Experience with Competitive Procurements and Centralized Resource Planning to Advance Clean Electricity

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Executive Summary

Efforts to decarbonize the electricity sector are changing, and will continue to change, the mix of resources used to generate electricity. As the mix of electric generating resources evolves, existing market structures and planning efforts must evolve in response to accommodate these untraditional resource types, many of which are intermittent. With the urgent task of needing to turn over the existing capacity fleet, market structures must be designed to both encourage and support new investment in clean resources. Some electricity market experts (Joskow 2019; Corneli 2018) have suggested that some type of periodic, centralized, competitive, long-term procurement (operating parallel to current daily short-term markets) could be the best way to accomplish these tasks. In addition, system-wide planning efforts could be necessary to realize these goals of achieving a decarbonized system without compromising system effectiveness. This paper refers to such a procurement process as a long-term market.

Centralized procurements for the purpose of acquiring new clean energy resources, and planning that accommodates these resources, have ample precedents. Existing institutions and mechanisms can provide useful insights and lessons for future market design. The aim of this paper is to review real-world experiences with similar institutions and mechanisms in various settings to glean relevant lessons for future long-term centralized market designs. These experiences include (1) competitive centralized procurement for encouraging clean energy and (2) utility integrated resource planning (including those plans incorporating all-source utility requests for proposals [RFPs]) as it relates to planning for and optimizing grid operations with a high proportion of clean, intermittent resources on the grid. This paper also describes past experiences and associated reviews to inform the future design of long-term procurements of new clean generation based on experiences with procurements and planning within and outside of the United States.

The review of competitive procurements includes the experiences of both states (including New York and Massachusetts) and countries (including Germany, Brazil, South Africa, and Spain). Many of these jurisdictions have long relied on centralized procurement mechanisms for acquiring new clean resources, and several analyses have documented their successes and challenges. While most of these procurements have focused almost exclusively on enabling investment in new renewables, typically as part of implementing a policy agenda, they provide useful insights on effective design of long-term procurement of clean capacity resources more broadly. A summary of the competitive procurement programs discussed in this paper is provided in table format in Appendixes A and B.

This review of recent developments in planning processes to inform associated all-source procurements focuses on the experience of US state regulators and utilities in developing resource planning that improves integration of intermittent renewables, thereby providing useful lessons for centralized markets that seek to ensure successful integration of such resources. In particular, this review focuses on recent experiences in states such as Hawaii, Colorado, and California, which seek to identify the optimal mix of resources needed to balance grid operations and support intermittent resources. Such experiences illustrate the role that planning could play in facilitating efficient long-term markets. Backgrounders explaining the regulatory context of the integrated resource planning approaches discussed in section 3 are covered in Appendixes C, D, and E.

Notably, this literature review simply provides a summary and analysis of existing design features of certain procurements and integrated resource plans (IRPs) and how those have functioned. Where possible, the review highlights how they have succeeded or failed in achieving their intended goals for adding and integrating clean resources. The review does not provide normative analysis for how procurements should be designed to achieve these goals, but rather it provides a reflection on how others have sought to address these challenges.

Overview of Long-Term Procurement Discussion

The review of procurements of new generation from clean resources is divided into four sections representing the stages of procurement: (1) choosing what to procure, (2) design of the bidding process, (3) evaluation of bids, and (4) contract award and implementation.

In section 2.1, we focus on the products procured through existing procurements, such as energy versus environmental attributes, and discuss the arguments for and against each approach. We also discuss how existing procurements have treated different technology types, and we review how some programs have enabled a combination of resources to be bid together.

In section 2.2, we review how existing procurements have designed the bidding process to encourage competitive outcomes while also minimizing risk by requiring certain qualifications for bidders to participate.

Section 2.3 explores the different methods that procurements have used to evaluate bids in order to select the optimal resource mix and achieve certain goals, such as policy priorities or planning criteria.

Finally, section 2.4 focuses on the contract award stage of procurement, with lessons that touch on how to balance ensuring timely project completion with enabling flexibility that projects may need, encouraging financeability of projects, and reducing counterparty risk.

Design choices at each of these stages can affect the outcomes of the procurement (including cost) and the extent to which these outcomes fulfill the intended purpose of the solicitation, such as meeting policy goals or expanding the use of a particular technology or energy product.

Overview of Integrated Resource Planning (IRP) Discussion

The review of IRPs focuses on recent developments in utility and state practices around integrated resource plans and associated all-source RFPs. These examples explore real-world approaches to identifying which resources (generation and complementary) to procure or develop, with a particular emphasis on integrating intermittent resources. The states on which we focus were selected because they are intentionally choosing to procure a high proportion of renewables relative to other sources, which has increased the importance of optimizing resources to reliably balance supply with demand.

We begin with an introduction to integrated resource planning, generally, in Section 3.1. Section 3.2 then examines early decisions in the IRP process, including options for modeling tools, examples of how planning studies are set up, and the inputs used in modeling future resource mixes. Section 3.3 describes some of the ways in which planning is currently evolving to better accommodate resource portfolios that have high penetration of renewable resources. Approaches for estimating the capacity provided by resources in high renewable penetration scenarios, accounting for the increasing importance of modeling that accurately reflects the flexibility of resources and incorporating bid data into planning, are included.

Sections 3.4 and3.5 look at broader topics, including how IRP can be better integrated with other electricity system planning activities and emerging governance issues that IRP efforts face. There has been increased interest in these topics in areas with ambitious clean energy goals.

Integrated resource planning across the United States is currently evolving to better address the changing grid mix, and the recent changes in regions with planned high levels of renewable energy are useful examples. Lessons from their experiences dealing with system-wide operations can help inform the proposals for long-term markets regarding how to confront these anticipated challenges.

Takeaways

Our review of existing competitive procurements globally provides some key takeaways related to procurement design, bidding, bid evaluation, and project realization:

- The type of product and technology chosen in the procurement design stage influence which party bears most of the performance risk and how diverse the portfolio of resources procured will be.
- Various measures can be taken during the bidding process to promote competitive outcomes, but many of these face a trade-off between encouraging competition and reducing contract fulfillment risk.
- Some procurements have demonstrated how the bid evaluation process can be used to advance certain policy goals or give procurements a system-wide review.

- Once winning bidders are selected, contract provisions can be used to mitigate risk associated with contract fulfillment (such as delays or underbuilding) and to reduce counterparty risk.
- Recent developments in integrated resource planning in the United States, particularly in California, Hawaii, and Colorado, similarly provide useful lessons for advancing clean energy:
- Utilities in these states, all of which have aggressive clean energy goals or growing penetration of intermittent renewables, are beginning to alter IRP processes to better plan for a low-carbon energy mix.
- New enhancements include improving planning inputs, such as keeping technology cost information up-to-date, in some cases by using real market bids. Other enhancements include increasing the geographic and temporal granularity of models to better optimize renewables within planning efforts.
- Within the modeling itself, planners are updating their approaches to capture future system needs and better measure the capacity and resource adequacy and balancing contributions of various resources.
- There is interest in better addressing demand-side resources, such as energy efficiency or demand response, of which Hawaii's new integrated grid planning process is a key example.
- There is a desire to strengthen the essential coordination between state regulators and utilities, as well as among load serving entities themselves, for successful decarbonization planning in the electricity sector, as seen in California.
- There is also growing interest in strengthening planning by leveraging bidding data, as seen in market-based IRPs generally. All-source bidding tied to integrated resource planning illustrates efforts to determine needs in a technology-neutral manner to uncover a wider range of solutions, as seen in Colorado.
- Several US states are exploring ways to develop more comprehensive planning that better links transmission planning, distribution planning, optimization of centralized and distributed resources, and other processes.

Contents

1. Introduction

1.1. Objective

Rapid decarbonization of electricity generation is essential to mitigating climate change. The transition to low- and zero-carbon technologies is underway, driven by a combination of policy and market forces. However, stronger federal and state policies are likely necessary to achieve the required speed and scale of the transition in the years ahead. Electricity markets will also have to change to both facilitate the transition and accommodate a new mix of resources.

Given the major turnover in capacity that is needed, market structures that encourage and support new investment in clean generation as well as efficient system operation and reliable electricity supply will be key. Existing capacity markets, such as those operated by eastern US regional transmission organizations, are not well equipped to bring about this transformation, but new forms of long-term centralized markets could evolve to take their place.[1] Indeed, several electricity market experts and other authors (Joskow 2019; Corneli 2018) have suggested that some type of periodic, centralized, competitive, long-term procurement (operating parallel to current daily short-term markets) will be necessary to facilitate investment in the range of resources required for a reliable decarbonized electricity grid in the future. Changes will also be needed to practices that support investment planning and resource procurement in traditional vertically integrated utilities to support investment in an efficient mix of low- and zero-carbon electricity resources.

The development of such long-term markets (i.e., procurements) and planning tools has several precedents. This paper reviews real-world experiences with similar institutions in various settings to glean relevant lessons for future long-term market designs, including (1) competitive centralized procurement for encouraging clean energy and (2) utility integrated resource planning (including all-source utility requests for proposals [RFPs]) as it relates to optimizing grid operations with a high proportion of clean, intermittent resources on the grid. This paper also describes past experiences to inform the future design of long-term procurements of new clean generation based on experiences with procurements and planning within and outside of the United States.

1 As a part of a joint project conducted by researchers from Resources for the Future and the World Resources Institute, four proponents of establishing centralized markets for the long-term procurement of new capacity and associated resources to help support the transition and ensure a reliable electricity supply were invited to develop a long-term market design. The authors, Steven Corneli, Eric Gimon, Brendan Pierpont, and Susan Tierney, had each previously published a vision of how such a centralized long-term market might work. An early draft of this paper was provided to these authors as an input to the further development of their original proposals. The four papers by these authors are available at **https://energyinnovation.org/wp-content/uploads/2019/06/Wholesale-Electricity-Market-Design-For-Rapid-Decarbonization-Long-Term-Markets-Working-WIth-Short-Term-Energy-Markets.pdf and https://www.analysisgroup.com/Insights/publishing/resource-adequacy-and-wholesale-market-structure-for-a-future-low-carbon-power-system-in-california/**.

Section 2 of this paper explores the real-world experiences of procurements for clean energy, while section 3 reviews utility experiences with integrated resource plans (IRPs) and all-source procurements.

The discussion of new generation procurements in section 2 is organized by the stages of procurement. Design choices at each of these stages can influence the outcomes of the procurement (including cost) and the extent to which these outcomes fulfill the intended purpose of the solicitation, such as meeting policy goals or expanding the use of a particular technology or energy product.

In this section, we use the term procurement broadly to refer to the entire process used to acquire long-term contracts. A request for proposal (RFP) that outlines procurement demand, bidding rules, and evaluation criteria is typically the first step in the procurement process that many of these programs use. We use the term auction to refer to the step in a procurement process when resources are selected based on cost. In the few cases in which the term auction does not accurately reflect the resource selection process, we refer to this process more generally as bid evaluation.

Section 3 focuses on lessons from the literature about real-world examples of resource planning and optimization as seen in IRPs and associated all-source RFPs. These examples, drawn largely from Hawaii, Colorado, and California, explore real-world approaches to identifying which resources (generation and complementary) to procure, with a particular emphasis on integrating intermittent resources. The examples included here are intentionally choosing to procure a high proportion of renewables relative to other sources, which has increased the importance of optimizing resources to reliably balance supply with demand. This section explores how the IRP process unfolds, including the overall framing of planning studies, options for and choices of electricity system modeling tools, and new approaches to obtaining modeling inputs, such as incorporating bid data on costs. It also discusses how IRPs might be better integrated with other electricity system planning activities and emerging governance issues, both of which have surfaced as topics of interest in states with ambitious clean energy goals.

Integrated resource planning across the United States is currently evolving to better address the changing grid mix, and the recent changes in regions with planned high levels of renewable energy are useful examples. Lessons from their experiences in dealing with system-wide operations can help inform the proposals for long-term markets regarding how to confront these anticipated challenges.

2. Lessons Learned from Clean Energy Procurements

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Competitive procurements for clean energy within the United States and abroad provide useful lessons for the design of long-term centralized electricity markets. These lessons provide key insights for designing long-term procurements that minimize costs while achieving policy goals, encourage competitive outcomes, mitigate risk, and achieve system-wide efficiency.

Competitive procurements are used in many countries and in US states with the goal of supporting cost-effective investment in new energy generation in accordance with public policy goals. Procurement design varies by country, the type of product procured, and the technologies selected. These design features typically reflect policy priorities of the program in procuring new generation resources. The sections below organize the review of procurement design into four steps: (1) choosing what to procure, (2) design of the bidding process, (3) evaluation of bids, and (4) contract award and implementation. Each section provides examples of lessons learned about procurement design during that particular stage.

2.1. Choosing What to Procure

The first step in procurement design is to choose what to procure (energy, capacity, environmental attributes, or a combination thereof) and to determine whether the clean energy procurement will be technology-neutral (open to bids from all qualifying technologies that meet certain criteria, such as being considered "clean" or low-carbon) or technology-specific (e.g., limited to zero- carbon renewable technologies or a specific technology such as solar). Choices about time frames, such as the length of long-term contracts and lead times to commercial operation, are also important and are discussed further in section 2.4.

