Energy-Efficient and Resilient Infrastructure: Simulation, Validation, and Installation

Advanced, high-performance computing at the National Renewable Energy Laboratory (NREL) has enabled access to vast data resources with cutting-edge software techniques to understand, design, plan for, and maintain energy-efficient and resilient infrastructure. Thanks to strong partnerships, we have focused much of our efforts on cities and airports, but the technology we have developed will easily translate to seaports, inland ports, military installations, or other complex and large-scale, energy-intensive systems. We can digitally simulate and explore current and future scenarios to make data-driven decisions for optimizing **advanced energy systems, transportation and building operations, infrastructure planning and expansion**, and **battery storage** to guide short- and long-term investments, electrification strategies, and integration of new technologies.

Resilience of advanced energy systems

Energy systems can be vulnerable to risk from natural disasters, cyberattacks, user error, and a changing climate. Planning holistically and implementing technical solutions to anticipate, prepare for, and adapt to changing conditions can strengthen systems to withstand, respond to, and recover rapidly from disruption.

NREL developed an effective methodology for expertly analyzing and providing decision support to federal agencies, states, local and international governments, and other stakeholders to make **advanced energy systems more resilient.**

Increasing efficiencies in transportation and building operations

Long-term planning of **transportation operations, traffic patterns**, **and infrastructure expansion** can be difficult due to the complexity of interacting systems and uncertainty of future landscapes. Through the Athena project, NREL leveraged transportation data, machine learning, statistical modeling, advanced simulation, and modern optimization to build a digital twin operational modeling framework (*below*) for forecasting traffic flow and simulating novel scenarios that can be applied across the installation and expansion of various systems and infrastructures. An extension of this work, the Morpheus project, used similar digital twin technology in its framework to **optimize building operations** through model predictive controls (*top of next page*). The application of advanced and autonomous control has the ability to decrease energy expenditures, costs, and faults for big facilities. Both frameworks allow for a data-driven approach to weighing energy consumption, efficiency, risk, and economics for improved planning and decision-making.

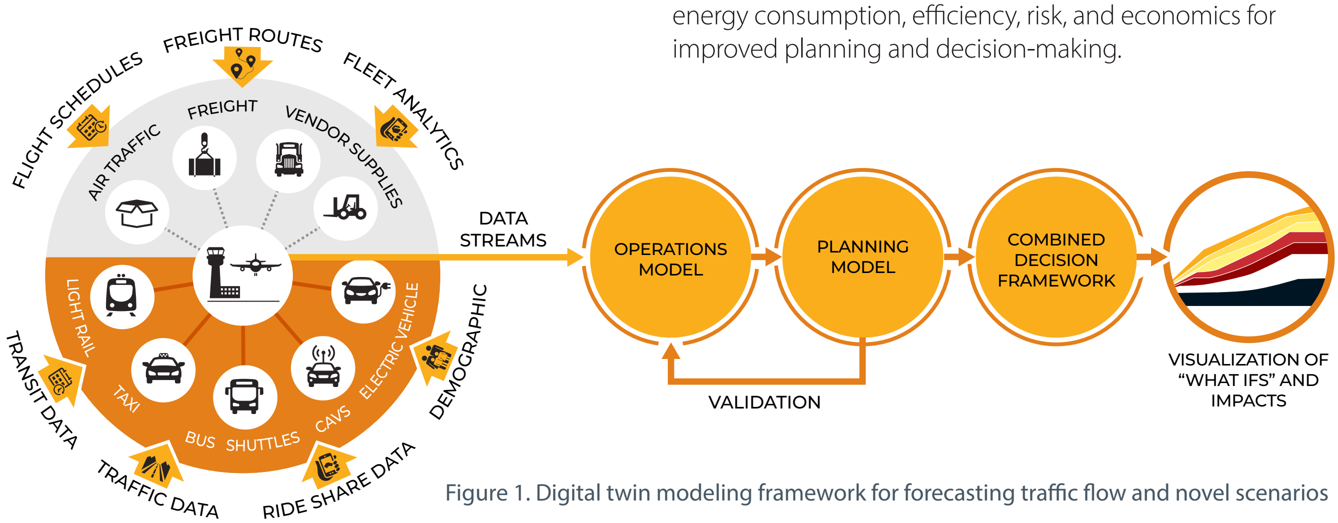

Figure 1. Digital twin modeling framework for forecasting traffic flow and novel scenarios

Developing and evaluating clean energy transition pathways

The City of Los Angeles set a target of reliable, 100% renewable energy by 2035 and engaged NREL to provide rigorous, integrated engineering-economic analysis to inform decisions. Through the LA100 study, NREL developed a framework (*below*) for preparing and evaluating potential pathways to economic growth, energy security, and clean electricity resources. Individual scenarios with the same outcome can be evaluated under different projections of future demands, energy investments, electrification of various infrastructure, customer demand, and economics, revealing possibilities resulting from investment, timing, and other decisions. The possibilities that these scenarios reveal can provide key insights and trends before undertaking **substantial investments in infrastructure**.

