Challenges of Digit(al)ization to Energy Policy: A Role for Big Data Analytics

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Abstract

This essay discusses challenges facing energy policy makers in the Big Data analytics era, including how best to promote new approaches to energy delivery arising from the industry's embrace of digitalization, and how to reconcile differences in resource reporting arising from disparate rates of digitization and inconsistent data handling.

Introduction

The transition to greater digitization and reliance on Big Data analytics across the global energy landscape has led to a range of policy challenges, particularly with regard to the regularization of data access and availability, data quality, information alignment, and uncertainty reduction. Various options exist to address these situations and to inform policy makers of the role Big Data analytics may play.

Big Data analytics rely on large volumes of data, and the ownership of the available data is, and will continue to be, a further situation requiring resolution (Chase and Berzina 2018). It has been suggested that, at least in the energy space, the data may actually become more valuable than the electricity, oil, or other energy resources being produced and sold (Toonders 2014; The Economist 2017, Bhageshpur 2019, Sadowski 2019, Tiwari 2019). How data ownership, security, quality, and privacy should be formalized or regulated to facilitate inter-economy collaboration are additional policy issues that must be addressed. However, given different approaches to legal ownership and access to data among companies and countries, there will likely not be a one-size-fits-all policy prescription that can be relied upon. Furthermore, consistent access to data—particularly data that are equivalent—will also be required in order for policy makers to both understand what is being done across the energy sector and to better analyze markets to provide stronger foundations for policy prescriptions (U.N. 2018).

This brief exposé identifies some of the energy data and digitization challenges encountered across the globe and suggests policy initiatives that can be used to resolve barriers to data sharing that result from a lack of standardized analytical and management approaches. It also addresses some of the terminology disparities that energy policy actors must navigate, and it describes the role of Big Data analytics in making future evidence-based policy decisions for the energy industry.

Digitization, Digitalization, and Digital Transformation

As is the case in most disciplines, the terms digitization and digitalization are often used interchangeably in conversations about energy policy and economics. However, they actually have very different meanings. Digitization is essentially the conversion of data and information that exists in analog (e.g., paper) files to digital (electronic) format; i.e., bits and bytes that can be interpreted, and acted upon, by computers. Digitalization, on the other hand, is the process of using digitized data and information to simplify established workflows and/or make them more efficient. In this sense, digitalization facilitates the migration of established systems and processes from a human orientation to one that is software-driven. Kahn et al. (2015) discuss the impact of digitization on economies and economic activity, while Brennen and Kreiss (2016) note that digitalization also pertains to the way in which social domains are restructured around digital communication and media.

While digitalization does not actually result in a changed workflow – just a more efficient one – digital transformation uses digitalization and digitized data to alter the way organizations and political jurisdictions conduct their activities, encouraging them to reconsider or reimagine the ways that things get done. At its core, digital transformation is the integration of digital technologies into all aspects of the entity's activities. Various authors have addressed the concept of a digital economy as an outgrowth of digital transformation (Deloitte n.d., OECD 2014; Ahmad and Mokal 2023).

Digitalization is rapidly transforming the delivery of energy and the deployment of energy technologies around the world. Both the International Energy Agency (IEA 2023) and the European Union (European

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Commission 2024) describe the impact of digitalization on all sectors of the energy economy, as well as their policies to further advance the energy transition through digitalization. Nazari and Musilek (2023) review the overall impact of digitalization on energy, and Jaffe (2021), in particular, makes the case that the digitalization of energy is a primary mechanism with which to harness innovation and promote resilience and national security in the United States.

Big Data and Big Data Analytics

Digitization is the movement and activity that gives rise to Big Data. While there are many definitions, forms, and dimensions of Big Data, it is essentially the largest, or most complex, compilation of information that cannot be managed or processed using more-traditional data management principles and techniques. Admittedly though, what is "big" to one group or entity may not be "big" to others. Perhaps better described as an information ecosystem consisting of elements extracted from disparate sources, the concept and reality of Big Data has emerged due to (1) the rapid growth of information storage capacity and computing power, (2) an ever-expanding number of artifacts delivered through social media, telecommunications, and Internet streaming, and (3) the rise of physical data capture devices and advanced instrumentation (e.g., sensors, quick response (QR) codes, radio frequency identification (RFID), supervisory control and data acquisition (SCADA) systems, and other "smart" tracking/recording devices). This change in the way that data and information present themselves has come to be known as the variety-volume-velocity data paradigm (Lee 2020).