The main takeaways from the procurement design choices discussed in this section are that (1) the type of product and the method by which it is procured influence which party bears market risk or performance risk, and (2) resource carve-outs that encourage technological diversity could have grid benefits but come at a cost. In this context, market risk refers to the uncertainty associated with market revenues, while performance risk refers to the uncertainty associated with generation of the resources due to factors such as weather.

2.1.1. Product Procured

Procurements for new clean energy offer long-term contracts for a variety of different products, including energy, capacity, environmental attributes, or some combination of these. Inclusion of related transmission expansion is also an option. Generally speaking, the type of product procured influences which party bears the risks associated with the project's generation and with wholesale markets.

Three state-level renewable procurements in the United States illustrate common types of long-term procurement products and demonstrate the varying levels of involvement and corresponding risk of the government agencies when procuring clean energy generation. The least involved approach, and also likely the least risky for the counterparty, is a competitive procurement for long-term contracts for renewable energy credits (RECs) only and does not include the purchase of energy, capacity, or ancillary services. This is the approach taken in New York, administered by the New York State Energy Research and Development Authority (NYSERDA 2019). Renewable projects in New York that obtain contracts with NYSERDA must therefore sell these other energy products elsewhere, either through a separate bilateral contract or through the wholesale markets directly, and NYSERDA does not bear the market risk associated with selling those other products.

In Massachusetts, participating renewables have the option of submitting long-term contract bids for clean energy and RECs combined, RECs only, or either of those bids packaged with transmission (MA DOER 2017). The proposals do not include capacity, however, and thus developers must participate in the ISO New England operated forward capacity market and earn those revenues separately.

New Jersey's competitive procurement for offshore wind renewable energy credits (ORECs) includes the purchase of energy, capacity, renewable attributes, and ancillary services (NJ BPU 2018). In exchange for the all-inclusive OREC price, winning projects are required to participate in the regional wholesale markets (energy, capacity, and ancillary services markets) and return the market revenues to ratepayers, which provides the offshore wind developers some of the characteristics of a fixed-for-variable financial swap, more commonly referred to as a "contract for differences." This approach therefore transfers the market price risk to state electricity consumers, while guaranteeing winning projects a fixed OREC price per megawatt-hour (MWh) for 20 years. Some states, such as Maryland and New York, also use ORECs as part of their offshore wind procurements, while others, such as Massachusetts, Rhode Island, and Connecticut, purchase the power only through PPAs in their offshore wind procurements. Beiter et al. (2020) argues that both approaches create long-term financial certainty for financing.

A long-term contract for a certain amount of capacity, for which the buyer (counterparty) agrees to purchase all energy delivered from that project, results in the counterparty taking on some performance risk associated with the intermittent resource. This method is commonly used for smaller technology-specific procurements that come from public policy efforts to increase deployment of a particular technology where it may not be necessary to guarantee a certain number of MWh. Examples include the procurements used in Japan for solar photovoltaics (PV) and in Denmark for offshore wind, which procure a limited amount of capacity incrementally but pay a fixed rate per MWh. (Both typically range from about 200 to 600 megawatts [MW] per tender.)

Larger long-term procurements that may rely more heavily on intermittent resources for energy adequacy could require more precision for energy procured through long-term contracts. These contracts are financial agreements in which a developer commits to deliver a certain number of MWh and make up the difference if they fall short (IRENA and CEM 2015). These types of contracts typically include provisions to reduce the risk of system underperformance.

Brazil, which conducts very large auctions for renewables and relies entirely on long-term competitive auctions to procure generation, contracts for energy directly in MWh (Förster and Amazo 2016). Contracts include several stipulations to allocate the risk of underperformance of renewable technologies to the developer rather than the buyer. Wind plants, for example, are capped at how much energy they can offer into the auction given their size, which reduces the risk of underperformance for the energy offtaker (Förster and Amazo 2016). Generators that are awarded long-term contracts through Brazil's auctions for new generation are also subject to underperformance penalties if their annual energy delivery is 10 percent lower than the energy contracted (Hochberg and Poudineh 2018).

2.1.2. Technology-Neutral versus Technology-Specific Procurements

Existing clean energy procurements differ with respect to the breakdown of technology types procured. Some of the existing programs, such as Denmark's offshore wind procurement, focus on a single technology, while others, such as Spain's renewable procurements, are more technology-neutral. Some US utilities have conducted "all-source" procurements that take bids from a broad set of technologies generally not limited to clean resources (covered in more detail in section 3.3.3).

These experiences generally demonstrate that technology bands are seemingly effective at encouraging investment in a certain technology type and in some cases contribute to a reduction in technology costs. However, such technology-specific bands can also increase the costs of a procurement. On the other hand, while more cost-effective in the short term, technology-neutral procurements can result in procurement of only a few select technology types, which may or may not be desirable from a grid operations or policy standpoint.

2.1.2.1. Technology-Neutral

Technology-neutral procurement can lower costs of procuring new generators by enabling lowest-cost technologies to win. Experience with technology-neutral auctions has shown that the lowest-cost technology type typically dominates in these procurements. For example, along with several technology-specific auctions, Germany conducts a technology-neutral auction that allows both solar PV and wind energy to compete, and solar PV has consistently outcompeted wind in the rounds that took place in 2018 and 2019 (Enkhardt 2019), despite separate wind and solar procurements successfully procuring those specific technologies. Similarly, Spain conducted a technology-neutral auction in May 2017 for 3,000 MW, of which 2,900 MW were awarded to onshore wind based on bids (Kruger et al. 2018).

In the United States, Massachusetts conducted a technology-neutral renewables auction in 2017 that awarded 100 percent of the 9,554,940 MWh of clean generation and environmental attributes auctioned to Hydro-Quebec, a hydroelectric power company, despite receiving over 40 bids from various wind, solar, and hydro plants (MA DPU 2019). The hydro contracts were the lowest-cost resources procured and are expected to save ratepayers money (all else equal) over the long term, and hydro is a flexible, clean energy resource that is also expected to serve the commonwealth during the winter months.

While they can lower procurement costs, technology-neutral auctions can also effectively block newer, more expensive technologies from participating, thus forgoing some of the potential future benefits of diversity in resources, particularly renewable ones. As a result, in the long run, technology-specific procurements may be more cost-effective relative to technology-neutral procurements, even if the latter are more cost-effective in the short term (de Mello Santana 2016). The extent to which this is true depends on how the technology-specific tranches of resources are selected and the complementarity across these tranches, as well as the technology's potential for cost reductions from scaling up deployment.

Technology neutrality can also be problematic because it treats all MWh from different sources equally, when in fact different technologies vary in their value to a region. For example, additional solar capacity in a region with an existing high penetration of solar generation is less valuable than a new wind farm, which could increase renewable generation during hours when the sun is not shining.

Experience from these auctions indicates that some renewable technologies are unable to compete against one another in some places on cost alone, particularly when the costs considered are based on the individual plant and do not include system-wide costs. If procurement managers seek a diverse set of resources, this issue can be addressed administratively in many ways, including those methods used by Germany, South Africa, and Brazil through technology-specific procurements. Another way to keep technology neutrality while also ensuring that the system benefits from multiple technologies is to consider both costs and system value rather than costs alone (discussed further in section 2.3.1).

2.1.2.2. Technology-Specific

Some procurements are fairly technology-specific and seek specified quantities of particular technologies with further definition, in some cases, by size categories. Procuring specific technologies can help ensure diversity of renewable energy types, which might have some grid benefits and technological learning benefits that could enable technologies to compete on a level playing field in the future. Another way to obtain some of the system benefits of diversity is through a broader approach to evaluation criteria (discussed in section 2.3).

Especially as the penetration of renewable resources grows, a diverse set of intermittent resources (in terms of both technology type and location) could be increasingly important for balancing grid operations. Different renewables generate during different times of the day and year, and a diverse set of resources can help mitigate some of these fluctuations in generation (locational constraints are discussed in section 2.3).

The extent to which technology bands are more efficient than technology-neutral procurements depends on how much the technology bands reflect the benefits of each technology type of the system overall. In some cases, the technology bands may be set administratively and reflect political considerations rather than grid benefits.

Many of the existing programs include technology-specific capacity requirements within their procurements in order to procure a diverse set of resources. South Africa and Germany are among the programs that allocate specific capacity targets (denoted in MW) within a broader procurement for specific technologies, which allows projects to compete within their technology class.

South Africa's Renewable Energy Independent Power Producer Procurement (REIPPP) program, which began in 2011, allocates auction demand into eight different technology classes: onshore wind, concentrating solar power (CSP), solar PV, biomass, biogas, landfill gas, small hydro (less than 40 MW), and small renewable projects (1–5 MW) (IRENA 2018). Eskom, the offtaker for the long-term renewable contracts, is South Africa's national vertically integrated utility and follows an integrated resource plan (IRP). The allocation of these technology classes is based on the IRP, which allocates most of the auction demand to wind and solar because of their lower costs relative to the other technologies (IRENA 2018). From 2011 to 2015, 48 percent of auction demand was allocated to onshore wind, 36 percent was allocated to solar PV, and the rest was allocated to the remaining technologies (IRENA 2018). Multiple technologies were chosen to avoid procurement of one technology and promote competition among technologies (Eberhard et al. 2014).

Notably, the technology bands are distinguished by project size as well, which is useful for encouraging smaller distributed renewables that may be more expensive than their utility-scale counterparts but are able to offer other grid benefits, such as a reduction in the need for transmission and distribution upgrades.

Germany similarly divides auction demand by technology but has different classes: solar, onshore wind, combined heat and power (CHP) plants, innovative CHP systems, and biomass, as well as one solar and wind combined auction. Germany's technology-specific tenders can also be held at different times. For example, in 2019, six auctions for onshore wind, five for solar, and only two for biomass were held (Bundesnetzagentur 2020). As with South Africa's procurement, solar and wind are allocated the most capacity in the German tenders.

While these countries' procurements have carved-out bands for renewables other than solar and wind, most are quite small. The bulk of Germany's tenders have been allocated and then awarded to solar and wind projects. South Africa's tenders from 2011 through 2015 solicited only 320 MW of bids for biogas and biomass, which is about 3 percent of the total REIPPP demand. Of the 320 MW auctioned, only 84 MW of biomass were awarded contracts because few bids were made for these technologies (IRENA 2018).

Other countries have addressed the issue of technological requirements differently. Spain's renewable procurement replaced its feed-in tariff scheme in 2015, and this serves as a source of supplemental revenue to that provided by the wholesale energy markets for renewable projects that compete for government subsidies for investment remuneration. Rather than submit bids for a specific subsidy value, bidders bid a discount to a standard payment per MW for a reference standard plant, which is intended to capture the amount projects are anticipated to need in government subsidies in order to be profitable (del Río 2017c; Kruger et al. 2018). In the July 2017 auction, which succeeded the May 2017 auction described earlier, auctioneers introduced a technology-specific discount rate ceiling to level the playing field for different technologies, which resulted in a more diverse selection of both wind and solar awards (Kruger et al. 2018).

Brazil takes a different approach to defining the technology-specific tranches in its multitechnology procurement. In Brazil, all renewables compete in one renewables-only auction, but the awards to different technologies depend on the breakdown of bids submitted. For example, if 50 percent of the submitted bids are from wind, then 50 percent of the awardees will be from wind as well (Hochberg and Poudineh 2018). This method enables these renewables to compete with other same-technology projects without being outcompeted by a different lower-cost technology, and then to receive pay-as-bid contract terms. However, similarly to other approaches to creating technology carve-outs, this method could result in higher procurement of a costly technology, depending on the breakdown of the bidding volume and whether many high-cost technologies bid if the carve-outs are set very differently from what the efficient outcome would be without them. Consequently, Brazil has caps in place for solar and biomass in these auctions that prevent the auctions from awarding these renewables above a certain percentage of the total, which would then be awarded to the lowest-cost bidders (Hochberg and Poudineh 2018).

These example procurements demonstrate several approaches for allowing multiple technologies to participate in a procurement and enhancing the opportunities for a diversity of technologies to be selected. However, in many cases the methods used to identify technology bands do not explicitly factor in other criteria that affect the value of the associated renewable generation, such as when the renewable resource is most likely available, potential transmission constraints or bottlenecks, and other locational or siting constraints that could affect project completion. Requiring such additional information to be factored into bids and into the bid evaluation could therefore be important to yield an efficient outcome for the long-term contract procurement. While none of the procurements reviewed here have used additional criteria to set resource-specific tranches, some programs include criteria like these in the resource selection process.

Another option for encouraging multiple technologies to compete without explicitly creating technology bands is to procure different technology product types defined by performance attributes. For example, California's distribution utilities, Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), and Southern California Edison (SCE), conduct large-scale procurement for types of renewable "products," which are separated into three main products that refer to the resource's generation profile: as-available, baseload, and dispatchable. With PG&E, for example, while specific carve-outs are not made for each of these generation types, these resources are evaluated for their "energy benefit," which is the value they provide to system operations (PG&E 2014). As a result, resources that are paired with energy storage, for example, are valued higher than those without.

