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# Energy system planning
## Multi-level modeling for an electrified future

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# Introduction

The energy sector is transforming, driven by advanced technologies, evolving consumer behaviors, and economic and environmental policy. Some natural gas and electric utilities are facing unprecedented challenges as a result of this transformation. However, electric utilities are coming under pressure to proactively plan for and deploy capital intensive infrastructure to prepare for an increase in demand forecasts.[1] This increase is driven by expectations for economic growth, advances in the adoption of efficient electric end use technologies, sustainability policy driving a movement toward electrification, increasing cost-competitiveness of renewables and electrified solutions, and new demand for large load from data centers and other industrial applications. Thus, utilities are in the unique position of having to solve for shifting supply and delivery, while reducing the emissions of their own assets and contributing to economy-wide abatement or their customers at the same time.

The electricity system should be modernized and transformed at pace if utilities are to meet the increasing demand expectation of economies affordably and reliably as their new and existing customers adopt a diverse array of electro-technologies. Balancing the power, utilities and renewables (PU&R) sector's respected principles of safety, affordability, and reliability will also likely require extensive system optimization and innovation given the changes occurring.

In the face of these challenges and opportunities, integrated system planning—across geographic regions and electrical system value chain segments (i.e., generation, transmission, and distribution)—is increasingly important. Accordingly, many PU&R companies around the globe are seeking to enhance their capabilities in economic modeling and advanced energy forecasting; scenario and probabilistic system planning; and analytics to inform the resulting capital allocation.

### Shifting supply and demand paradigms

Not long ago, many utility planners and regulators were facing a world where load growth was flat or even declining. Some utility leaders were contemplating the possibility of future stranding of assets because energy efficiency was front and center and customer-owned distributed energy resources (DER) created the potential for load erosion.[2]

Now, load growth has rebounded sharply in many regions due to population increases and improving standards of living in developing countries, transport and industrial electrification (e.g., electric vehicles and electric furnaces), and data center expansion around the world due to the escalating demand for artificial intelligence (AI).[3]

Underpinning many of these factors is the proliferation of efficient, economic, and popular end-use technologies, which is fueling demand in ways that can be hard to pinpoint. For instance, in the transport and heating sectors, it can be difficult to identify which buildings may convert to air- or ground-source heat pumps or when and where large quantities of electric vehicles may be adopted. Similarly, in commercial and industrial sectors, it can be challenging to predict future power demand, and if not done well, utilities could risk either over-building and deteriorating their earnings, or under-building and capping the economic activity or customers access to electric supply in their service territories. Variable peak loads, especially for transportation and seasonal heating and cooling, can further complicate these shifting supply-and-demand scenarios.

# Key planning challenges

Today, many utilities are planning for load growth in an uncertain environment. That uncertainty can be driven both by quickly evolving technology and changing policy. For instance, utilities may anticipate that AI data centers will continue on their trajectory of expansion and power consumption, and then a new chip design or algorithm or permitting regulation may come along and diminish those expectations. Despite this volatility, utilities are often expected to be capable of sustaining the connection between economic development and energy, since a region cannot grow if it does not have the energy capacity and infrastructure to support new businesses.

On the supply side, the continually improving economics, control, and performance of distributed resources is helping utilities to deliver on these expectations, despite demand uncertainty. But managing a vast network of mixed generation sources (i.e., bulk fossil-fuel-fired plants, nuclear, and hydro, along with intermittent renewables, distributed resources, and storage technologies) means supply and demand profiles vary greatly across states and provinces, nations, and regions. This can cause unintended consequences, making it increasingly difficult and costly for utilities to anticipate and provide the capacity to enable economic growth.

For example, California often has an excess of solar photovoltaic (PV) power on sunny days during the spring when fewer people are running their air conditioning.[4] This has led the state to explore storage options and more transmission capacity for flowing power to northern parts of the state and/or exporting it to neighboring states.[5] In some regions this phenomenon has also caused regulators to curtail financial incentives for rooftop installations, frustrating solar installers as well as consumer groups that are concerned about equity, accessibility, and affordability among lower-income ratepayers.[6]

Similarly, progressive solar PV policies, implemented to cope with electricity price spikes spawned by the Russia-Ukraine war, are changing the supply-demand paradigm in Europe.[7] At the same time, many European companies have begun to electrify their vehicles in order to meet European Union regulations related to the sale of internal combustion engines after 2035.[8] Together, the effects of these policies and economics-driven customer behaviors are prompting utilities to plan both for an increase in variable loads and an influx of distributed energy resources on their systems.

