Regional Investment and Operations (RIO) Platform

Energy system planning necessitates looking decades into the future over the lifetime of potential investments being made today. Adding to the inherent challenge is that those decades are almost certain to usher in a dramatic change in how electricity is consumed and produced: from the rapid penetration of low-cost renewables; to the engagement of customers to provide demand-side flexibility to the system; to the deployment of new technologies that provide supporting grid services. Traditional planning methods using production simulation, with an emphasis on detailed, static representations of electricity systems are being supplemented or supplanted by capacity expansion models that can better model the set of interconnected decisions anticipated in that future. However, these tools struggle to effectively model key aspects of future systems, limiting the robustness of their results for system planners and policymakers. The RIO platform can operate as the central platform of a modern planning framework, designed with the specific intent of better capturing the investment and operational dynamics of future systems that will soon be at hand.

Drivers of Modern Electricity System Planning

RIO has been designed to fill the analytical gaps left by other resource planning models when planning systems and evaluating resources in the face of transformational electricity system change. The drivers of the need for reevaluating traditional system planning methods include:

Aggressive Policy. A focus on achieving greenhouse gas targets and other environmental goals is encouraging the deployment of a much broader set of resources, including renewables and traditionally less competitive technologies such as storage, than traditional resource planning exercises ever needed to anticipate. Specific policies like renewable portfolio standards, clean energy standards, cap and trade, and carbon tax policies contribute to dramatic shifts in resource portfolios.

Economics. Even absent supporting policy mechanics, renewables, even with their need to be supported by additional technologies like energy storage, are starting to compete on cost with traditional resources in some localities. Hawaii and Chile are the harbingers of this phenomenon. As prices continue to drop, economics will begin to drive system change, regardless of policy, in increasing numbers of electricity systems around the world.

Demand-Side Awakening. Customer loads have historically been imagined as a static input to resource planning exercises. Planning, in concept, has been applied exclusively to the supply-side of electricity system. However, large marginal price spreads between renewables and conventional generation coupled with technological progress that allows automated and informed customer participation offers the promise of changing that. The economics of self-generation are also becoming more favorable as technology prices decrease. Demand side participation will likely play a far greater role in future least cost electricity systems.

Wide Uncertainty. Uncertainty from policy development, fuel price, technology price, technology availability, exchange rate risk, credit risk, customer participation rates, nuclear future, biofuel availability, implementation challenges, longer planning horizons and many other sources impact the decisions that we make. The uncertainty around many of these factors may be greater than in the past because of new technologies and fuel sources, and longer planning horizons. Decisions we make now about long-lived resources or far reaching policy will be made without knowing how these uncertain factors will manifest themselves over time. Our decisions therefore need to be robust to many future conditions.

Cross-sectoral dependencies. Economy wide carbon targets create dependencies between sectors of the economy that were previously weak or did not exist. The electricity system may be used in the future to produce fuels, either to store energy for later electricity production or to fuel non-electric sectors. Optimal investment planning needs to look more broadly at energy, rather than just electricity consumption, to make sure these important dependencies are not missed.

Each of these on their own represents a significant challenge to traditional modeling and planning paradigms. Taken together, they suggest an entirely new approach is needed. The imperative for such an approach exists even today given that any investment made now competes with a broad set of resource alternatives that may change in value significantly with time and depends on the trajectory of future investment decisions; transformational changes in system conditions raise the specter of asset stranding; and policymakers need to establish the viability of their long-term electricity policies.

RIO Platform Description

RIO blends capacity expansion and detailed sequential hourly system operations to effectively capture the value each resource type can offer the system as part of an optimally dispatched portfolio. Rather than being a snapshot valuation, either as price taker with static prices, or during a single year in time, RIO captures the full set of dynamics over the lifetime of the system or the lifetime of a resource. It is a powerful tool for both planning and asset evaluation applications. Investments that look attractive under current system conditions may not be cost effective over a lifetime of operations. RIO puts every investment into the lifetime context of future policy, fuel pricing, technology pricing, and demand side potential. Without this context, large near-term investments are very risky considering the scale of system change likely to occur over a resource's lifetime. RIO meets the policy goals of each system modeled but is primarily driven by economics. Investment dynamics, such as the tipping point between investing in new thermal or building new renewables, or even generating energy from existing thermal resources or investing in renewables, are easily demonstrated by RIO, and elucidate the dynamics driving value for one resource versus another.

What makes RIO Different?

RIO can be differentiated from other conventional planning tools on three dimensions shown in the figure below.

1. The first is the ability to determine **optimal investment** trajectories in addition to optimal operational strategies. Here, RIO stands out. It can select the least cost path through a rapidly expanding state space of options and accurately capture the operational benefits of new technologies and novel grid solutions. In effect, it can quickly compare every potential investment plan against ever other to decide which is lowest cost. This would be an impossible task using only production simulation. RIO also exceeds the capabilities of conventional capacity expansion because it incorporates optimal investment in long term storage resources, electric fuel production, demand-side resources, and sophisticated retirement/repower of existing generation.
2. The second dimension, **temporal granularity**, is how well the model can capture the timesteps necessary for optimal investment. This is the key metric in systems with high levels of variable generation (wind & solar) where correctly characterizing the various balancing solutions – short duration batteries, long duration storage, electric fuels, demand flexibility, biofuel use – requires high temporal resolution. RIO has the edge on conventional capacity expansion models by allowing linkages between operational snapshots for certain parameters such as storage state-of-

charge. Conventional production simulation has high inter-annual granularity but typically does not model multiple future years.