2.1.3. Combination of Resources Procured

Some of the authors' proposals have suggested that a combination of resources bidding together is practical and efficient for long-term procurements. This design enables procurement managers to take a holistic approach to long-term planning. Some existing procurements, mainly the US state-level renewable procurements, have enabled multiple resources to bid together, such as generating resources with transmission.

The Massachusetts renewable energy auctions allow for "packaged bids" of resources that include transmission investment. If bidders choose to include transmission in their bids, then the transmission bids are submitted as a separate fixed cost-of-service rate and must be approved by the Federal Energy Regulatory Commission (FERC). Bidders are also required by law to protect ratepayers from transmission cost overruns and must include some form of cost containment measures in their bids. The Massachusetts Department of Energy Resources (MA DOER 2017) suggests using cost containment measures such as caps on capital costs or a binding rate structure. When selecting the bids, transmission costs are incorporated into the quantitative evaluation that considers the competitiveness of the bids and the expected transmission costs (and associated benefits, if any).

The New York renewable energy credit (REC) procurement allows joint bids of renewables with energy storage. Evaluation is based on a point system, of which 10 percent of the criteria are related to operational flexibility and peak coincidence. Within this category, projects in certain regions of the state can earn additional points for pairing with energy storage (NYSERDA 2019).

In section 3.3.3 we address examples of IRPs where bid data becomes an input into utility planning and procurement, such as in Colorado and Hawaii, allowing combinations of resources to bid together and be evaluated against specific evaluation criteria.

2.2. Design of the Bidding Process

The rules that govern bidding during this stage in the procurement can influence bidder behavior and auction outcomes accordingly. Procurement managers can adjust bidding rules to encourage competitive and efficient auction outcomes, thus ensuring that the auction fulfills its purpose of procuring clean generation at a low cost. Careful design of an RFP or the equivalent is also critical to achieving the goals of the procurement.

This section reviews five key elements of bid design:

- Volume setting
- Project size requirements
- Ceiling price
- Bidder prequalification requirements
- Pricing construct

Design options such as setting the procurement demand volume to be a function of the supply offered can influence competition of a procurement. Other options, such as prerequisite requirements or completion bonds, can also influence the number of bidders and the level of competition. The examples given here demonstrate that there are typically trade-offs between encouraging participation, and thus competitive outcomes, and mitigating contract performance risk. Prerequisite requirements reduce risk by filtering out risky developers up front and thereby limiting the potential for underbidding and nonperformance, but if they are very strict, they can discourage some likely well-performing participants from bidding, if the requirements are difficult for them to meet, and thus lower competition (IRENA and CEM 2015).

Economic theory tells us that markets are efficient and perform best when they are competitive, meaning that participants bid in a way that accurately reflects their costs and do not have incentives or opportunities to influence the market clearing price. The number of competitors needed in an auction for a competitive market outcome to occur is in some sense dependent on other features of market design, including the rules governing price determination and limits on free entry to the market (both of which are discussed later). But assuming that other features are consistent with free entry for bidders who can make good on their bids and limited incentives or opportunities to game the bidding in the auction, more competitors will typically lead to a more efficient outcome.

2.2.1. Volume Setting

Some countries have used volume setting, or setting the amount of capacity or energy to procure in a market-dependent way, as a method to encourage competitive outcomes. Brazil, for example, uses a downward-sloping demand curve for its renewables auctions, which adjusts auction demand according to a supply-demand ratio; if fewer bids are made during the first round, then the procurement demand is lowered to meet this ratio (Hochberg and Poudineh 2018). This method helps ensure that the volume of bids exceeds the auction's volume, thus enabling competition and avoiding undersubscription, which can lead to higher prices. Another feature of this method is that because the demand curve is downward-sloping, the auction will procure more renewables if they are available for low prices.

South Africa also lowered available capacity in the tenders following the first bidding round that was undersubscribed with the intent of increasing competition, after observing in the first round (2011) that most projects bid close to the price caps because they were aware of the low level of competition (Eberhard et al. 2014). During the next round, which took place in 2012, average bid prices fell by 41 percent for solar PV and 21 percent for onshore wind, due in part to increased competition among bidders after the capacity offered was reduced (with a constant ceiling price) (Eberhard et al. 2014).

However, lowering an auction's volume can also introduce new risks. Nonrealization of selected projects is a risk that most procurements face. Therefore, Kreiss et al. (2017) suggest that the auction volume be set higher than needed to account for some risk of nonrealization.

Notably, volume setting is a tool for procurements that represent a small portion of overall demand for energy or capacity, where the volumes of the product procured can be altered without consequence. In the future, as decarbonization goals become more aggressive and vast procurements of clean energy are needed to meet electricity demand, volume setting will most likely be based on system needs and not be used as a tool for encouraging competitive procurement results.

2.2.2. Project Size Requirements

Similarly to some of the technology bands for small projects discussed earlier, project size requirements have influenced competition in Japan's solar PV auctions. Japan's first three auctions had a minimum project size requirement of 2 MW and were undersubscribed. For the fourth round, the minimum size requirement was reduced to 500 kW for the 300 MW auction. As a result, the fourth round saw a threefold increase in the number of bids, and the average bid price decreased by $13/MWh from the third to the fourth round, conducted in December 2018 and September 2019, respectively. Japan's experience has run counter to the notion that economies of scale are important for reducing costs; in fact, the lowest bidders in the fourth round were the small players (IRENA 2019). One explanation for this result could be that there are simply more small-scale solar projects than large-scale ones, as was evident in Japan's auction, with most bidding projects being under 500 kW. Another is that larger projects (particularly those over 40 MW) are subject to stricter permitting requirements (IRENA 2019). Consequently, particularly for solar, enabling small projects to participate could increase competition and lower prices.

Placing a cap on individual project size can increase the number of projects required to meet total demand and thus encourage many participants and increase competition. Such an approach was used in South Africa's renewable procurements, with capacity caps per project that differed by technology type (e.g., solar PV was 75 MW, while onshore wind was 140 MW) to ensure multiple winners (Eberhard and Naude 2016).

2.2.3. Ceiling Price

Some procurements, such as Japan's solar PV auctions or South Africa's renewable auctions, have included a ceiling price as a cost containment measure, which prevents bids from rising above a certain price threshold. If a ceiling price is in place, no winning bids can be above that price. Ceiling prices can help prevent high prices due to collusion, but if they are set too low, this can discourage bidders with true costs above the ceiling price (IRENA and CEM 2015).

Revealing an auction's ceiling price is a strategy employed by some auctioneers to influence the competition of bids. This strategy can attract bidders and may lead to lower prices, but it may also have the unintended effect of anchoring bids to a certain price and thus enabling bidders to inflate their bids (del Rio 2017b). The latter outcome was seen in South Africa's first renewable auction round, in which the submitted bids were right below the disclosed ceiling price (IRENA 2019).

On the other hand, if ceiling prices are not disclosed, bidders could unwittingly bid above the ceiling price, resulting in no awards. In Japan, for example, the second round of solar PV auctions resulted in no contracts being awarded, because all the bids came in above the undisclosed ceiling price (IRENA 2019).

Brazil's descending clock auction design for renewable procurements purposely discloses a high initial ceiling price to attract many competitive bidders. Before the auction's first round, the auctioneer announces a high price ceiling. In the first round, bidders indicate the quantity they are willing to supply at the declared price, and then the auctioneer continues to lower the ceiling price, causing high-cost bidders to drop out until the supply is equal to a certain volume higher than the auction demand, which is unknown to the bidders. In the second round, the remaining bidders must submit a price that is lower than the ceiling price, and then the lowest winning bidders are awarded pay-as-bid contracts (IRENA and CEM 2015).

2.2.4. Bidder Prequalification Requirements

Bidder requirements influence the number of bidders able to participate in a competitive procurement and can therefore affect the efficiency of the auction outcome. Some nations' experiences have demonstrated that the level of required prerequisites presents a trade-off between competitiveness of the auction and risk of delivery (IRENA and CEM 2015).

Some competitive procurements use a prequalification round to ensure that bidders meet certain eligibility criteria, such as good financial standing or past experience. Denmark, a European leader in offshore wind development, holds a prequalification round for its offshore wind competitive procurement, in which prospective bidders must first qualify for the procurement before they are allowed to submit a bid. The qualifications are determined on a case-by-case basis, but they include proof of financial standing, such as investor guarantees, and past experience with offshore wind development (Kitzing et al. 2015). This method enables procurement administrators to eliminate high-risk bidders before bid selection.

While most procurements include either a prequalification round or some prerequisite requirements for participating in an auction, the strictness of the requirements can vary. One potential downside of having strict requirements could be to limit the number of bidders eligible for the procurement, which could lead to an undersubscribed auction.

Germany's onshore wind auctions require that projects obtain all permits before bidding, but the permitting process for wind projects has become more intensive and time-consuming in recent years (IRENA 2019). As a result, auctions in 2018 and 2019 were undersubscribed, and prices rose from the 2017 auctions (WWEA 2019).

Relaxing some conditions and allowing more bidders to participate can result in more competitive auction outcomes, as was seen in Japan's fourth round of solar PV auctions described earlier, which relaxed requirements on project size. On the other hand, too few requirements can encourage unqualified parties to participate in the auction and increase the risk that winning bidders will not be able to fulfill the contract under awarded prices.

In Spain, renewable energy auctions (just wind and biomass in the first round, and all renewable technologies in subsequent rounds) have had relatively minimal requirements regarding permit status and bid completion bonds; in the first round, bidders were not required to demonstrate any past experience or any secured permits (including land permits) to compete (Kruger et al. 2018). Consequently, the first round was very competitive, and because of Spain's unique auction structure (as described in section 2.1.2.2), it led to all projects bidding aggressively and thus not securing any government subsidies (del Rio 2017a).

Another explanation for the intense competition for Spain's first renewable energy auction is that the auction volume was set very low relative to the volume of bids received. In the first round, which requested 500 MW of wind, over 2,500 MW participated in the auction and 10,000 MW were in the pipeline (del Rio 2017a). This fierce competition may have led to underbidding, where projects bid below their true costs in order to get selected, and perhaps could have been avoided if the volume had been set higher and the likelihood of being selected had been greater. Uniform pricing, as was used in Spain's auction, is more prone to underbidding than a pay-as-bid scheme because it gives bidders more reason to bid below their true costs to increase their chance of clearing the market and earn the higher clearing price (del Rio 2017a).

Penalties for failing to deliver can deter bidders from underbidding if they face sufficient financial risk. Several countries have attempted to prevent underbidding, and ultimately failure to deliver, by imposing penalties on projects that are delayed or unable to build (discussed in section 2.4.1).

2.2.5. Pricing Construct

Most of the procurements discussed here are sealed bid auctions with a single round and award either pay-as-bid or uniform clearing price contract terms. Under a pay-as-bid structure, winning bidders are awarded their bid amounts. Most of the renewable procurements discussed earlier, including Denmark, Germany, and South Africa, as well as Mexico, use pay-as-bid terms. Another design option is to use a uniform clearing price, in which all winning bids receive the same price, as is done in Spain. The price awarded to all bidders is typically the highest of the winning bids necessary to meet the total demand. Note that structuring the reward in that way is less efficient than when a uniform price auction pays the lowest rejected bid to everyone, as in that case no winning bidder has an ability to influence the price, and thus there is no incentive to bid strategically (del Rio 2017b).

Literature on auction theory provides useful insights on the efficiency of pay-as-bid versus uniform pricing. In pay-as-bid auctions, bidders have an incentive to bid higher than their true costs in order to earn a profit if selected (at the risk of lowering their chance of winning), whereas in a uniform pricing scheme in which the price is set at the highest accepted bid (or the lowest rejected bid), bidders have an incentive to bid as low as possible in order to maximize their chance of being selected, with the assumption that a higher bid will be selected and set the price (Haufe and Ehrhart 2018). However, in some situations, uniform pricing can lead to aggressive bidding that is possibly below cost, known as underbidding (discussed in the case of Spain in section 2.1.2.2).

Anatolitis and Welisch (2017) model Germany's onshore wind auction under pay-as-bid and uniform pricing schemes using an agent-based model. The model assumes that bidders under each structure will behave rationally and set their bids accordingly. The study finds that while pay-as-bid auctions have slightly lower costs than uniform pricing auctions, these two pricing constructs do not differ substantially with respect to economic efficiency despite incentives to bid higher under pay-as-bid rules.

The literature on empirical evidence for pay-as-bid versus uniform pricing design for long-term markets of this nature is thin. It is noteworthy, however, that most existing procurements examined here use pay-as-bid structures. Some of the literature discussed in this section suggests that because pay-as-bid may encourage strategic bidding behavior, uniform pricing could be a more efficient alternative (particularly when price is set at the lowest rejected bid). The evidence for that superiority is not strong in these capacity procurement settings, however, and the potential for underbidding is an important consideration.

2.3. Evaluation of Bids

Procurements typically use an array of criteria for evaluating bids, rather than only comparing bid prices. The extent to which certain criteria are included in the resource selection process can have a major influence on which bids are selected.