In addition to the challenges of managing changing supply and demand profiles, digital technology is advancing rapidly, many utilities are finding it hard to keep pace.[9] Lack of digital maturity can increase planning challenges, as teams can be prompted to work with disparate unintegrated systems. This can limit planners' capacity to help address the demands of multiple stakeholders, ranging from executives and boards to regulators and ratepayers. It can also limit their ability to model "what if" scenarios as well as to gain insights from big data and the volumes of information collected daily.

Manual processes and the inability to readily mine data for insights often amplifies the demands placed on planning departments, which in turn can cause leaders to hire more people to do the work or to ask those who are already under strain to do more. Amid an energy transition that often requires greater financial efficiency, a solution may be needed for enhancing the planning capabilities of utilities without unduly expanding headcount or creating retention concerns by placing increasing demands on hard-to-find engineers who are likely already being asked to do a lot.

# Smart planning considerations

Meeting these multi-pronged challenges will likely require utilities to view planning through a new lens, seeing it not as a lengthy strategic exercise with static inputs and outputs but instead as a technology-enabled, responsive and continuous capability that can readily accommodate changing variables. Here are five key considerations for advancing the planning process:

### 1 Connect with stakeholders and understand customers deeply

Rarely can a utility forecast load based on straightforward assumptions. Today, a utility should deeply analyze load data to understand how customers are adopting technology. The energy sector should better leverage customer context provided by millions of meters collecting end use profiles at the hourly level, informing bottom as opposed to top down demand forecasts. It should also work with multiple stakeholders, including governments, policymakers, and customers to understand how electrification strategies and policies could impact its service territory. Broad stakeholder engagement should be the norm to understand how municipal and regional economic development and company and sector electrification initiatives may impact future capacity needs. Ultimately, the aim of utilities to become "customer-centric" should now be fulfilled—understanding an individual customer's current, planned, or potential future energy use, as well as how they value their electric services. Are customers willing to exchange reliability for more affordability or flexibility in their energy use? Such trade-offs should be understood in a way that can help drive tangible operating improvements over time.

### 2 Get real about capability and capacity gaps

Many utilities will likely need to greatly improve their ability to plan capital allocation and execute capital projects. Workforce and contractor limitations can pose significant constraints. Hiring more people may not be a feasible solution given tight talent markets. Instead, utilities may need to leverage technology, such as AI, to enhance productivity of their existing staff while building new capabilities they have not needed before, such as corporate development or collaboration teams. No utility can do it all. Collaboration with third-party entities may become increasingly important to building sufficient capacity, such as working with charging infrastructure providers to enable demand response or with AI technology vendors to enable dynamic, intelligent grid operation.

### 3 Make choices based on facts

Despite the opportunity to support sustainability -related policy, the laws of physics and economics still apply. Energy transition pathways, velocities, and costs can vary across jurisdictions based on resource availability, economic conditions, and system constraints. Consequently, utilities may increasingly need to enhance their planning capabilities—becoming much quicker in simulating the impact of new technologies or policies, and engaging earlier to help better shape outcomes for their customers and service territories. This includes communicating effectively, bringing economic, scientific, and customer-based data-driven facts to the table when working with governments and policymakers so they understand the real costs and feasibility of the solutions they're contemplating.

### 4 Embrace non-wires alternatives

The rate-making environment is becoming more stringent, putting pressure on many utilities to rapidly prove the comparative value of various types of infrastructure solutions.[10] In addition to demonstrating the need for more capacity in a particular area, utilities often have to show they have considered and compared wires solutions and non-wires alternatives. Facing both capital and talent constraints, non-wires alternatives—such as distributed energy resources (DERs), microgrids, batteries, and demand flexibility programs—can offer utilities viable ways to expand their capacity and improve customer service.[11] However, many utilities will likely need to enhance their analytic planning platforms and business-case-building capabilities so they can convey the value of deploying these innovative solutions more transparently in shorter cycles. For this, they may need to adopt new tools, such as simulations and probabilistic modeling.