3. The final dimension, **spatial granularity**, is how well the model can represent the locational aspects of power system operations and planning. Due to the tradeoffs necessary to bring in additional temporal granularity, RIO uses a more limited number of transmission zones to still achieve reasonable run-times (<10). Due to the trade-off between temporal and spatial granularity, the best model for any application will depend on the questions being investigated. Conventional capacity expansion will give a better look at transmission expansion and siting of conventional resources. RIO, on the other hand, is the best for optimal system planning with high levels of wind & solar or very low carbon emissions targets.

RIO Key Features

RIO has been designed with future energy system challenges in mind. Unique features include:

Dynamic day selection. RIO models operations on representative subsets of days in each future modeled year, retaining the detail needed to determine optimal operational and investment decisions while reducing the total runtime of the model. The application of advanced statistical methods allows the platform to curate a statistically representative set of days to analyze hourly system operations. This is different than many capacity expansion models that represent a static set of representative days or time-slices.

Harmonized short-term and long-term electric balancing operations within a single-optimization. This is unique in capacity planning frameworks and critical to a faithful representation of systems with stringent greenhouse gas or renewable targets. Higher renewable penetrations challenge the ability of electricity system planners to balance supply and demand across all time horizons – minute to minute; hour to hour; and season to season, and even interannually. RIO can assess system reliability across all of them by dynamically assessing the capacity contributions of all resources.

Explicit representation of demand-side flexibility. Optimal investment and hourly operations allows for determination of cost-effective flexible load from demand-side assets like electric vehicles and heat pumps. The model can also optimize these assets with explicit feeder-level representations to understand the scale and allocation of the value of flexibility across the distribution and bulk systems.

Alternative fuel production investment. This allows electric fuels like hydrogen and synthetic methane to compete with traditional forms of electric storage. It allows for the optimal deployment of biofuels towards renewable and greenhouse gas emissions targets, as well as competition between electric and non-electric fuel demands, revealing synergies and competitive dynamics across the whole energy economy.

Integrated carbon economy. The model allows for the representation of future economies that capture, transport, utilize, and sequester carbon. This includes technology representations and optimal investments in capture technologies like direct air capture facilities and point-source capture from powerplants, biofuels production, and hydrogen reformation. It includes also includes the utilization of CO2 for methanation and liquid fuels production to displace fossil alternatives. Finally, it includes a spatially explicit carbon sequestration supply curve.

Sophisticated policy accounting. This includes detailed RPS accounting to assess 100% CES policies; tiered REC representation and eligibility binning; specified out-of-state resource emissions contributions; carbon taxes; carbon caps; and renewable fuels policies.

Example RIO Applications

RIO can be applied to a broad set of problems. Examples of these include:
Asset evaluation, including the following 3 approaches:

1. **In & out analysis.** Compare the optimal system cost with and without a particular solution to find its value to the system. This can be used to evaluate specific investments, or as an evaluation of robustness to the availability of a particular technology.
2. **Technology breakeven analysis.** At what price point do technologies become part of a least cost resource solution, and when? This is a powerful tool for asset evaluation, determining the price as which, based on other assumptions about the system, a particular investment becomes competitive. In cases where not all benefit streams are represented in RIO, for example when customers also derive benefit or when there may be specific benefits on the distribution system from deferral of infrastructure, breakeven analysis shows how much these other benefits need to be to justify investment. This is powerful for DER investment modeling, where rather than using static avoided cost streams, RIO can provide breakeven analysis results for each technology that can feed into local portfolio selection processes.

3. **Sensitivity analysis.** Evaluate the sensitivity of investment cost effectiveness to uncertain variables such as competitor pricing, policy changes, fuel prices etc. This type of analysis can be used to build a robust value proposition to take to investors and regulators.

Integrated Resource Planning (IRP). RIO is the ideal tool for least cost resource planning. As part of a comprehensive IRP process, a RIO derived plan could be supplemented with near-term production simulation and powerflow analysis to determine an investment plan.

Benefits of new transmission. RIO could be used for either optimal capacity expansion to identify investment opportunities or used to evaluate transmission build scenarios. The RIO transmission model is a zonal pipe-flow model.

Demand side program valuation. RIO can be used to target least cost investment and operations of demand side technologies. This can be used to guide development of programs, tariffs and policies that get as close as possible to that target.

Pairing with economy wide decarbonization modeling. RIO can produce least cost energy system planning results, given a set of assumptions from economy wide planning models such as EnergyPATHWAYS. This allows for a trade-off and assessment of electricity policies against other clean energy policies. It also allows for a full assessment of sector coupling opportunities between electricity and fuels, heat, and mobility.