Some procurements award contracts to the lowest-cost bidders, thus minimizing costs of purchasing electricity relative to other methods, such as a feed-in tariff. Spain's renewables procurement bases resource selection on cost alone (Kruger et al. 2018). More often, program managers value other criteria, such as location on the grid or local economic development, in addition to the bid price. This section reviews how procurement designs account for total costs to the grid and consider contributions to other policy goals.

Application of multiple criteria allows for a more holistic approach to procuring new generation. Including these criteria and evaluation processes can, however, prolong the procurement process relative to a simpler price-based auction (Kreycik et al. 2011). In section 2.2.4, we noted how the design of the bidding process can incorporate requirements for bidder prequalification. These aim to screen out bids that would not be viable. Notably, some procurements use measures of viability in their bid evaluations (e.g., bidder experience).

2.3.1. Accounting for Total Costs to the Grid

Some of the procurements discussed here evaluate projects on the basis of each individual plant's costs levelized over its lifetime, which is referred to as the levelized cost of energy (LCOE). However, the LCOE metric can be a misrepresentation of a plant's true costs because it fails to account for some factors, such as a plant's production profile and intermittency, which can affect the value that the electricity generated by the plant brings to the grid (Joskow 2011). Some studies have explored incorporating system-wide costs into the LCOE calculation or developing alternative measures that reflect the value to the grid of new sources of generation to better compare the costs of different plants (Bartlett 2019).

While they do not use a system-wide levelized cost or value estimate per se, some procurements take a more holistic approach to project evaluation by including criteria beyond the project's direct costs to include considerations for grid costs or factors that affect the value of the energy from a new resource to the grid. These include locational preferences due to transmission constraints or the impacts of a unit's generation profile on total system costs and on other aspects of grid reliability and security.

New generation may rely on existing transmission lines to connect to the grid, which can be problematic if those lines are already congested. Some programs have thus incorporated geographic restrictions into bid selection. Day-ahead and real-time energy markets account for location through locational marginal pricing, which helps address short-term transmission constraints and can provide important signals for investment location. Procurements can address longer-term locational constraints, such as building new generating resources in unconstrained areas or considering transmission system expansion as part of procurement.

Germany has experienced transmission bottlenecks due to high onshore wind development in the northern part of the country (IRENA 2019). To combat this issue, Germany's renewable auctions have implemented several measures in the procurement design to discourage projects from building in congested areas. These measures are particularly important given Germany's practice of socializing congestion costs instead of reflecting them in regional energy price differences.

One method that Germany has employed in its onshore wind auctions to promote geographic diversity of projects and thereby limit transmission congestion is a reference yield model, which adjusts the bid price depending on how a project compares with a reference yield condition for the project's generation. If a project's production would be lower than the reference, its tariff is adjusted upward, and vice versa if the production is higher than the reference. Doing so enables projects to be built in areas with lower wind speeds while competing with other wind projects and helps avoid transmission congestion (IRENA 2019, Kruger et al. 2018). In general, this method is considered to have been successful thus far in Germany for encouraging geographic diversity and avoiding some transmission constraints (IRENA 2019).

Germany's procurement program similarly discourages smaller distributed resources from developing in areas that would require upgrades of the distribution infrastructure. For the joint solar and wind auctions, projects sited in areas that may require distribution upgrades are penalized by requiring an additional premium on their bids, and they are thus less likely to be selected in the auction (IRENA 2019).

Mexico's renewable energy auction similarly incorporates location into the bid selection process. When optimizing bids in each auction, the National Center for Energy Control (CENACE) adjusts bids up or down depending on the interconnection point that generators specify in their bids in order to account for locational differences in supply and demand on the system. However, the adjustment is done only to award-winning bids and does not affect the bid price paid under the pay-as-bid contract terms (Hochberg and Poudineh 2018).

Another key selection criterion used in some procurements, particularly for variable renewable resources, is their production profile. Renewable energy production profiles vary by technology type, location, time of day, and time of year. A higher penetration of intermittent renewables into the grid increases the influence of these factors on balancing load and creates complications for grid operators if production is concentrated in a certain time or place (such as too much solar energy, which produces during the day and most during the summer). Many existing procurements take these performance factors into account when selecting winning resources with an eye toward their implications for system-wide operations in the long run.

In Brazil, a renewable plant's generation profile, given its location and expected seasonal and daily variation, is included in a cost-benefit index that the auctioneers use to rank bids. One of the factors that influences the cost-benefit index is complementarity of the resource with other energy resources, such as wind projects that complement existing hydroelectric resources, for which projects would receive a higher index (IRENA 2019).

New York's RFP released in April 2019 for renewable energy credits based bid selection on a combination of bid price (70 percent) and qualitative evaluation (30 percent). These qualitative criteria include economic benefits to New York (such as in-state jobs), project viability (information on permitting, interconnection, and site control), and operational flexibility. Projects are awarded up to 10 points for operational flexibility and peak coincidence. For this evaluation, projects earn higher evaluation points if the expected production avoids overgeneration during times of low demand in their zone. Projects colocated with energy storage can also earn credit in the evaluation (NYSERDA 2019).

The Massachusetts long-term renewables RFP from 2017 also addresses the differing production profiles of renewables in its evaluation criteria by favoring projects that produce during times when additional generation is most needed. Specifically, New England faces natural gas pipeline constraints when heating and electricity needs are both high. For this reason, projects are evaluated on their ability to enhance system reliability, particularly during winter months.

2.3.2. Contribution to Other Policy Goals

Government agency-run procurements for new generation are typically a result of legislative action and therefore typically include many policy priorities. Most of the procurements discussed here originate from policies that require procurement of renewable electricity (as opposed to an all-source procurement). Another observed policy priority is an emphasis on local economic development, which is included as a resource selection criterion in many of these procurements. Economic growth, including local jobs, can help improve acceptance of new renewables in local communities that may otherwise face opposition to the projects.

One example is South Africa's REIPPPP program, which bases all renewable procurement resource selection decisions on multiple economic development criteria that, in total, account for 30 percent of the bid selection decision, with the remaining 70 percent based on bid price (IRENA 2018).

Some state programs have similarly included economic development criteria in bid selection. Massachusetts's procurement for clean energy generation (energy and associated RECs) evaluates projects on their ability to deliver economic benefits to the commonwealth in the form of local jobs and benefits to low-income ratepayers (MA DOER 2017). New Jersey's offshore wind procurement requires that bidders submit cost-benefit analyses that present their bids as the costs to the state along with the benefits, defined as specific economic benefits such as in-state jobs created, in-state manufacturing, and tax revenues (NJ BPU 2018).[2] In New York, 10 percent (10 points of 100) of the bid's score is based on economic development criteria, which include long-term and short-term economic benefits to the state, both during project construction and after (NYSERDA 2019).

Other procurements use locational preferences to minimize environmental harm from project siting. In Massachusetts, for example, the request for long-term contracts issued in March 2017 uses both quantitative and qualitative criteria to evaluate projects, and the qualitative evaluation gives preference to projects that are sited in already developed areas in order to minimize environmental harm to greenfield locations.

2.4. Contract Award and Implementation

Contracted parties must achieve commercial operation in a timely manner for a procurement to be successful. Procurement managers can impose certain penalties, such as financial penalties or contract cancellation on delayed projects, as a method to mitigate some risk and ensure that contracted projects deliver in a timely manner.

Procurement design must also enable project financing, which is critical for obtaining debt financing and ultimately for successful project completion and delivery. Design elements such as contract term and interaction with wholesale markets can affect the financeability of a project. Another element to consider is how procurements can mitigate counterparty risk, which could similarly affect contract delivery.

2 Political economy considerations like these can create a trade-off between maximizing economic efficiency of procuring lowest-cost resources and pursuing other policy goals.

2.4.1. Delay Penalties

Countries have imposed different lead-time requirements on when winning projects must be commercially operational. In the event that winning bidders do not meet these deadlines, program managers impose various penalties on delayed projects, including withholding of completion bonds and penalties applied to contract terms over the lifetime of the project.

Project completion lead-time requirements vary significantly by procurement. In Brazil, winning renewable projects have from three to six years, depending on the auction, to reach commercial operation (Hochberg and Poudineh 2018). By contrast, Germany requires projects to be built within two years of the procurement before the completion bond is withheld (IRENA and CEM 2015). In South Africa, winning projects are required to start construction within 180 days of the effective date or their contracts are canceled (IRENA 2018). Japan, on the other hand, allowed winning projects in its first solar PV auction to set their own lead times, with some setting them as far as 10 years in the future. As with many design features, trade-offs exist with setting project lead-time requirements: setting deadlines too soon can increase the risk that many projects will drop out, whereas setting them too far in the future could encourage underbidding if bidders assume costs will fall (IRENA 2019).

A common design feature to ensure project completion is a commitment bond, in the form of a bid bond and completion bond. A bid bond must be posted before bidding and is used to ensure that bidders follow through and sign a contract if selected (the bond is returned to losing bidders). A completion bond is required after a contract is signed and is forfeited if a bidder fails to deliver on the project (IRENA 2019). These bonds discourage bidders from bidding below their true costs if they are selected and are unable to fulfill the duties of the contract, since they hold some financial risk. Many countries, such as Brazil, Germany, Japan, and South Africa, require both bid bonds and completion bonds (though these requirements can vary by technology), as do some programs in the United States (where these are often called securities rather than bonds), such as the clean energy procurements in New York and Massachusetts.

While bid bonds can reduce the risk of contracts failing to deliver, they can also be onerous and lead to undersubscribed procurements. For example, Japan's solar PV procurements ran first bidding rounds, which had a lot of initial interest from bidders. However, many bidders that qualified in the first round ended up not submitting bids in the auction because of a combination of permitting struggles and strict requirements on completion bonds (IRENA 2019). A highly priced bid bond can also disadvantage smaller companies in the bidding process, as seen in Brazil's renewable auctions, which have been dominated by a few large companies (Förster and Amazo 2016).

Some procurements penalize delayed or underbuilt projects through contract penalties. In Germany, for example, winning solar PV projects are penalized at 3 euros/MWh for the entire plant's lifetime if the project is delayed more than 18 months after the award. South Africa penalizes underbuilding and terminates contracts that result in less than 50 percent of the original contracted volume being built or if project construction has not begun within 180 days of the contract being awarded.

Past experiences of procurements in Brazil, the United Kingdom, France, and others have had low realization rates of less than 50 percent within the specified realization period (Kreiss et al. 2017). Kreiss et al.'s (2017) analysis of existing procurements in these countries shows that higher bid bonds are positively correlated with higher realization rates but also with higher bid prices, thus representing another trade-off that procurement managers face.

2.4.2. Financeability

Energy projects secure energy financing through debt and equity investors. Typically, these financing agreements depend on stable and low-risk returns from the energy projects that arise from all the different sources of project revenue both within and outside the long-term contract.

Long-term foresight is essential for helping these projects secure financing, and thus procurements that provide projects with certainty into the future are more likely to succeed in procuring new resources.

All the long-term procurement contracts discussed here are for at least 15 years, with most about 20 years in length, which is around the typical length of a power purchase agreement (PPA) and provides long-term certainty to project owners. The contracts also mainly provide a fixed payment rate, some with an escalator, over the contract term.

Many of the factors discussed in earlier sections affect project financeability. For example, the ability of a project to deliver energy to the grid will depend on system constraints and likelihood of curtailment. If a solicitation takes these mitigating factors into account and, as a consequence, selects projects that are more likely to deliver energy as contracted (or to maximize energy production when the contract is for all energy output), this helps improve financeability. As the grid evolves, so too will deliverability risks for particular projects, and a procurement process for subsequent contracts that anticipates these future changes will be more robust to potential adverse effects.

2.4.3. Counterparty Risk Mitigation

Counterparty risk is the possibility that the contract will not be honored as a result of the counterparty's default. This risk could affect energy price, quantity, or both and thereby reduce contract revenue. This issue is a particular concern for technologies such as wind and solar, which have experienced significant declines in capital cost over time. Contracts that were signed 10 years ago, which reflected project costs at that time, are now priced above current wholesale prices. If the counterparty defaults, these projects would have to sell into the wholesale market or contract with a new party at what would likely be significantly lower prices. Contract certainty is also important even for mature technologies that face significant market risk and rely on the contracts to be able to meet their debt obligations. For both of these reasons, the buyer in a procurement must be credit-worthy enough to be able to pay out its obligations under the contract as contractually specified liquidated damages in the event it defaults on the contract itself.

Historically, counterparty risk has been low for contracts with utilities because they serve a captive retail load. However, the certainty of the utility's load has changed as community choice aggregators (CCAs) and competitive retail providers pick off load from utilities, thus potentially affecting the utility's ability to honor contracts. CCAs and competitive retail suppliers tend to be less creditworthy counterparties than utilities because of their less robust balance sheets and relative lack of bonding authority and other means to shore up their creditworthiness (Gramlich and Lacey 2020).