The rise of Big Data has become nowhere more apparent than in the energy industry. The value and importance of Big Data has spawned an ever-expanding and always-enlightening conversation across all segments of the industry (Feblowitz 2012, Ferguson and Catterson 2014, Schuelke-Leech et al. 2015, Akhavan-Hejazi and Mohsenian-Rad 2018, Shobol et al. 2019, Kozman et al. 2024). Perhaps first championed in upstream oil and gas, it is now embraced all across the energy landscape; from wind, solar, biomass, and geothermal energy in the renewables space, to coal mining and coalbed methane extraction, carbon capture-utilization-sequestration, refining, production and transportation of liquefied natural gas (LNG), smart grids, battery storage, and beyond.

Though sometimes conflated with Big Data, Big Data analytics is the discovery, interpretation, and communication of meaningful patterns and trends within these large data sets. However, as some have said, it is not really about more data … it is about a deeper look which the increasing variety and volume of data facilitates. Big Data analytics may involve well-known statistical or computational tools, or, because of the complexity of the information, it may involve the application of newer generation computing architectures and algorithms more commonly associated with artificial intelligence (AI) and machine learning (ML). However, the technical aspects of Big Data analytics are not all that new, much of the computational theory having been known for some time. It is the application of such tools to larger and more-complex data sets that can yield insights not extractable from small sample data scenarios.

Policy Challenges

Virtually all sectors of the energy industry are fully pursuing digitalization and employing Big Data analytics to improve operations (Eissa 2020, Mohammadpoor and Torabi 2020, Bist et al. 2021, Asthana et al. 2022, Turetskyy 2022, Patel et al. 2020, Thomas et al. 2023). This transformation presents new and evolving policy challenges. The challenges have to do not only with advancing the ways in which energy gets delivered, but also with the manner in which the data themselves concerning energy resources and delivery get synthesized and reported. An important aspect of the digitization challenge is that the rate of digitization varies across different sectors of the energy industry, as well as in different countries, around the world. Further, data differences, particularly with regard to aggregation and the processing of unstructured data, frequently present policy makers with difficult choices as they try to reconcile data sets and sources to construct meaningful comparisons. The same or similar data may not be collected, values may be obtained from sources about which uncertainty persists, some data may be combined whereas others are not, and the combination approaches or weightings may not be the same. This is not a new situation, but it is one that is exacerbated by the variety and volume of data employed. Finally, the various algorithms associated with Big Data analytics do not produce unique solutions. Unless the exact same data set is used and the exact same algorithm is applied, the resulting predicted values are guaranteed to be different and/or to be more uncertain. This non-uniqueness of solutions makes the development of energy policy across sectors and/or political jurisdictions a very difficult proposition.

Finally, energy policy makers and economists have heretofore largely relied on the scientific method to produce estimates and projections, an approach that for decades has depended on the theory surrounding traditional small-sample statistics that is probabilistic in nature. However, with the advent of Big Data and Big Data analytics, there is very little reason to rely on t-tests, F-tests, and the like, since the availability of Big Data essentially implies that the entire population is known (Anderson 2008, Kitchen 2014). Big Data analytics, data mining, artificial intelligence, and machine learning are purely data-driven ventures that rarely rely on theory, allowing the data themselves to tell a story apart from more-conventional probabilistic statements.

The challenge for all economies, then, is two-fold. First, private and public sector players across all energy sectors are already adopting Big Data analytics – but perhaps in different ways – to improve their bottom lines and efficiency of operations; so, policy makers and regulators will need to understand how this shift may affect their decisions. Second, the same policy makers and regulators may well find that the adoption of Big Data analytics in their own workflows enhances their specific decision-making processes. A change in emphasis of this nature could improve the fact-based decisions that will allow policy makers to more effectively, and efficiently, meet domestic and international aspirations, such as those presented in Sustainable Development Goal 7 (SDG7) (U.N. 2023).

Proposed Actions

Harmonizing the quality and flow of energy data, incorporating improved transparency and more consistent and rapid accessibility, are needed in order to take full advantage of the power and benefits of Big Data analytics and digitization in the energy policy arena. At a minimum, this requires development of a full understanding of the current focus on Big Data and digitization across all energy sectors within all economies. To establish this baseline knowledge, the United Nations (U.N.) or similar high-level organization should initiate, coordinate, and fund one or more information-gathering fora, with the goal of publishing a database and report summarizing various approaches over the next two to five years. Academic institutions, government agencies, and national research organizations/laboratories can help. Such information can be critical to the decision-making efforts of the private sector involved in creating the energy capacity growth that will support global economic development. An initiative of this nature would also help enhance and standardize in-house governmental capabilities in digitization techniques and Big Data analytics sufficient to properly interpret the information being developed by the private sector and presented to government policy makers. This effort would ultimately lead to more effective government decision-making regarding the allocation and development of energy capacity and resources, as well as a more efficient global energy system.

