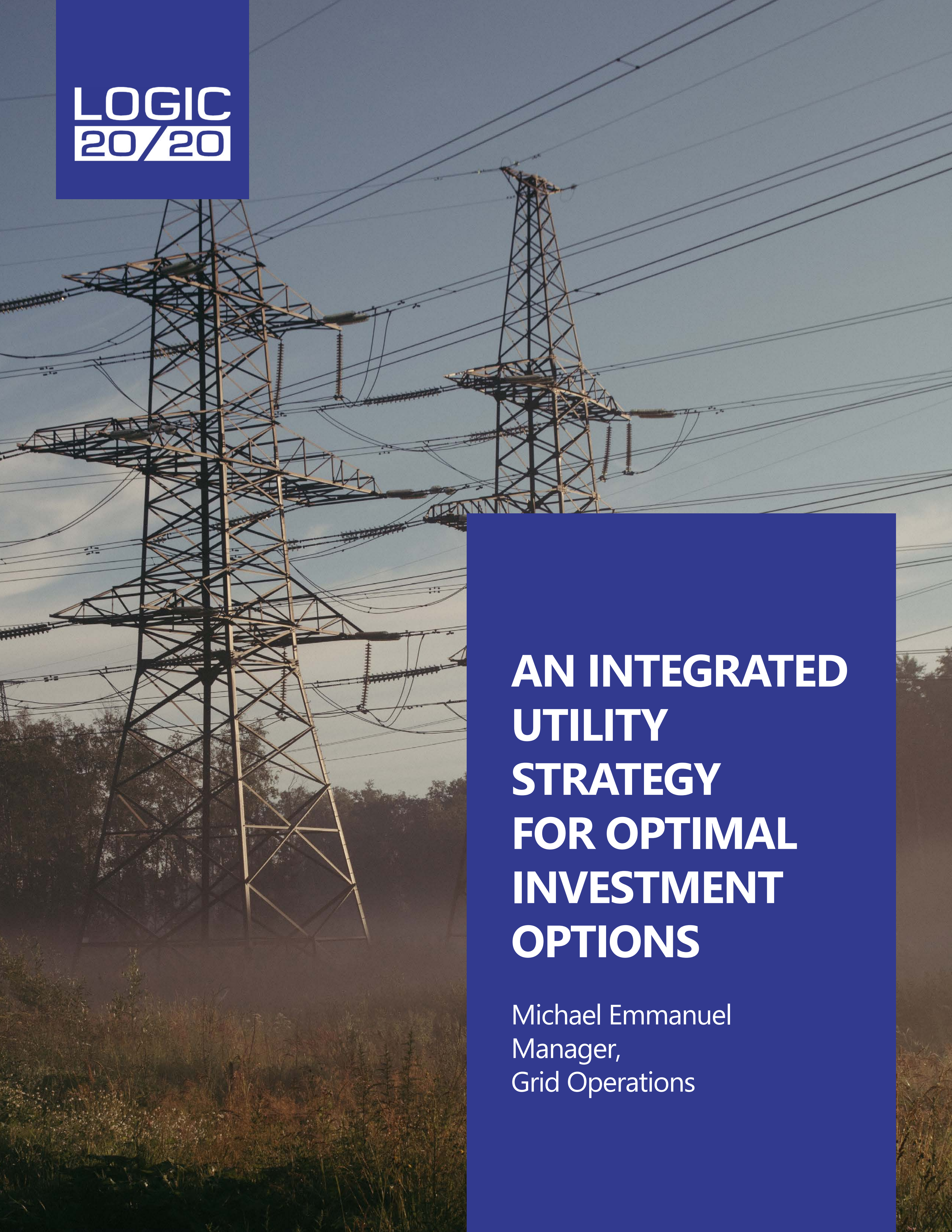

AN INTEGRATED UTILITY STRATEGY FOR OPTIMAL INVESTMENT OPTIONS

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Increasing renewable energy deployments can impact safe, affordable, and reliable operations of the grid by **triggering violations of grid constraints** such as capacity and voltage thresholds. With this in mind, utilities and authorities having jurisdictions (AHJs) over the grid are addressing integration issues in several ways. These include **investments in new initiatives, new regulatory regimes, revised interconnection standards,** and **technology solutions**—or a combination of these pathways.

A pivotal question is how stakeholders should objectively **determine the optimal investment option** or mix of options to accommodate the increasing amount of renewable energy resources.

Key aspects of an integrated strategy

I've identified two broad key aspects of an integrated utility strategy for optimal investment options.

Technology solutions

As distributed energy resources (DERs) continue to evolve and prices continue to drop, opportunities to innovate with them continue to grow in several ways.

DER deployment scenarios

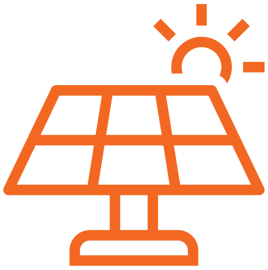
DER deployment scenarios can have huge techno-economic impacts on the grid depending on characteristics such as X/R ratio, load types, feeder length, and topology. Examples of these include random and close/far from the feeder head deployments of distributed solar photovoltaic (PV) systems. Deployment scenarios will have varied impacts on grid constraints, hosting capacity, and associated infrastructural upgrades. A careful and detailed analysis of “sweet spots” on the grid, discovered through rigorous analysis where DERs can be integrated, can provide techno-economic benefits to systems such as upgrade deferral, increase in hosting capacity, and reduced cost of upgrades.