For most of the procurements examined in this paper, the counterparty is typically a government entity that conducts the auctions. In South Africa, for example, winning bidders sign contracts with Eskom, the national utility (IRENA 2018). In some cases, such as those in Massachusetts and Brazil, the procurement manager acts as an intermediary between the energy developers and the utilities, and executed contracts are distributed among the electric utilities (Hochberg and Poudineh 2018; MA DOER 2017). Enabling multiple counterparties to execute contracts with multiple developers can mitigate some risk of both nonperformance and nonpayment (de Araujo et al. 2008). Beyond the concern of counterparty creditworthiness, there is the policy risk that the government would make changes affecting ongoing contracts, as exemplified by retroactive cuts made by Spain to its feed-in tariffs for solar power.

3. Real-World Examples of Resource Planning and Optimization

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In addition to these insights from competitive procurements, further lessons for future market design can be found in the evolution of resource planning and optimization in areas that are already experiencing high levels of variable renewable energy and/or have set ambitious decarbonization goals for their power sectors. Unlike the history of renewable energy procurements, these examples address how to plan for higher amounts of renewable energy alongside future grid needs and resource adequacy.

We begin by reviewing the general IRP process used across the United States today and recent trends. We then look at potential lessons based on various components of the IRP process, drawing generously from the experiences of California, Hawaii, and Colorado. These three states provide strong examples of IRP processes that are evolving to better align planning with clean energy goals by improving the inputs and approaches to the core modeling, balancing long-term visions and near-term actions, optimizing across a broader set of planning activities, and developing transparent processes that stakeholders support.

For all these areas, a form of integrated resource planning is the key process driving planning and influencing future procurements, although we highlight the variations in each area and overlap with other processes. In general, resource planning across the United States, which partly drives procurement, is shaped by the regulatory structure in that region. Table 1 provides a general mapping of these responsibilities. These differences are important when considering the individual circumstances for planning in a state. For example, California's planning is split across more parties as the state overlaps with its regional transmission organization (RTO)[3] and has retained vertically integrated utilities in a partially restructured market. Colorado and Hawaii, on the other hand, have vertically integrated utilities and do not operate within an RTO, leaving the utility full responsibility over planning. These states have recently reformed their planning processes, and we include summaries with more details in Appendixes C–E.

3 There are twelve differences between Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) as defined by FERC in Order No. 2000, though these differences are not substantive enough for the industry to regularly differentiate between the two. The terms are generally used interchangeably and sometimes we just use RTO in this paper for simplicity.

Table 1. Resource Planning under Varying Regulatory Environments

	States located outside of an RTO/ISO	States located within an RTO/ISO	
Planning function	Vertically integrated utility model	Vertically integrated utility model	Restructured utilities
Resource adequacy	Utility	RTO/ISO Utility	RTO/ISO Load-serving entities
Generation planning	Utility	Utility	Competitive generators
Transmission planning	Utility	RTO/ISO	RTO/ISO
Distribution planning	Utility	Utility	Load-serving entities
Public policy goals	Utility State commission	Utility State commission	Load-serving entities State commission
Examples	*HI, CO, NM, AZ, EIM states, southeastern states*	*Most MISO states, SPP states, CA*	*TX, NYISO, PJM states, ISO-NE states*

Source: Adapted from Kahrl et al. 2016.

Note: This table includes the abbreviations of RTOs/ISOs such as the Midcontinent Independent System Operator (MISO), Southwest Power Pool (SPP), New York Independent System Operator (NYISO). ISO-New England (ISO-NE) and PJM Interconnection (PJM) both have legacy acronyms as ISO-NE is no longer an ISO and operates as an RTO. PJM used to be an acronym for Pennsylvania, Jersey, Maryland but no longer represents these states along and covers a much larger territory. Finally, the Western Energy Imbalance Market is often referred to as just the EIM as it is here.

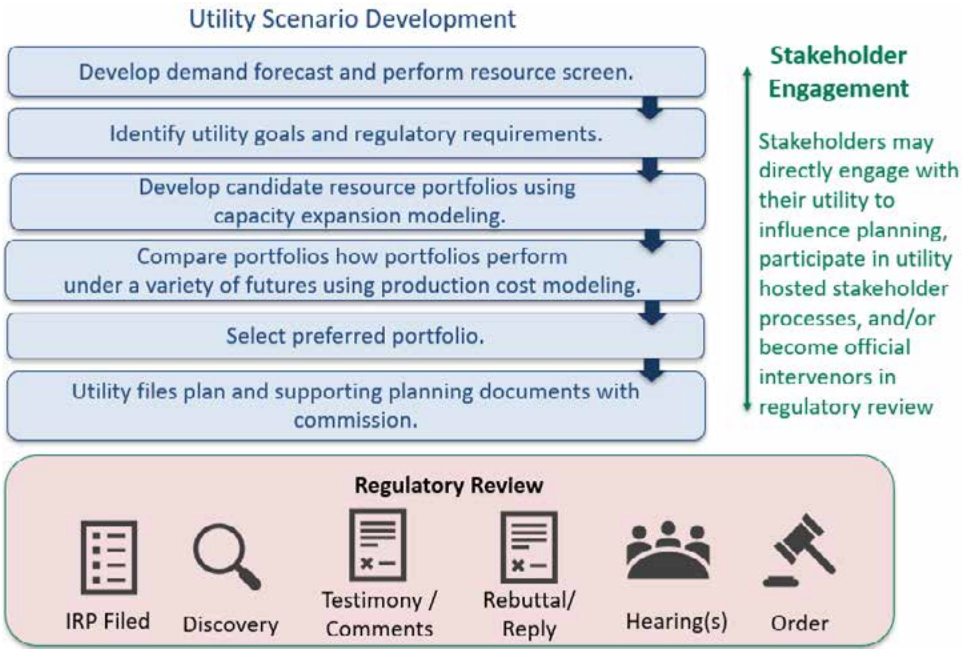
3.1. Introduction to Integrated Resource Planning

Integrated resource plans (IRPs) are developed through structured planning processes used by utilities to articulate a long-term vision for how they will meet future demand. This paper describes IRP examples that highlight how they are evolving to better identify which resources to procure or develop, while maximizing intermittent resources.

Unlike traditional long-term utility planning, IRP requirements are often set at the state level and require examination of demand-side resources (e.g., energy efficiency, demand response) in addition to supply-side resources (new generation or power purchases). Interest in IRPs developed in the 1970s–1980s to encourage utilities to consider a broader range of resources and portfolio strategies to meet future demand. At the time, the industry was facing several challenges still present today, such as excess capacity and slowing demand growth (Kahrl et al. 2016). Regulators also sought a mechanism for balancing the needs of customers and utilities while meeting the targets of new environmental regulations (Kahrl et al. 2016). Minimum levels of stakeholder outreach were sometimes incorporated into IRP requirements to increase transparency and public input into planning. While IRPs are used in 30 states, and 9 more have similar long-term planning requirements, IRPs play a much stronger role in areas served by vertically integrated utilities.

Despite differing approaches across utilities and states, the development of integrated resource plans has tended to follow a common process and modeling approach, as illustrated in Figure 1. Most utilities begin their process by reviewing projected load growth over the planning horizon (typically 10–20 years) and performing a resource screen to identify their existing resources and other potential resources that could be added to meet future need. Around the same time or shortly thereafter, planning includes a review of state-mandated requirements and the utility's own internal goals for the process. To identify possible combinations of resources that could meet future needs, capacity expansion models (CEMs) are used to optimize around key inputs and goals, including state requirements and least-cost solutions. These models produce several candidate portfolios that could meet goals in a variety of ways. Candidate portfolios are compared under various future scenarios, including sensitivities such as different fuel prices and potential carbon policies, using production cost models (PCMs) or stochastic modeling approaches that quantify risk associated with the different resource portfolios. Selection of a "preferred portfolio" takes these results into account but may also include qualitative analysis and consideration of impacts such as job creation, clean energy policy goals, or stakeholder views (Kahrl et al. 2016).

Figure 1. Generic High-Level IRP Process



Source: Ratz and Bird 2020.

Note: This oversimplified version does not include feedback between steps.

While Figure 1 generally maps IRP planning and indicates that CEMs and PCMs are often used, the types of models used by each utility and for what purpose do vary greatly. Also, several different versions of CEMs and PCMs are available from a variety of providers. Some models, such as PowerSimm, WIS:dom, GridPath, or Power System Optimizer, can be used as both a CEM and a PCM. Some utilities do not use both model types, and many utilize PCMs alone. Many models are licensed out to utilities to be used with little customization and are proprietary. Other models have been customized to specific areas and are available with more transparency but less transferability (Desu 2019). Finally, both CEMs and PCMs are available at different scales and can also be adjusted to address regional- or national-level analysis.

Typically, the majority of planning is done by the utility, either internally or with some coordination with other stakeholders. Smaller utilities with less in-house capacity may outsource the IRP process to a consultant to design and manage. Regulatory oversight of this process varies greatly across the United States. In some states, the public utilities commission (PUC) has the authority to deny a plan or order revisions. In other states, the commission is limited to simply acknowledging whether the plan meets state requirements. After selection of the preferred plan, the utility may submit this plan and the underlying analysis to the commission. In states with greater oversight, the plan and analysis may be submitted within an official docket that allows parties to become formal intervenors and submit testimony related to the plan. Finally, many municipal utilities and Generation and Transmission (G&T) cooperatives develop IRPs for board approval, without oversight from their state PUC.

Even if a commission approves a portfolio, IRPs are generally not considered binding. They are more often used to develop a strategy for future resources and are updated every two to five years to reflect changing conditions. Many do, however, include an action plan covering the next one to three years that is more directly tied to near-term procurement decisions. Utilities that propose or make investments that deviate significantly from an improved plan may face regulator scrutiny when looking for related approvals (such as a certificate of public convenience and necessity, or CPCN) or cost recovery within a rate case.

While IRPs have been used for decades, their processes and tools are evolving as regulatory requirements, stakeholder involvement, and utility-led advancements respond to new challenges facing the industry. Rapidly declining costs for renewable resources and for lithium-ion batteries, increasingly distributed resources, and new flexible demand management technologies require grid operators and resource planners to optimize technologies with distinctively different characteristics than in the past. In addition, these technologies interact differently with each other on the grid, requiring planners to update their approaches to managing peak demand, as well as their concepts of baseload power (Chang et al. 2017), flexibility, resource adequacy, and reliability. Finally, the improved optimization of these resources is a critical component in achieving ambitious state and utility goals that target 100 percent clean or renewable energy in the next two decades. Significantly more evolution is needed within resource planning to identify these future portfolios and effectively guide procurement.

3.2. IRP Model Choice, Framing, and Inputs

In recent years, there has been increased focus on ensuring IRP models are equipped to address today's challenges, use inputs that accurately capture state goals, are connected to broad trends outside of the planning horizon and scope, provide up-to-date cost and operational parameters for new resources, examine accelerating retirement of existing resources, and consider the full range of resource options. New forms of long-term centralized markets may also need to rely on sophisticated modeling used for resource planning or decarbonization scenarios. While IRP models are evolving, future IRPs will still need to continue to refine assumptions related to demand-side resources, capacity factors for renewable energy, and renewable energy integration costs.

This section uses examples from Hawaii and California to examine how IRP modeling has evolved to accommodate a changing resource mix and state goals and expectations for the future.

3.2.1. Advanced Capacity Expansion and Production Cost Models

The choice of modeling tools in IRPs affects how renewables are optimized. Many models currently do not include the full range of constraints needed to shape future portfolios (Kahrl et al. 2016). There are also concerns that IRP models used today are not accurately modeling emerging technologies or accounting for future extreme weather (Desu 2019).

Some IRP models are evolving to increase granularity, more accurately capture grid interactions, better address weather impacts, and incorporate needed constraints. We highlight RESOLVE, PLEXOS, and SERVM here as examples from California and Hawaii; however, there are other advanced models, such as WIS:dom (Weather-Informed energy Systems: for design, operations and markets). Currently, the most popular models across IRPs are Aurora, Strategist, System Optimizer, PLEXOS, PROSYM, and EGEAS (Desu 2019).

RESOLVE is a capacity expansion model used in California and Hawaii that is designed to address renewable integration strategies. RESOLVE inputs include greater granularity in wind and solar supply curves, more specific geographic detail on resource availability, and performance characteristics specific to resource type. For example, storage resource characteristics include round-trip efficiency and operating limits.[4] RESOLVE also co-optimizes investment and operational decisions and gears operational detail to focus on primary drivers of renewable integration challenges, including transmission and flexibility. The model optimization constraints include hourly load, California's renewable portfolio standard (RPS) target, planning reserve margin, greenhouse gas (GHG) limits, and ability to develop new resources (Schlag et al. 2016).

California's IRP modeling uses RESOLVE as the capacity expansion model to develop candidate portfolios and SERVM as the production cost model to examine the possible performance of these portfolios under various scenarios. Production cost models simulate portfolio operations with greater temporal granularity to capture costs and reliability impacts. Many use one representative calendar year (Kahrl et al. 2016), while SERVM covers a greater range. SERVM also models commitment and dispatch of resources chronologically to capture startup times, ramp rates, minimum up times, and minimum down times (Wintermantel 2019).