### 5 Use scenarios and simulations for rapid planning

Many utilities currently plan in five-year cycles. This timeline is likely no longer sufficient in high-growth regions. Things are changing so quickly that some infrastructure additions are out of sync with demand by the time they are built. Utilities may increasingly need to embed this uncertainty into their planning processes by using scenarios and simulations to rapidly model where and when loads may appear. With some forecasts suggesting that load-growth may double by 2050, many planning organizations could benefit from an integrated set of models that can dynamically look at the whole system across multiple scenarios.[12] This set includes:

- **Decarbonization analytics & roadmap explorer (DARE):** A macroeconomic model to show the economic impacts of the energy transition, potential effects upon capital allocation, and how energy prices and affordability may be affected over time.

- **D-TIMES:** An energy system model to assess the interplay of energy sources in an economy. This model enables utility leaders to understand the technology investments needed under different energy-and-sustainability policy objectives and provides detailed energy balances for various sectors such as buildings, transport, agriculture, and advanced computing.

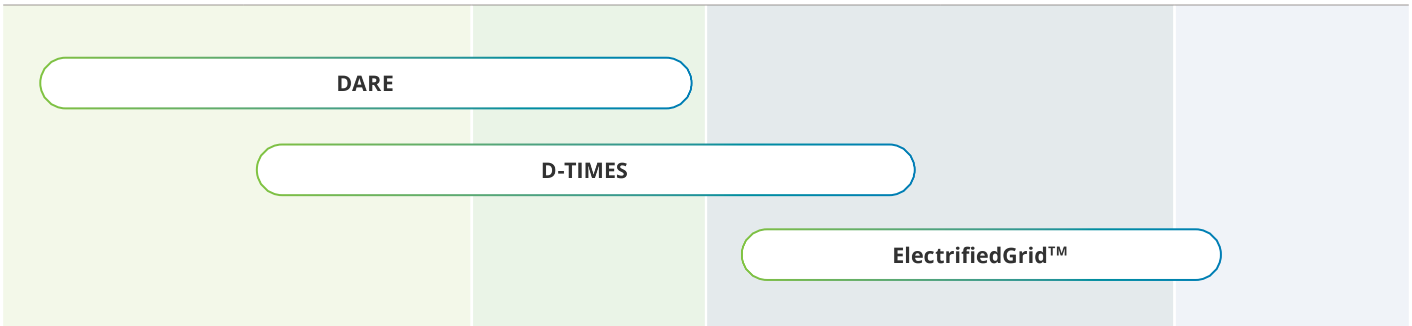
- **ElectrifiedGrid™:** A digital-twin-based system planning model that combines geospatially significant technology adoption and load forecast models to help assess the impacts of emerging electro-technology loads on electricity infrastructure at each position of the value chain.

As an integrated set, these models span multiple levels of the system to help PU&R companies identify and answer important questions related to the energy transition at both the macro and micro levels of energy supply and delivery system(s). Together, they could empower leaders to understand energy markets, forecast trends, and make informed decisions (i.e., policy and response)—and ultimately, to undertake integrated system planning (see figure 1).

Figure 1: Deloitte Global smart energy planning assets

| Macroeconomic & energy markets | | Generation & transmission | Distribution | | Consumption |
|---|---|---|---|---|---|
| **Model descriptions** | | | | | |
| **Macroeconomic modelling** Comparative statics and dynamics of aggregate quantities, equilibrium modelling, demographics and domestic product. | **Energy systems modelling** Multi energy system pathway analysis. Hybrid top-down & bottom-up. | **Bulk system (Generation and transmission) modelling** Nodal electricity, linear asset, power and flow modelling; capacity/congestion analysis. | **Geospatial technology adoption and load modelling** Top-down disaggregation, bottom-up adoption/ propensity modelling. | **Distribution system modelling** Full connectivity, power flow modelling; energy and peak power analysis, supply/demand balancing; integration of asset and customer data sets. | **Corporate & facility-level modelling** Marginal abatement cost curve (MACC) analysis, fleet decarbonization planning, etc. integration of asset and customer data sets. |