Conclusion

The energy digitization transition is already occurring around the world, reaching into the energy sectors of each and every country. As such, each country is, and will continue to be, faced with the challenges of addressing the issues raised by digitization and how these may affect economic development. In addition, digitization will likely influence the paths each country takes to meet SDG7 goals of “ensuring access to affordable, reliable, sustainable and modern energy for all.” Finally, digitization particularly impacts resource estimation, data synthesis, and reporting. Without some degree of consistency and standardization, along with a commitment to data quality and equivalency, the ability to formulate and sustain coherent energy policy may be elusive for the foreseeable future.

References

Ahmad, Z., Mokal, M.N. (2023), An overview of economic growth in the era of digitalization, in Economics, Banking & Financial Management (D.A. Ode, R. Baa, et al., eds.). Stockholm, Red’Shine Publications, 37-46.

Akhavan-Hejazi, H. Mohsenian-Rad, H. (2018), Power systems big data analytics: An assessment of paradigm shift barriers and prospects. Energy Reports 4:91-100.

Anderson, C. (2008), The end of theory: The data deluge makes the scientific method obsolete. Wired (June 23), https://www.wired.com/2008/06/pb-theory.

Asthana, A., Dubey, P., Encinas, A., Mohanrangan, A., Pande, A., Fios Siliceo, L.F., González, J.R., van Schalkwyk, W. (2022), A new approach to advanced analytics in utility asset management. McKinsey & Company, 11 p., https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/a-new-approach-to-advanced-analytics-in-utility-asset-management#/.

Bhageshpur, K. (2019), “Data is the new oil—and that’s a good thing.” Forbes (November 15), https://www.forbes.com/sites/forbestechcouncil/2019/11/15/data-is-the-new-oil-and-thats-a-good-thing/?sh=188ee15c7304.

Bist, N., Tripathi, G., Sircar, A., Yadav, K. (2021), Artificial intelligence based optimizing solutions for the geothermal power plants. Proceedings, 46th Workshop on Geothermal Reservoir Engineering, Paper SGP-TR-218, Stanford, CA (February 15-17), https://www.researchgate.net/publication/345977316_Artificial_Intelligence_Based_Optimizing_Solutions_for_the_Geothermal_Power_Plants.

Brennen, J.S., Kreiss, D. (2016), Digitalization, in The International Encyclopedia of Communication Theory and Philosophy (K.B. Jensen and R.T. Craig, eds.), John Wiley & Sons.

Chase, P., Berzina, K. (2018), Transatlantic policy challenges of the digital energy nexus. The German Marshall Fund, Policy Paper 28, https://www.gmfus.org/publications/transatlantic-policy-challenges-digital-energy-nexus.

Deloitte (n.d.), What is digital economy? Unicorns, transformation and the internet of things. https://www2.deloitte.com/mt/en/pages/technology/articles/mt-what-is-digital-economy.html.

Eissa, H. (2020), Unleashing industry 4.0 opportunities: Big Data analytics in the midstream oil & gas sector. International Petroleum Technology Conference, Paper IPTC-19802-Abstract, Dhahran (January 13-15), https://onepetro.org/IPTCONF/proceedings-abstract/20IPTC/3-20IPTC/D033S076R002/154550.

European Commission (2024), Accelerating the digital transformation of the European energy system. European Union, https://digital-strategy.ec.europa.eu/en/policies/digitalisation-energy.

Feblowitz, J. (2012), The big deal about big data in upstream oil and gas. Hitachi Data Systems and IDC Energy Insights, https://www.hds.com/go/energy-resource-center/en/home/pdf/the-big-deal-about-big-data-in-upstream-oil-and-gas.pdf.

Ferguson, D., Catterson, V. (2014), Big data techniques for wind turbine condition monitoring. Proceedings of the European Wind Energy Association Annual Event (EWEA 2014), Barcelona (March 10-13), https://pureportal.strath.ac.uk/en/publications/big-data-techniques-for-wind-turbine-condition-monitoring.