The new integrated grid plan (IGP) process used by Hawaiian Electric Company (HECO) pairs PLEXOS as the production cost model used with RESOLVE. In previous IRPs, including the plan rejected by the Hawaiian Public Utility Commission (HPUC) in 2014, HECO had relied on Strategist. In that proceeding, the commission found that Strategist could not simulate hourly ramp-up-and-down constraints of a high renewable energy portfolio and did not sufficiently address feasibility or costs of system operations and the need for resources to provide ancillary services (HPUC 2014). PLEXOS provides HECO with high granularity production simulation that addresses ramping needs, regulation needs, system curtailment, and unserved energy (HECO 2019).

4 Round-trip efficiency compares the amount of energy a storage resource takes in with releases onto the grid.

While these models can be considered more advanced, planners must continually refine elements of the modeling process to meet changing needs. California has made several recent adjustments that reflect the evolution of planning approaches. In past IRP proceedings, atakeholders had expressed concern that RESOLVE optimizes "primarily supply-side resources, including some DERs such as battery storage and some forms of demand response. Thus, energy efficiency, behind-the-meter PV, and some forms of demand response still must be input as assumed baseline resources that are not further optimized by the model's resource selection algorithm" (CPUC 2018). The California Public Utility Commission (CPUC) responded by including more behind-the-meter resources to be selected by the RESOLVE optimization function. In 2019, RESOLVE modeling also was updated to begin to address retention of dispatchable gas, which would minimize system costs for the California Independent System Operator (CAISO), rather than assuming these resources would be available indefinitely. Several advances have been made to SERVM in recent IRPs, including added precision in assessing the contribution of storage to the grid. SERVM modeling no longer bases storage capacity on assumed discharge time, but makes use of the effective load carrying capability (ELCC) curve (discussed in more detail in section 3.3.1) to quantify the impact a resource has on reliability in relation to the full portfolio of resources on the grid. The challenges facing IRP modeling and recent advances suggest important considerations for centralized procurements that are attempting to minimize system costs based on modeling.

In a recent report from GridLab, Synapse Energy was hired to perform an alternate IRP process for the Duke North Carolina territory, using models that better captured the full value of renewable and distributed energy resources, and was able to arrive at an optimized clean energy scenario that the utility's process would not have been able to model (Wilson et al. 2019). This example highlights efforts to improve modeling in regions that might not yet be experiencing high penetration of renewable energy already.

3.2.2. Integrating State Goals and Use of Framing Studies

A common theme across Hawaii, Colorado, and California, and other states is the realization by PUCs and other state agencies that if IRPs are not framed by state goals, the utilities may be less likely to achieve them. California is a key example, where planning is designed to achieve the state's goals to reduce economy-wide GHG emissions 40 percent from 1990 levels by 2030 and achieve zero-carbon retail sales to customers by 2045. California pursues these goals by setting up initial modeling around these constraints, using state-level assessment of aggregated plans, and supplementing the IRP with additional studies as needed.

While most IRPs are developed at the utility level, California takes a statewide approach. California recently updated its planning process to a two-year cycle that is designed to balance "a system-wide perspective with a consideration of the unique circumstances of each individual LSE [load serving entity]" (CPUC 2018). The process begins in year one, with a round of IRP planning and portfolio selection at the state level conducted by the CPUC.

To integrate carbon constraints, the CPUC works with the California Air Resource Board (CARB) to translate the state's overall carbon goals into expected emissions levels for the electricity sector. The CPUC then uses this input to develop a reference scenario to meet California's GHG planning target through 2030, which becomes the portfolio to guide the load serving entities (LSEs) as they develop their own portfolios in year two. The CPUC also works with CARB to develop a GHG planning price to help LSEs accurately compare the emissions impacts of supply-side and demand-side resources within their portfolios.[5] During year two, individual LSE portfolios are submitted to the CPUC, aggregated into a hybrid system portfolio, and assessed as to whether they will collectively meet state goals. From this assessment, the CPUC issues a preferred system plan to be used to guide procurement moving forward.

In the 2017–18 IRP cycle, the CPUC found significant issues with the individual IRPs submitted by LSEs. The CPUC concluded that they "collectively did not result in a diverse and balanced portfolio of resources needed to ensure a sufficiently reliable or environmentally beneficial statewide electricity resource portfolio" (CPUC 2019a). This process has recently enabled California to identify issues in resource plans across the state and find ways to move toward more effective approaches. (Further details are found in Appendix C.)

Similarly, Hawaii's recent evolution of its IRP process also included several commission reviews of proposed plans' alignment with state goals, with several plans being rejected. HECO's 2013 IRP was rejected because of a lack of analysis that demonstrates "feasibility or accurately determine[s] the cost of incorporating the extensive amounts of variable renewable generation presumed in the final Resource Plan," among other things. Rejection of the power supply plans that followed also cited insufficient analysis "to maximize the lowest-cost renewable resources on each island" (HPUC 2014).

Moving forward, IRP processes may need to be supplemented with additional studies to fully address pathways for states to achieve their ambitious renewable energy goals. The CPUC has supplemented California's IRP planning with additional analysis and framing studies, such as examination of scenarios linked to a California Energy Commission deep decarbonization report that extend out to 2045 or additional studies looking at the longer-term role of natural gas. The CPUC observes that "some near-term decisions may depend on changes to the electricity sector that result from post-2030 economy-wide decarbonization." The 2045 Framing Study included three potential pathways to capture major strategies outside of the IRP decisions: high electrification, high biofuels, and high hydrogen (CPUC 2019e).

3.2.3. Resource Cost and Operational Assumptions

There has been increased interest in ensuring the assumed capital and operating costs used in IRPs are the most current possible, as rapidly changing costs for emerging technologies can result in assumptions that are quickly out of date (Kahrl et al. 2016). Storage costs observed in IRPs, for example, have highlighted knowledge gaps facing

5 A GHG planning price represents the marginal cost of GHG abatement within the reference system portfolio.

utilities in accurately capturing resource costs. A review of IRP inputs found that the range of estimates of lithium-ion battery costs was greater than $1,900 per kilowatt (kW), compared to a range of about $850 per kW for combustion turbine costs (Cooke 2019). Past studies have also found inconsistencies in IRP solar data across plans, as well as uncertainty among utilities about how to project future cost curves (Sterling et al. 2013).

Utilities often rely on engineering cost estimates for resource options from their internal teams, external consultants, or public sources such as the National Renewable Energy Laboratory or Lazard. Regulators have used frequent comprehensive updates to plans, or just partial updates, as one approach for keeping cost data current. As seen in Colorado and Hawaii, another approach is to use market data and bids as inputs in addition to estimated costs. (We discuss approaches to integrating market-based data in greater detail in section 3.4.) Stakeholders have also argued that the need exists for utilities within a region to make use of similar cost inputs and that regionalized planning could be of value.

In addition to better cost assumptions, recent improvements have been made to operational assumptions in IRP modeling. For example, a key advance in RESOLVE's operational model used in California is smart sampling of historical wind and solar data. Capacity expansion models typically model dispatch on the grid using a set of representative weeks (Kahrl et al. 2016), which may not capture the highs and lows of variable resources. RESOLVE uses a smart day-sampling algorithm that identifies 37 representative days and then assigns weights to them so that distributions of hourly load, hourly net load, hourly wind, hourly solar, and daily hydro energy generation match long-run distributions (CPUC 2020a).

Several other planning approaches embedded in IRP analysis may also evolve to better optimize higher levels of renewable energy. Notably, planning around peak demand may no longer be sufficient to ensure an optimized portfolio, especially as grids with a higher penetration of variable renewable energy or distributed energy have different supply and demand curves than those considered in the past. Ultimately, as these new resources replace traditional fossil generation, IRP modeling or related studies could optimize how long to continue drawing from fossil resources and potentially address retirement timelines. These needs relate to approaches to resource adequacy that affect planning requirements.

3.3. Planning Approaches for Integrating Variable Renewables

Once an IRP model has been selected and inputs defined, adjustments can be made within the analysis to better capture the changing nature of grid operations as renewable energy increases, as well as the contributions of potential new resources. The examples from California, Hawaii, and Colorado in sections 3.3.1–3.3.3 show how IRPs are evolving to better plan for grid services such as capacity or flexibility and how market solutions are incorporated into planning.

3.3.1. Determining Capacity Contributions

Increasing penetration of variable resources requires a better understanding of their contributions, in terms of capacity and resource adequacy, to future potential portfolios, as well as the costs they impose on systems. In general, IRP processes have used one of four approaches for establishing the capacity value of resources: rule of thumb, net capacity factor, exceedance probability, or reliability-based calculations (Kahrl et al. 2016). Rule of thumb simply uses capacity contribution values from other IRP plans as acceptable values. Other plans assign a net capacity factor, which is calculated as the resource's output during peak demand hours divided by their total net rated capacity. Plans that make use of exceedance probability calculate the minimum amount of output a resource will provide during a set of peak hours. California, for example, previously used a 70 percent exceedance level approach calculated from select peak hours over three years of historical data. The calculation identified the amount of generation a renewable resource would provide or exceed during 70 percent of those hours and also included a "diversity benefit," which estimated the greater reliability of a diverse portfolio of resources (CAISO 2019).

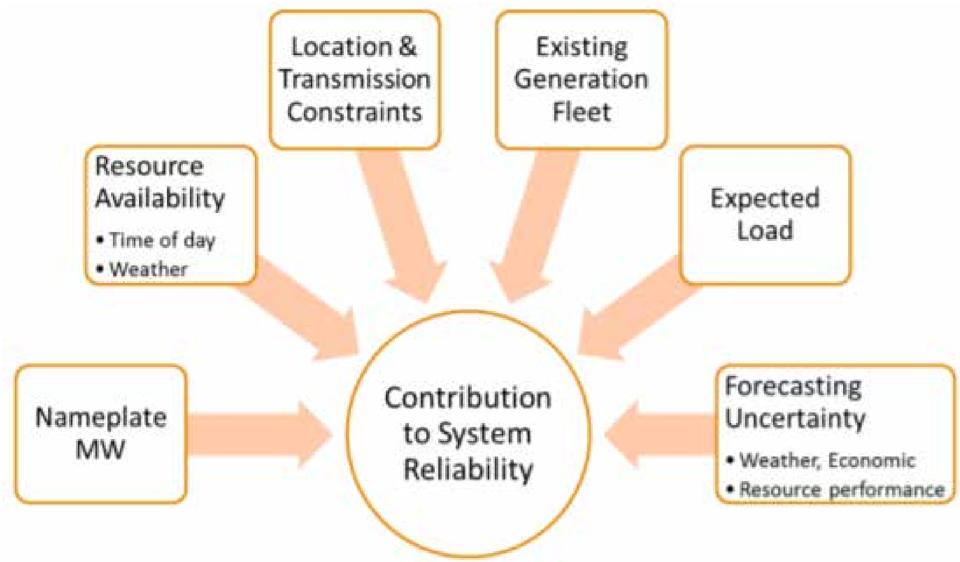
In 2018, California shifted toward the fourth approach, a reliability-based method, in response to the changing characteristics of the state's load profile and resource portfolio. There are a few variations of reliability-based methods, including equivalent conventional power, effective load capacity, and effective load carrying capability (ELCC). California has adopted an ELCC method, which the CPUC calculates, to be used in IRP planning, renewable procurement, and CAISO's resource adequacy planning.[6]

Overall, these methods use Monte Carlo or other stochastic modeling to determine the reliability impacts of either adding or subtracting a resource or set of resources to or from the grid (Madaeni et al. 2012). This approach captures the contributions of a resource in relation to the overall portfolio, which is important as higher penetration of dispatch-limited resources decreases their marginal capacity value. This declining contribution reflects the fact that wind turbines or solar generators will operate at similar times. Integrating storage affects this relationship as well, although storage is also limited in its dispatch availability.

Unlike exceedance probability, which looks at only a subset of hours, ELCC approaches analyze all hours of the day at once and do not optimize around peak demand alone. This shift is important as increased renewable penetration in portfolios, such as California's, faces future loss of load expectation more closely related to system flexibility than peak demand (Chang et al. 2017). In addition, hourly profiles for wind and solar production are based on detailed weather data and account for location and transmission constraints. Figure 2 shows common ELCC inputs.

6 ELCCs can be calculated on both annual and monthly bases. Once ELCCs for broad resource types have been estimated, the process can also drill down further to study more specific resource types, such as fixed-tilt solar versus tracking solar.

Figure 2. ELCC Inputs



Source: CPUC 2014.

Using ELCC, California found that while solar initially provided high capacity value toward peak demand, the capacity contribution was declining and is projected to continue declining through 2030 unless integrated with storage (Sioshansi 2019). Similarly, high penetration of storage resources flattens peak demand, and the need for storage resources that discharge longer than four hours increases. The CPUC has built out ELCC analysis in the most recent IRP cycle to capture this dynamic, as well as the diversity benefits of storage in combination with wind and solar, to better understand how storage can contribute to reliability within a high renewable penetration portfolio (Carden and Wintermantel 2020). Similarly, in the Southwest Power Pool, ELCC analysis has found solar capacity contributions begin in the 60–80 percent range but can fall as low as 15 percent as solar penetration increases (Ferrari 2020).

