations, LLNL-CONF-738350, Siebel Energy Institute Future Markets Workshop, Washington, DC, July 26, 2017. <https://www.osti.gov/servlets/purl/1393323>
- Sumittra Ganguli , David M Anderson, Madison L Moore. "**On the Measurement and Quantification of Electricity Affordability in the Commercial and Industrial Sectors – A Cost Burden Approach.**" Submitted to: *Energy Policy*, Elsevier Publishing Co.
- Anderson, David M., 2018. Electricity Affordability Metrics for the U.S. Webinar organized by Clean Energy States Alliance, <https://www.cesa.org/event/electricity-affordability-metrics-for-the-u-s/>. June 14, 2018.

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- Vugrin, E., Castillo, A., and C. Silva-Monroy, 2017. Resilience Metrics for the Electric Power System: A Performance-Based Approach. Sandia National Laboratories, SAND2017-1493. <https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2017/171493.pdf>

4. List of Awards or Recognition: N/A

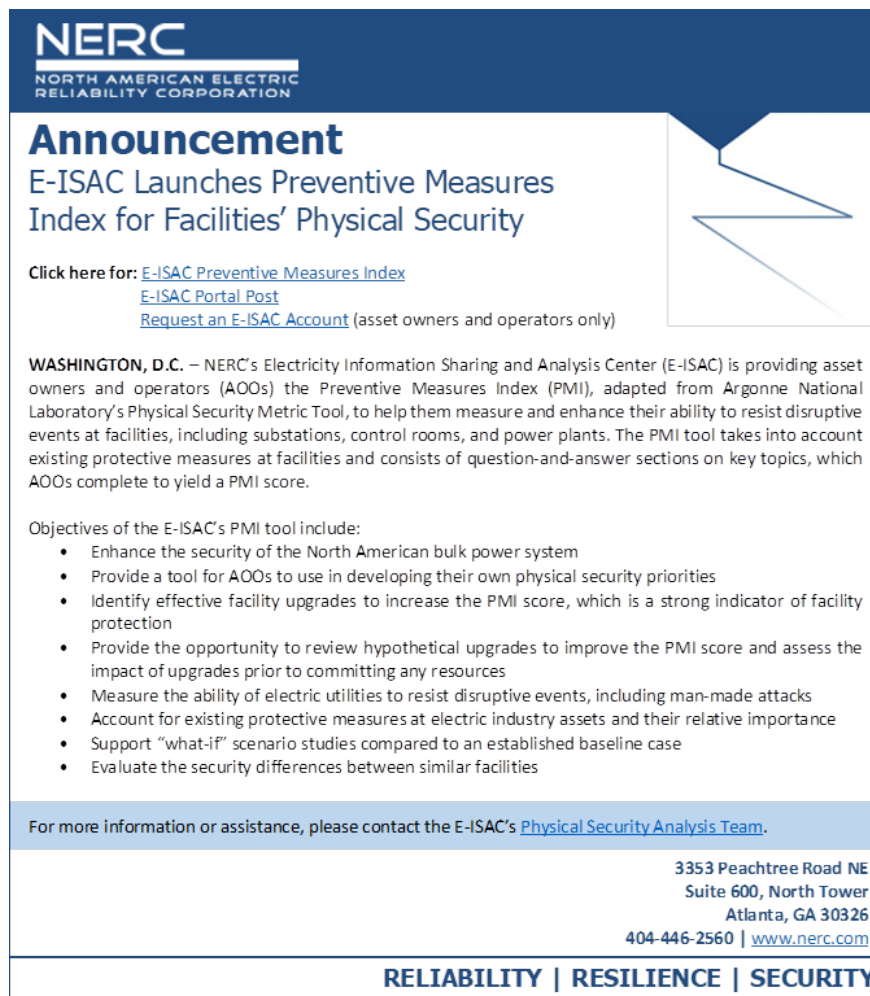
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5. List any ROIs – Software, Intellectual Property, Licensing, Patents, Etc.

Tools:

- Affordability dashboard. Web-based to explore affordability of electricity geographically for the continental US. Available at: <https://gmlc.pnl.gov/affordability/>
- The physical security tool developed by Argonne in the GMLC 1.1 project was provided to the E-ISAC for their distribution to interested members. There was a NERC Announcement – E-ISAC Launches Preventive Measures Index for Facilities’ Physical Security – on June 25th, 2020:



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Announcement

E-ISAC Launches Preventive Measures Index for Facilities’ Physical Security

Click here for: [E-ISAC Preventive Measures Index](#)
[E-ISAC Portal Post](#)
[Request an E-ISAC Account](#) (asset owners and operators only)

WASHINGTON, D.C. – NERC’s Electricity Information Sharing and Analysis Center (E-ISAC) is providing asset owners and operators (AOOs) the Preventive Measures Index (PMI), adapted from Argonne National Laboratory’s Physical Security Metric Tool, to help them measure and enhance their ability to resist disruptive events at facilities, including substations, control rooms, and power plants. The PMI tool takes into account existing protective measures at facilities and consists of question-and-answer sections on key topics, which AOOs complete to yield a PMI score.

Objectives of the E-ISAC’s PMI tool include:

- Enhance the security of the North American bulk power system
- Provide a tool for AOOs to use in developing their own physical security priorities
- Identify effective facility upgrades to increase the PMI score, which is a strong indicator of facility protection
- Provide the opportunity to review hypothetical upgrades to improve the PMI score and assess the impact of upgrades prior to committing any resources
- Measure the ability of electric utilities to resist disruptive events, including man-made attacks
- Account for existing protective measures at electric industry assets and their relative importance
- Support “what-if” scenario studies compared to an established baseline case
- Evaluate the security differences between similar facilities

For more information or assistance, please contact the E-ISAC’s [Physical Security Analysis Team](#).

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The E-ISAC posted the recording of the training session on their portal (here: <https://www.eisac.com/portal-home/document-detail?id=125850>), so that

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owner/operators not able to make the call could get the benefit when they work with the tool, or reference as they have questions. The E-ISAC also took a survey at the end of the training session and received great feedback.

Section 4: Final Costing

Each Lab Financial POC Completes Final Costing of GMLC Projects for their lab. PIs, Lab Leads will need to assist but not required to report financials with this final report.

Section 5: Final Thoughts/Comments

Final Thoughts	Comments
Lessons Learned	Metrics development activities are a long-term endeavor that requires working with specific stakeholder communities to test the usefulness of new metrics definitions and their associated data requirements. This project laid the foundation by establishing an interdisciplinary research and analysis team that covers the very broad spectrum of metrics necessary to capture full breadth of attributes of the evolving grid.
Opportunities for Improvement	The breadth of 6 metrics area may need to be adjusted to better capture equity questions that relates to investment strategies. The topic of equity reaches new public interest, but is not well defined so that stakeholders can make more informed decisions regarding the trade-offs between grid modernization objectives (e.g. improved reliability, resilience) and equity.
Future Projects: Ideas for future work? Possible next steps and research direction?	We recommend targeted metrics development projects to further defined metrics in the area of flexibility with specific focus on retaining flexibility of future investments (future-proving or value of optionality) As mentioned above: the issue of equity among customer classes in investment strategies is a new area that needs more rigorous characterization and definition
Other:	N/A