International Energy Agency (IEA) (2023), Digitalisation. https://www.iea.org/energy-system/decarbonisation-enablers/digitalisation.

Jaffe, A.M. (2021), Energy’s Digital Future: Harnessing Innovation for American Resilience and National Security. Columbia University Press, 248 p.

Khan, S., Khan, S., Aftab, M. (2015), Digitization and its impact on economy. International Journal of Digital Library Services 5:138-149.

Kitchen, R. (2014), Big Data, new epistemologies and paradigm shifts. Big Data & Society, April-June:1-12.

Kozman, J., Lowery, S., Lamb, J. (2024), End-to-end workflow for managing large volumes of data from CCUS. Proceedings, SPE/AAPG/SEG Carbon Capture, Utilization, and Storage (CCUS) Conference & Exhibition, 251-260, Houston (March 11-13), https://doi.org/10.15530/ccus-2024-4014747.

Lee, A. (2020), Volume, velocity, and variety: Understanding the three V’s of big data. DataSource.ai (April 7), https://www.datasource.ai/en/

data-science-articles/volume-velocity-and-variety-understanding-the-three-v-s-of-big-data.

Mohammadpoor, M., Torabi, F. (2020), Big Data analytics in oil and gas industry: an emerging trend. Petroleum 6:321-328.

Nazari, Z., Musilek, P. (2023), Impact of digital transformation on the energy sector: A review. Algorithms 16(4), 211, https://www.mdpi.com/1999-4893/16/4/211.

Organization for Economic Cooperation and Development (OECD) (2014), Measuring the Digital Economy: A New Perspective. Paris, OECD Publishing, 115 p.

Patel, H., Prajapati, D., Mahida, D., Shah, M. (2020), Transforming petroleum downstream sector through big data: A holistic review. Journal of Petroleum Exploration and Production Technology 10:2601-2611.

Sadowski, J. (2019), When data is capital: Datafication, accumulation, and extraction. Big Data and Society 6(1):1-12, https://doi.org/10.1177/2053951718820549.

Schuelke-Leech, B.-A., Barry, B., Muratori, M., Yurkovich, B.J. (2015), Big Data issues and opportunities for electric utilities. Renewable and Sustainable Energy Reviews 52:937-947.

Shobol, A., Alil, M.H., Wadi, M., Tür, M.R. (2019), Overview of Big Data in smart grid. Proceedings of the 8th International Conference on Renewable Energy Research and Applications (ICRERA). Brasov, Romania (November 3-6), 1022-1025, https://ieeexplore.ieee.org/xpl/conhome/8974144/proceeding.

The Economist (May 6, 2017), The world's most valuable resource is no longer oil, but data, https://www.economist.com/leaders/2017/05/06/the-worlds-most-valuable-resource-is-no-longer-oil-but-data.

Thomas, G.A.S., Muthukaruppasamy, S., Saravanan, K., Muleta, N. (2023), Revolutionizing smartgrids with Big Data analytics: A case study on integrating renewable energy and predicting faults, in Data Analytics for Smart Grids Applications: A Key to Smart City Development (D.K. Sharma, R. Sharma, G. Jeon, and R. Kumar, eds.). Intelligent Systems Reference Library 247:179-198, Springer, Cham, https://doi.org/10.1007/978-3-031-46092-0_11.

Tiwari, S. (2019), "Data is the new oil, even in the oil and gas industry." TowardsDataScience (May 10), https://towardsdatascience.com/data-is-the-new-oil-even-in-the-oil-and-gas-industry-a3daa58d743d.

Toonders, J. (2014), "Data is the new oil of the digital economy." Wired, https://www.wired.com/insights/2014/07/data-new-oil-digital-economy.

Turetskyy, A. (2022), Data analytics in battery production systems. D.Ing. thesis, Technical University of Braunschweig, Institute of Machine Tools and Manufacturing Technology, 186 p., https://www.researchgate.net/publication/364336764_Data_Analytics_in_Battery_Production_Systems.

United Nations (U.N.) (2018), International recommendations for energy statistics, https://mdgs.un.org/unsd/energy/ires/IRES-web.pdf.

United Nations (U.N.) (2023), The sustainable development goals report: Special edition, https://unstats.un.org/sdgs/report/2023.

Zheng, M., Wong, C.Y. (2024), The impact of digital economy on energy development in China. Innovation and Green Development 3, 100094, https://www.sciencedirect.com/science/article/pii/S2949753123000620.