3.3.2. Modeling Flexibility and Storage Resources

State regulators, utilities, and modelers increasingly consider the need to update IRP processes to better address the growing demand for flexibility on the grid, which is considered key to reaching higher levels of renewable resources (Porter 2015).

Planning is increasingly shifting away from a focus on peak needs to address flexibility required during other times as well.[7] For example, with increasing penetration of variable resources, resources that can rapidly shift demand or balance variability are more important. A recent study in Florida of the Tampa Electric Company's solar resources highlights the importance of increasing focus on operating reserves and modeling approaches. The study used RESOLVE modeling to examine the economic value of using solar more flexibly, such as including dispatch up or down rather than

7 Historically, reliability planning using loss of load expectation was pioneered in the 1940s. It was calculated by hand for peak hours because of computational restraints.

just “must-take.” The study identifies the level of penetration in the system at which “must-take” solar is no longer feasible and finds that allowing flexible operation reduces CO_2 emissions as well as operational costs (Nelson, et. al.2018).

Similarly, HECO’s 2016 Power Supply Improvement Plan (PSIP), developed after the rejection of its 2014 IRP, included expanded analysis of flexibility needed to reach Hawaii’s 100 percent renewable energy goals. The HPUC required HECO’s PSIP to address reduction of must-run generation, increase flexibility, and develop demand response and storage for grid services, among other improvements. The HECO PSIP analysis included additional modeling using Ascend’s PowerSimm modeling tool, which could address costs associated with renewable expansion plans. PowerSimm used stochastic modeling to assess a range of possible trade-offs between cost and risk for each portfolio. It also analyzed needed load shifting accomplished through increased battery storage and sought a balance between storage costs and minimizing renewable curtailment. PowerSimm was also used to examine regulation and ramp statistics related to various portfolio strategies, including 100 percent renewable generation, across both daytime and nighttime (HECO 2016).

One of the key elements of properly evaluating flexibility in future portfolios is ensuring that modeling approaches accurately capture the contributions that storage can provide in future systems and enable considerations of cost versus benefit. Examples such as Hawaii’s PSIP represent advanced analysis, but many of other IRP modeling approaches across the United States need further development. Emerging best practices for integrating storage into IRPs include subhourly modeling intervals to capture both capacity and flexibility contributions (five-minute intervals), net-cost analysis that examines cost of storage net of its flexibility benefits, and models that explicitly address flexibility and risk (ESA 2018). Many models used by utilities today need to be augmented in order to meet these needs (Desu 2019).

3.3.3. Market-Based IRPs and All-Source Procurements

For some states, the use of all-source procurements either as an outcome of their IRPs or as part of their planning processes provides a new mechanism to strengthen the link between solutions the market can provide and what the utility plans to procure. All-source procurement has been defined as a solution where “a utility solicits competitive proposals from companies in the market for plausible ways to address all or part of a resource need, looking across the full range of resource alternatives: power supply, demand-side management, energy storage facilities, and the like” (Henderson 2018, 1. States can require this style of procurement, or a utility may choose to pursue all-source procurement and seek PUC approval to do so. In this section, we highlight how all-source procurement, integrated into planning, can help IRPs better respond to rapidly evolving resources and technologies.

The concept of all-source bidding is not new; it was popular in the 1990s as a better alternative to decisions based solely on avoided cost. Difficulties implementing the Public Utility Regulatory Policies Act, as well as central plant cost overruns and canceled projects, which increased utility interest in minimizing their capital investments, led to competitive bidding (Kahn et al. 1989). While many of the considerations for setting up all-source bidding are aligned with the considerations for the procurements discussed in section 2, we discuss all-source bidding here because of the role of the market in uncovering new resource solutions to inform both the development and implementation of IRPs. In addition, utility all-source bidding can combine both supply-side and demand-side resource bids, unlike technology-neutral procurements that still focus on renewable technologies (Pechman 1993).

California's current IRP process and other planning include all-source requests for offers (RFOs) as a procurement tool after needs are identified. In 2019, CAISO, the California entity responsible for resource adequacy planning, estimated potential capacity shortfalls in Southern California because of constrained natural gas, nuclear retirement, and limited opportunity for increasing out-of-state power imports (St. John 2019). The CPUC issued guidance for load-serving entities to procure needed resources by issuing all-source RFOs that both existing and new resources could respond to. This competition allows old resources to potentially be outbid by new preferred resources, affecting their retirement timelines (Wilson et al. 2020). The CPUC required utilities to set up solicitations to procure their respective portions of the 3.3 GW shortfall (St. John 2019) that treate resources on an even playing field, noting that "resources with different costs and benefits may be evaluated differently, so long as similar attributes are valued similarly," and required that solicitation design include other noncost considerations, such as localized air pollutant impacts in disadvantaged communities (CPUC 2019b). Hybrid projects with solar plus storage, which had not been properly valued in the past, were expected to be better assessed in these solicitations (St. John 2019).

As described earlier, traditional planning has made use of estimated costs as model inputs and optimized on these assumed values. IRP planning that integrates market data collected from these bids into optimization and portfolio selection is sometimes referred to as a market-based IRP (Bade 2018). In Hawaii and Colorado, the use of utility all-source procurements has gone further to source new market solutions and then integrate bid data into IRP processes.

Interest in all-source RFPs has driven examination into how resource planning processes can be paired with bidding to uncover inexpensive and diverse solutions to resource needs. While not every all-source RFP is tied to an IRP, a recent review of best practices highlights examples where utilities' resource planning models can be used to simultaneously evaluate multiple technologies against each other based on actual bids and find an optimal mix of solar, wind, storage, and gas resources, which single-source RFPs cannot do (Wilson et al. 2020).

For example, Colorado's Electric Resource Plan process begins with a round of more traditional planning to highlight needs. In phase 1, the Colorado Public Utility Commission reviews Xcel's analysis and planned RFP materials, and then approves a range of possible need scenarios. In the 2017 cycle, these scenarios included (1) a zero-need scenario, (2) a 450 MW need scenario, (3) a scenario procuring more than 450 MW but providing customer value, and (4) a clean energy plan, which retired two coal plants (Wilson et al. 2020). Phase 2 included an all-source RFP, screening of the bids based on levelized energy cost and other criteria, and then optimizing passing bids using IRP modeling. Xcel identified 11 portfolios using market data while illustrating strategies and need scenarios identified in phase 1. All of these portfolios were examined further using production cost modeling to see how they would perform under various future scenarios. Other notable elements of Xcel's process were clear and transparent bidding requirements and contract terms. Xcel's results and analysis of bids is also captured in a bid report filed within the IRP docket for commission review, providing additional transparency.

Similarly, in Hawaii's new Integrated Grid Planning (IGP) process, resource needs are first identified using theoretical cost data and IRP modeling tools. Rather than creating a preferred portfolio from this analysis, the next step is issuing a public request for information (RFI) on resource-based needs across multiple resource types that developers can respond to. This first RFI will solicit grid resources in categories including "renewable energy, capacity and grid services such as flexible load, fast-frequency response, regulating reserve, ramping capacity, and replacement capacity" (HECO 2018). Information from this RFI uncovers details on transmission and distribution investments needed to integrate new resources, which are made available for all developers. HECO then issues an RFP for proposed resources that now integrates these data. RESOLVE and PLEXOS are used in a second round of optimization, with the market data from the RFP and costs uncovered by the RFI (HECO 2018).

3.4. Comprehensive Planning

Most IRPs take the configuration of the existing transmission and distribution (T&D) systems as given, as T&D planning and resource planning are typically separate. If T&D upgrades are required to integrate some resources, market-based IRPs can better represent those upgrades and their costs when they are included in all-source bidding. Other tools and approaches are still needed to more fully link utility generation planning with broad planning for transmission and distribution, as well as for distributed resources. Interest in exploring new pathways for comprehensive planning is reflected in the Task Force on Comprehensive Electricity Planning recently convened by the National Association of Regulatory Utility Commissioners and the National Association of State Energy Offices. This initiative brings together commissioners and energy directors from 16 different states, including Hawaii, California, and Colorado, to develop approaches for aligning resource and distribution system planning (NARUC 2020).

3.4.1. Integration with Transmission Planning

California has created direct links between its IRP and transmission planning. In year one of the state's IRP process, RESOLVE and SERVM incorporate existing transmission constraints and consider future scenarios with varying transmission costs or availability to assess the impact of these uncertainties on optimal resource investments.

In year two, the CPUC considers how IRP portfolios best inform transmission planning, with the Reference System Portfolio (RSP) and Preferred System Portfolio (PSP) designed to be used as inputs into CAISO's annual transmission planning process (CPUC 2020b). In the 2017–18 cycle, CPUC asked CAISO to develop two sensitivities, one examining transmission buildout to meet large-scale in-state development of renewables and the other with a large amount of wind imported from Wyoming and New Mexico. In the 2019–20 IRP, the CPUC decided the PSP from the previous cycle would serve as the reliability and policy-driven base case in transmission modeling, while the more recent RSP (which examined deeper GHG reductions beyond 2030) would act as the future-looking, policy-driven sensitivity.

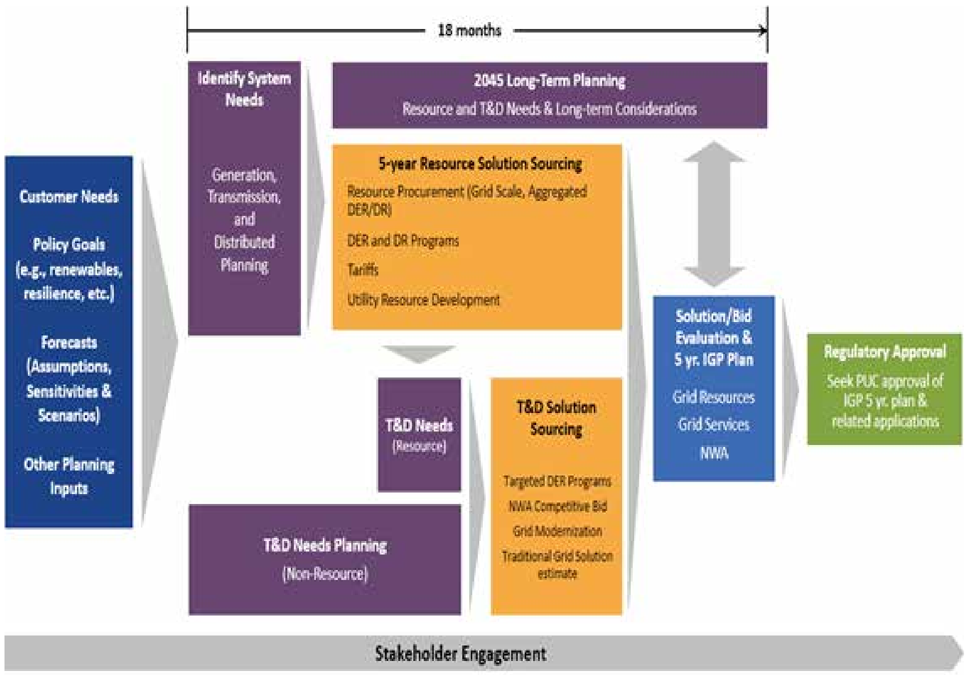
3.4.2. Integration with Distributed Energy Resource (DER) Deployment

Creating greater linkages between utility IRP planning and distributed resources can help utilities better understand the impact of these resources on the systems they operate. Information on distributed resources can be integrated into IRP planning in several ways, such as by adjusting load forecasts. There is also broader interest in linking IRP processes to distribution modeling and planning. A recent paper from the Smart Electric Power Alliance highlights growing interest across states to move from traditional distribution plans, which "focus on assessing the performance of the grid within the context of anticipated changes in load along the system," toward more integrated distribution plans that may include coordinating with generation or transmission planning, as well as taking a more proactive approach to distributed energy resources (DERs). Hawaii is highlighted as a key example, as are California, New York, Minnesota, Rhode Island, and Nevada (Chew and Culter 2020, 10).

HECO's new proposed IGP process, a successor to past IRP and PSIP approaches (explained in Appendix E), provides an advanced example where planning and procurement have merged across generation, distribution, and transmission. HECO first proposed the IGP approach within its most recent grid modernization strategy, highlighting the growing need for integration across activities traditionally captured in resource planning and those traditionally addressed through grid planning. The need for this integration has been more pressing in Hawaii than in other states because of the high penetration of DERs and land use constraints that limit utility-scale renewable or transmission solutions. The HECO approach to DERs is now to actively consider what capacity and grid services DERs provide, plan for these resources alongside other resources, and procure specific energy and services from these resources based on this planning.

The IGP process (see Figure 3) begins with HECO's IRP-style planning making use of RESOLVE, PLEXOS, and PSS/E transmission planning software to determine future resource and grid needs out to 2045 in a technology-neutral manner. We captured the ability of the IGP to seek market solutions to these needs in section 3.3.3. These market solutions inform the short-term, five-year action plan but are also used to project T&D needs and sourcing of DER programs, nonwire alternatives, grid modernization, and traditional grid solutions (HECO 2018). In the final step, data on needs and solutions are optimized using RESOLVE and PLEXOS again to create both the final five-year action plan and a long-term plan. The entire process is designed to take about two and a half years, with the intention of improving the connection between long-term planning and near-term procurement.