**Deloitte smart energy planning assets**




Source: Deloitte Global[13]

# Client story

## Fluvius accelerates net-zero journey with digital twin innovation

### The situation

Fluvius is the primary operator of electricity and gas distribution networks across Flanders in Belgium. Fluvius was created following the merger of an amalgamation of distribution system operators in 2018. The various legacy data systems of the merged entities created challenges with respect to data integrity and fragmentation. Fluvius faced challenges related to aging infrastructure, decreasing reliability, rapid electrification of transportation and heating, growth of distributed energy resources (e.g., rooftop solar panels), and increasing pressure on tariffs. They also faced new regulations in Belgium that restrict multi-utilities from conducting capital works on the same location within five years.

### The impact

Deloitte Belgium delivered a broad set of data-driven asset management solutions to help support the transformation of the Flemish energy network. One of the foundational achievements was the consolidation of grid data from legacy distribution system operators into a unified model, enabling consistent scenario modeling and advanced analytics across the network.

To support reliable system analysis and planning, the team developed broad models that accurately represented the connectivity and operational rules of the amalgamated grid. This enabled the subsequent development of a scalable, cloud-based platform to perform advanced load flow and scenario analysis. Capable of processing millions of scenarios in parallel, it provided insights into transformer and cable loading, voltage variations, and network losses, with robust sensitivity and uncertainty analysis. The impact of these scenarios was visualized in a unified ElectrifiedGrid™ digital twin representing the Fluvius network (i.e., both the electricity and the gas networks). This digital tool enabled spatial analysis of asset risk, maintenance prioritization, and integration of demographic and environmental data.

Driving excellence in asset management, Deloitte Belgium implemented end-to-end asset management solutions, including interactive dashboards, operational maps, export functionalities, and executive reporting, designed to enable transparent, data-driven decision-making and facilitate regulatory engagement.

To help strengthen investment planning, predictive models were developed for asset risk assessment and investment optimization, including financial impact modeling for capacity constraint mitigation. These investment planning tools harmonized risk, performance, and budget considerations across the multi-utility context, minimizing disruption and maximizing synergies.

Finally, the platform enabled transparent data sharing with regulators and other key stakeholders regarding scenario inputs, assumptions, and anticipated grid impacts. This began with Fluvius gathering future belief inputs from stakeholders (e.g., regulators, municipalities, and transmission system operators), including from other utilities. Based on these inputs, Fluvius defined 150+ different scenarios for modeling grid impacts and shared the output analyses with the regulator. This transparency helped Fluvius get alignment on the required capital expenditures to meet future grid needs, helping leaders to secure regulatory approval for their rate case application.

### The solve

- Deloitte Belgium developed a transparent, automated and reproducible risk-based and data-driven investment plan, which supported a ~US$4.7 billion (€4 billion) rate case application increase.
- By enabling the identification of investments in the grid network that could be avoided or deferred, this helped to reduce capital expenditures (CAPEX) by ~US$11.8 million (€10 million) relative to business-as-usual spending over 10 years. Furthermore, it improved the efficiency of analyzing network extensions, reducing operating expenditures (OPEX) by ~50%.
- Finally, the quality of Fluvius' grid data model increased from 60% to >90% of correctly connected circuits, supported by capabilities in detecting and rectifying incorrect switching states, connecting gaps, and geographic information systems (GIS) errors.

# Conclusion

### Scaling the energy transition for both business and social benefit

The energy transition is happening now. Regional and global supply-demand paradigms are changing due to an increase in electricity demand, driven by the proliferation of AI and Generative AI applications, electro-technologies, and sustainability policies coupled with reducing emissions within the existing electric system.[14]

As a result, attention is increasingly centered on the practical task of scaling electric systems to help meet the demands of growing economies. This is where the heavy lifting happens. Transparency requirements such as capacity maps in the European Union are driving utilities toward faster planning cycles and real-time data delivery.[15] But each situation is different. Thus, detailed analyses should be performed and actionable steps should be defined on a case-by-case basis. By leveraging new AI-enabled capabilities such as enhanced integrated modeling, predictive analytics, and digital simulations, utilities can plan system enhancements faster and with more specificity, ultimately helping to scale the energy transition for the benefit of business and society.

# Endnotes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