Technology hybridization

Another opportunity lies in hybridization of technologies such as collocated solar and energy storage systems and complementarity of wind and solar combinations. Hybrid systems can improve system reliability and resilience with other benefits such as demand reduction and increasing variable renewable energy sources integration.

DER aggregation

DERs aggregations can provide grid support and opportunities for small-scale DERs to participate in wholesale markets; however, they can present adverse grid conditions that will warrant infrastructural upgrades. It is important to consider these deployment scenarios because they present different grid impacts and associated upgrade costs. A detailed analysis of these can help utilities to determine the optimal investment pathway to accommodate increasing renewable energy deployments.



DER deployment scenarios can have huge techno-economic impacts on the grid.

DER siting and sizing

Optimizing DERs in the grid via optimal siting and sizing can have significant techno-economic benefits, such as infrastructure upgrade deferral and reduction in associated cost. Siting DERs in "sweet spots" in the grid along with optimal sizing can significantly reduce the possibility of violating grid constraints such as thermal and voltage thresholds. Unlocking the intrinsic dollar value of a DER can be a function of location. The DER's value could be lower or higher depending on locational prices influencing grid conditions such as congestion.

Taking advantage of the load evolution through increased efficiency levels and flexibility can provide techno-economic benefits to utilities such as reduction of thermal load and infrastructure upgrade deferral.

Grid management systems

Further, utilities are now unlocking additional value of DERs through coordinated control of DERs via the deployment of grid management systems such as DER management systems (DERMS), advanced distribution management systems (ADMS), and activation of grid support functions in smart inverters.

Load evolution

Taking advantage of the load evolution through increased efficiency levels and flexibility can provide techno-economic benefits to utilities such as reduction of thermal load and infrastructure upgrade deferral.

Utility and government solutions

Utility and government initiatives can play a huge role in determining an optimal investment option or mix of options.

Process improvement

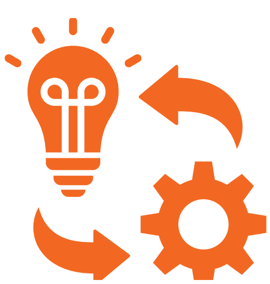
Utilities can embark on different business process improvement initiatives that can provide opportunities for cost saving, enhance customer experience, and improve operational efficiency while also enhancing grid reliability and resilience.

Technology and strategy solutions

Examples of technology- and strategy-related utility initiatives include early adoption of IT-enabled technologies such as smart meters before DER integration, increasing behind-the-meter (BTM) asset visibility, data integration strategies, digital transformation, change management strategies, innovation, and R&D initiatives.

Another question arises here: How should utilities objectively and optimally prioritize these initiatives, considering market and regulatory dynamics?

An initial step is to continue to engage with utility leadership for support and to narrow down to a few initiatives per time. Also, ordering initiatives by business needs, time-to-value, and dependencies such as regulatory and contractual requirements in an enterprise-grade solutioning can help utilities to continue to get ahead of the curve and maximize the benefits these initiatives.



Process improvement provides opportunities for reducing costs, enhancing customer experiences, and heightening efficency.

External incentives

Several external initiatives from AHJs such as the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) will have significant techno-economic impacts on utilities' long- and short-term planning and operations. These grants provide an unprecedented breadth of opportunities and challenges because of the significant investments they are driving in distribution technologies, generation, and grid infrastructure.

For instance, IRA funding is expected to accelerate the integration of an additional 270 GW of solar and wind by 2030. This implies that previously financially non-viable projects could become economically viable. The rhetorical question here is whether the grid infrastructure will be able to accommodate such a high amount of variable renewable energy integration. For its part, IIJA will eventually spur grid infrastructure upgrades, giving more headroom for greater grid capacity and resiliency.

In our view, every utility is facing the unique challenge of how to tactically manage their internal strategy and priorities coupled with external initiatives while maintaining safe, reliable, resilient, and affordable grid operations. Continuously assessing the strategic impact and prioritizing and identifying the most impactful initiatives—or combination of initiatives—to pursue are now pivotal requirements for maximizing benefits both for utilities and customers.

An end-to-end framework for evaluating investment options

There is a need to proactively characterize various planning and operations aspects so that utilities can objectively evaluate which investment option(s) is best over the long term for customers and the grid in addressing new network needs. An end-to-end, integrated perspective across the value chain will help capture all cost components needed for utilities, regulators, customers, and other stakeholders to make informed decisions on the optimal investment option(s).

This segment highlights major planning and operations dimensions in a system-wide scenario analysis to determine objectively the optimal pathway for accommodating an increasing amount of renewable energy integration.