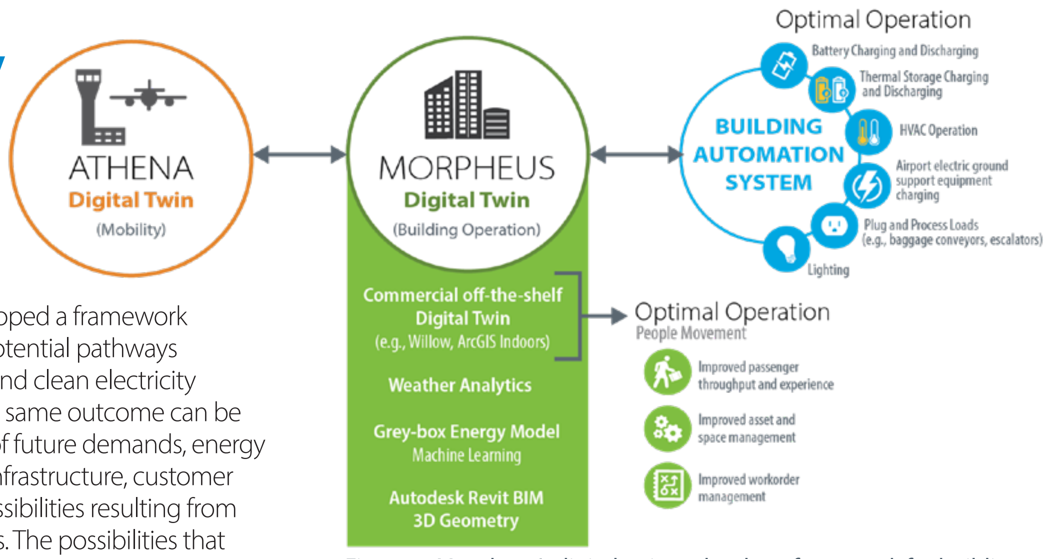

Figure 2. Morpheus's digital twin technology framework for building optimization operations

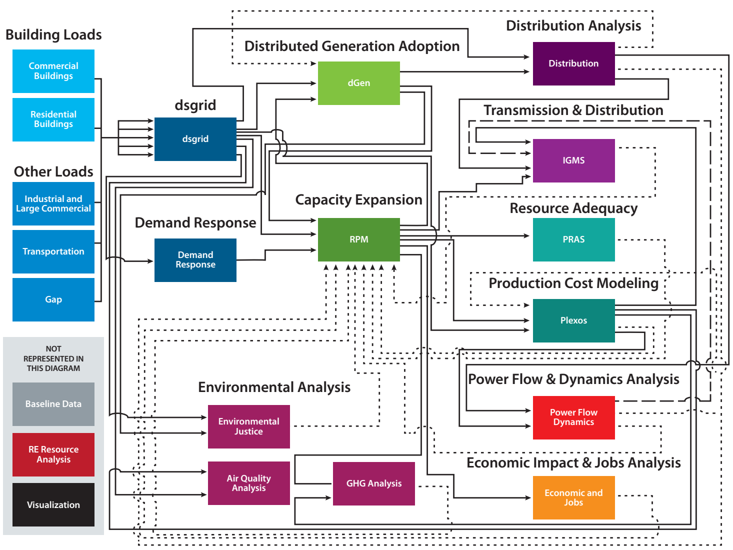

Figure 3. Overview of the LA100 study data flow for potential pathways to energy goals

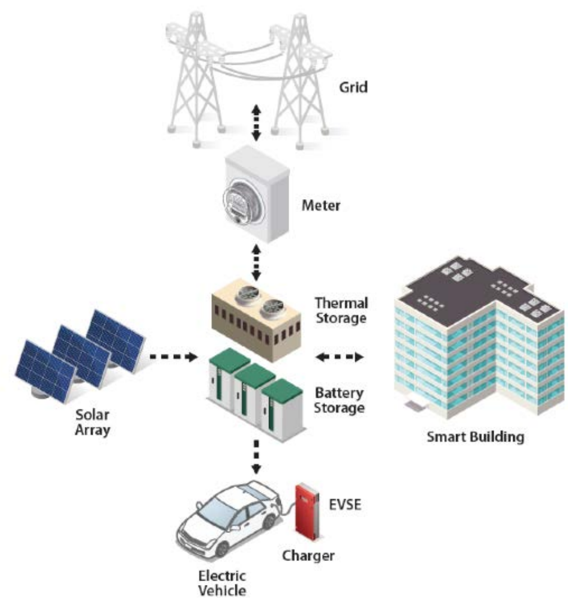

Figure 4. Illustration of the Behind-the-Meter Storage (BTMS) energy flow analysis

Optimizing battery storage for electrification across sectors

Planning for future energy storage can help you manage increasing electrification with little impact to the grid and minimal costs to building owners. The NREL EDGES model, which uses detailed, physics-based calculations and predictive controls, was used in the Behind-the-Meter Storage project to evaluate the potential for system and energy flow design for **thermal and battery storage in buildings**. This approach allows for an analysis of scenarios with varying parameters, creating a demand profile for each scenario, which can inform system design and cost for optimal configurations.

Partner With Us

Let's discuss how we can partner in **capability development, system level impacts, and developed approaches for these applications.**

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