Electricity demand and supply projection scenarios analysis

A pivotal step here is to characterize the system by analyzing various demand projection scenarios, including varying energy efficiency levels, and then investigating the supply scenarios to meet each demand scenario while considering transmission constraints. In addition, it is important to continue assessing customer adoption patterns of DERs, because this impacts both demand and supply scenario dynamics on the grid.

Planning and operational models

Investigating optimal investment pathways to accommodate increasing renewable energy integration involves a detailed analysis across all relevant timescales to capture key system dynamics and their costs implications. This can be achieved through various planning and operational models, including the following:

Capacity Expansion Model is a long-term system planning model used to investigate potential structural changes to the bulk power system based on years into future and to optimize generation investment, transmission capacity, and operational changes. These models analyze a range of possible future scenarios and sensitivities while considering technology options and potential technological innovations.

Unit Commitment & Economic Dispatch Model is used to confirm the operational feasibility of the built model from the capacity expansion tool in a more granular timescale. Such models are used to assess the optimal dispatch of each generation and storage units over the next few hours and days at minimum operating costs, while considering transmission network constraints and the limitations of each unit.

Dynamic Models are used to validate the outputs from capacity and production cost models by investigating the grid’s response after a large disturbance, such as loss of a large generator or a critical transmission line, over a short time frame (from subseconds to minutes). High resolutions are used in these models for voltage and frequency assessments and help capture, for instance, solar and load variability impacts.

Distribution System Analysis is used to evaluate hosting capacities and associated upgrade costs with load changes and DER penetration levels. The distribution system must be able to accommodate electricity demand growth and local DER projection scenarios from bulk power system models without violating grid constraints. Such accommodations come with additional upgrades in the distribution systems, which must be accounted for to have a complete cost implication assessment.

An end-to-end, integrated perspective across the value chain will help stakeholders make informed decisions on optimal investment options.

Achieving optimal investment options with increasing DER penetration may require utilities to transition from business-as-usual (BAU) traditional infrastructure upgrade strategies to DERs, hybrid DERs and/or grid approaches.

Investment pathways to achieving hosting capacity expansion in the distribution network include the following:

- **The BAU approach** includes reconductoring, DER with unity power factor & relocation of cap banks.

- **The DER approach** includes activations of grid support functions (GSFs) in smart inverters and hybridization of DERs such as solar + storage and complementarity of PV and wind. Other DER approaches include spatial distribution of DERs, which includes random and close/far from the substation.

- **The grid/system-wide approach** includes ADMS and DERMS deployments.

Transmission-distribution interface coordination

In regulated wholesale electricity markets where utilities maintain vertically integrated monopolies, owning and controlling generation, transmission and distribution systems, the complexities of transmission-distribution interface coordination may be managed more easily than in a deregulated space, where ownership and jurisdictional delineation play a huge role. Moreover, there are few or no interactions between transmission and distribution system operators. There is a possibility that multi-purpose DERs can receive conflicting dispatch instructions from these operators.

Developing an integrated utility strategy for optimal investment options would require a transparent framework to manage the transmission-distribution interface coordination. This framework will have to incorporate jurisdictional awareness, asset ownership, cost allocation, and distribution of upgrade costs across stakeholders and the ability to manage these key interfaces, data exchange, power, control, and market interfaces.

Cost-benefit analysis

A cost-benefit analysis assesses cost implications and benefits of various electricity demand-supply scenarios with associated infrastructure upgrades investigated in the planning and operation models. The output of this analysis can be used to make an informed decision on the optimal investment option(s).

Environmental analysis

Another important analysis is the investigation of environmental impacts such as greenhouse gas (GHG) emissions potential and environmental justice issues of the various electricity demand-supply scenarios. An optimal investment decision will not only consider saved dollar value, but also environmental impacts of those decisions.

Policy and regulatory framework

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Stakeholder engagement framework

A stakeholder engagement framework can help to investigate key stakeholders' interests such as least-cost, reliability, and fair-cost allocation schemes. This type of framework can be used to identify the training and upskilling required to enhance relationships in participating, for instance, in performance-based regulation to define emerging performance metrics, including equity (measuring local impacts of DER deployments) and network support services (granting independent power producers fair access to transmission and distribution networks).

Optimizing investments for the grid of the future

Evaluating optimal investment pathways and decisions to accommodate increasing amount of DERs requires an integrated end-to-end strategy covering key aspects of the evolving grid. For instance, siloed analysis covering only single domains, either transmission only or distribution only analysis can skew conclusions over a highly interconnected grid. Analysis covering transmission and distribution systems is pivotal in ensuring that costs of infrastructural upgrades to host increasing deployment of renewable energy resources are fully captured, allocated and accounted for by stakeholders involved.

Another important consideration is initiating a transparent framework to manage the transmission-distribution interface coordination. In most cases, transmission and distribution system operators rarely exchange information or coordinate activities, and this situation presents challenges such as complexities in cost allocation for investment upgrades across domains. In addition, identifying and prioritizing strategic investment opportunities and initiatives can help utilities get ahead of the curve and maximize benefits in a cost-effective way while aligning with their short- and long-term goals.

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