Figure 3. Simplified HECO IGP Process



Source: HECO (2020b).

In its early efforts to use customer DERs as grid resources, HECO reformed net metering approaches and established an advanced rate design that features utility controls and price signals to shift DER power export to hours when this power is needed most. To further utility procurement of grid services from DERs, one of the IGP working groups developed a grid services purchase agreement in 2019 that would allow utilities to contract with a customer-owned solar plus storage project for a portfolio of services, including capacity, demand response, frequency regulation, and spinning reserves (Cross-Call 2020). While this innovative approach offers examples of how various types of planning could be integrated, this process may be easier in Hawaii, as HECO is the vertically integrated utility for a small geographic area.

3.5. Governance Issues

While accurate modeling to identify optimal portfolios is key, PUCs have also become interested in better leveraging stakeholder processes and ensuring transparency of methods to encourage continuous refinement of planning approaches and tools. In some of our examples, the need for new independent entities to help guide planning has been suggested as well. Establishing potential new market designs that support new investment in clean generation and efficient system operation may raise issues around the governance of these markets, much as the recent evolution in IRP planning has.

3.5.1. Transparency

A theme common across recent IRP reforms, including those in California and Colorado, has been the need for greater transparency within IRP processes, allowing regulators and other stakeholders to assess the assumptions and methodologies used and understand how the preferred plan was selected.

In HECO's revamping of its IRP process in the development of PSIPs, one of the key factors that led to the eventual acceptance of its 2016 plan was the drastic increase in planning transparency. The utility retained a third-party consultant, which set up an organized planning process and shared vetted planning inputs in real time through its website (Trabish 2016).

Transparency can also help promote stakeholder buy-in. For example, in discussions on how to appropriately set resource adequacy in California, large utilities expressed concern about their inability to re-create CAISO's local capacity requirements and argued for increased insight into assumptions used to enable them to undertake supplemental analysis (CPUC 2018).

As planning processes become more sophisticated, planners must weigh increasing granularity and complex modeling against greater transparency. More analysis is needed to determine the extent to which greater detail in modeling has meaningful impacts on investment and procurement (LBNL 2016). Others have argued that an open-source approach is needed to increase credibility, transparency, and the quality of IRPs, as well as allow researchers and government agencies to make use of cutting-edge planning tools (Desu 2019).

3.5.2. Increased Stakeholder Involvement

A key element of newly reformed IRP processes has been a focus on expanding stakeholder involvement to collect insights and also create important buy-in for the resulting plans. The National Renewable Energy Laboratory has stressed that when modeling large grid areas, stakeholder input is needed across several stages, including scenario design, input assumptions, and model methodologies (Blair et al. 2015). While stakeholder involvement is not new in IRP, there is growing interest from new parties to become stakeholders and from PUCs to integrate their input (Maggiani 2019).

Stakeholder input was also another key element in the acceptance of HECO's PSIP plan. A range of stakeholders, including several government entities (the County of Maui, County of Hawaii and the State Energy Office), intervened in the PSIP docket. HECO's new IGP process includes even more stakeholder involvement from the beginning, with a forecast working group providing input into the model and scenarios. Other working groups have been developed around specific issues in the IGP process. The process also establishes a technical advisory panel of independent system planning experts and a stakeholder council, both of which remain involved throughout the entire process up until regulatory approval. The IGP stakeholder engagement approach also makes use of broader public engagement and individual outreach to specific stakeholders (HECO 2018).

3.5.3. Governance Reforms

Both Hawaii and California provide examples where reforms to the planning process may need to address the changing landscape of market participants. For Hawaii, the changing resource process has altered the way HECO views and engages with customers who own distributed generation. In California, distributed generation is also an important aspect of the grid, but the growth of community choice aggregators (CCAs) represents a somewhat unique challenge. CCAs are altering the resource mix for the customers they serve, but they also affect resource planning responsibilities, which has led regulators to examine more centralized planning and procurement.

One of the biggest challenges facing resource planning in California is managing the large shift in the state's resource mix and assets, coupled with a large migration of load to smaller CCAs. Within the aggregated California portfolio, the CPUC recently found that CCAs drive the majority of new resource buildout. However, overall IRPs submitted by CCAs have been insufficient. For example, many did not indicate clearly whether resources were planned or merely aspirational, making the collective CCA plans difficult to aggregate and unreliable sources of information for the CPUC (CPUC 2019a, 89 and 101). Aligning planning processes with state goals has been challenging, given disaggregated and vague planning information. While California has already moved to a more state-focused IRP that includes assessment across all plans to identify critical needs related to reliability and renewable integration, the state has also examined the need for centralized procurement, potentially by a new entity.

In response to the results of the 2018–19 cycle, the CPUC rejected the Hybrid System Portfolio, proposed an improved PSP, and also opened a procurement track within the IRP to address whether a centralized buyer is needed. This track identified near-term reliability needs and authorized LSEs to procure their portion of capacity, with investor-owned utilities providing backstop procurement if LSEs failed to procure resources themselves or opted out of procuring them. Interestingly, the CPUC's efforts to examine the necessity for centralized procurement within the IRP to meet future needs has developed in parallel with similar discussions related to resource adequacy.

Beginning in 2018, CPUC has considered designating a central procurement entity to resolve complications involved in resource adequacy planning (see Appendix C for more details). The stakeholder discussions surrounding what entity would be best suited to play such a central procurement role, and even whether one is needed, provide useful insights into the value of such an entity in future long-run market designs. Considerations include on the ability of that entity to take on financial costs and risks and to play a neutral role, as well as the significant time needed to establish a new FERC-approved structure. Stakeholders viewed favorably the simplicity and transparency of a market price that would accompany a solution similar to a capacity market, with decentralized buyers and sellers instead of centralized procurement, while noting that such centralized markets could not address targeted procurement for local and sublocal areas or preferred resources. In June 2020, the CPUC moved forward with the centralized procurement model, identifying PG&E and Southern California Edison SCE as the resource adequacy procurement entities (St. John 2020).

4. Conclusions

This paper has summarized and reviewed the experiences of existing procurement programs and utility integrated resource plans that enable decarbonization. The lessons gleaned from these experiences include those related to (1) designing a centralized procurement for clean resources that is competitive and achieves system-wide goals, and (2) planning and optimization techniques for successful integration of intermittent renewable resources.

Key takeaways from section 2, on procurements, include design features to promote certain technology types, ensure competitive outcomes, minimize costs, mitigate risk of contract fulfillment, and incorporate system-wide considerations. Takeaways from section 3 include modeling techniques for integrating renewables with respect to system capacity needs, improving temporal and locational granularity in models, examples of improved coordination between state regulators and utilities for advancing decarbonization, and improving system-wide transmission and distribution planning to successfully integrate clean resources.

This literature review has been descriptive rather than normative and reflects only the experiences of existing procurements and planning efforts in an attempt to provide lessons on their successes and challenges. Information specifically on how centralized procurements should be designed or what utility planning efforts should look like are areas for future research.

5. Glossary

all-source RFP: A request for proposal that does not specify a resource type and allows a wide range of technologies to bid.

Behind-the-meter: Energy resources, including generation and storage, that are connected to a customer's site, behind their meter, so that they augment energy pulled from the grid.

California Independent System Operator (CAISO): The state chartered, nonprofit public benefit corporation that operates the transmission facilities of all participating transmission operators and dispatches certain generating units and loads for California.

certificate of public convenience and necessity (CPCN): In some US industries serving the public good, a CPCN is needed to grant permission for various actions. In the utility industry, a CPCN from the utility commission is required before a utility is authorized to procure or build a new resource.

community choice aggregators (CCA): Community choice aggregation is a program that allows a local government to purchase electricity for its community either directly or from through parties. The local government or third party are then known as community choice aggregators.

effective load carrying capability (ELCC): A measure of the additional load that the system can supply with the particular generator of interest, with no net change in reliability (Milligan and Porter 2008).

Electric Resource Plan (ERP): In Colorado, an IRP-like, two-phase process for planning and procuring resources, performed by the utility every four years.

Federal Energy Regulatory Commission (FERC): An independent regulatory agency within the Department of Energy with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification.

fixed-for-variable swap: A financial arrangement, also known as a contract for differences, used to mitigate market risk in which the developer earns a fixed price for electricity while the counterparty takes on market risk and benefits or losses from market prices above or below the agreed-upon fixed price.

Hybrid Conforming Portfolio (HCP): In the California IRP process, the HCP represents the aggregation of LSE-conforming portfolios with adjustments to fit within the resource potential and transmission availability assumed in the RESOLVE model.

integrated resource plan (IRP): A long-term plan for a utility to meet forecast annual peak load and energy demand, plus a reserve margin, considering both supply-side and demand-side resources.

load serving entity (LSE): In California, utilities, community choice aggregators, and electric service providers that serve load.

market-based IRP: An IRP process that includes market-based data from bids into resource planning and optimization.

power purchase agreement (PPA): A contract with an energy project through which a customer agrees to purchase the energy produced by a generator over a specified period at a predetermined price per unit of energy. They may be physical PPAs, financial PPAs, or other structures.

Power Supply Improvement Plan (PSIP): In Hawaii, a five-year term action plan required by the PUC that outlines how a utility will meet state energy goals.

Preferred System Portfolio (PSP): In the California IRP process, the system portfolio developed by the CPUC in year one to guide LSE IRP development.

production cost model (PCM): In integrated resource planning, a model that captures hourly or subhourly operation of generators during a set period.

Reference System Portfolio (RSP): In the California IRP process, the system portfolio adopted by the CPUC to guide LSE procurement.

renewable energy credit (REC): A credit that represents the clean energy attributes of 1 MWh of renewable electricity, used in voluntary purchases and RPS compliance accounting.

renewable portfolio standard (RPS): A state-legislated mandate requiring utilities to use renewable energy or procure renewable energy credits (RECs) to account for a certain percentage of their retail electricity sales or a certain amount of generating capacity by a certain date.

request for information (RFI): A solicitation process to obtain general information on energy products, services or suppliers with intent of gaining a better understanding of the marketplace.

request for offer (RFO): A solicitation process that requests the submission of offers in response to specifications or a scope of services.

request for proposal (RFP): A solicitation process, often through competitive bidding, to obtain supplier proposals, which typically include price offers to supply energy and other provisions with the intent to contract for procurement.

resource adequacy (RA): A regulatory construct that a region or entity uses to plan for sufficient future resources.

resource screen: An early step within integrated resource planning in which potential resources that modeling could select to meet demand are identified.

stochastic modeling: Unlike deterministic models where outcomes are fully determined by inputs, stochastic modeling includes some random variation.

transmission planning process (TPP): CAISO's annual process to evaluate the transmission grid, identify reliability and efficiency needs, and establish a plan for meeting these needs..

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Appendix A: Country Summary Tables

This appendix summarizes key features of procurement processes in seven countries: Brazil, Denmark, Germany, Japan, Mexico, South Africa, and Spain. For each country, the tables provide a snapshot of the motivation behind procurements, procurement type, history and number of rounds, procurement size, frequency of auctions, number of rounds and payment structure, contract details, and participants. The tables also indicate whether combinations of resources are procured and includes links to websites for additional information.

Country	**Brazil**	**Denmark**	**Germany**
Motivation behind procurements (e.g., policy, planning)	Auctions are used to procure all capacity in Brazil.	Denmark's **goal** is to be 100% clean by 2050.	Energiewende has the goal of 80% renewables by 2050.
Procurement type	**Technology-neutral with restrictions for new renewables:** All renewable technologies accepted, but awards are given proportionally by the technologies that bid with effective caps for solar and biomass. In Brazil, all energy is contracted through auctions, including existing resources. Planning determines the types of resources and capacity auctioned.	**Technology-specific offshore wind auctions.** Separate auction for nearshore systems. Auction for ancillary services (can be multiple resources bidding together, such as wind and storage).	**Multiple technology-specific** auctions with one combined solar and onshore wind auction.
History and number of rounds	Auctions became the only method of procuring capacity in 2004.	Introduced in 2004, and there were 7 rounds between 2004 and 2016.	First started with solar-only auctions in 2014, then moved to all renewables in 2016.
History and number of rounds	Auctions became the only method of procuring capacity in 2004.	Introduced in 2004, and there were 7 rounds between 2004 and 2016.	First started with solar-only auctions in 2014, then moved to all renewables in 2016.

Country	Brazil	Denmark	Germany
Procurement size	Procurements are used to contract for all forecast load, which is determined based on demand function (with a suitable supply-demand ratio that is adjusted by availability of supply). Specific MW requirements are given for renewables.	Typically about 200–600 MW, varying by auction.	Typically 100–700 MW, depending on the technology.
Frequency of auctions	Typically 3 to 4 auctions per year.	Auctions are held once every few years, with auctions in 2005, 2006, 2008, 2010, and 2015.	Load-serving entities
Number of rounds and payment structure	Multiround descending clock auction with pay-as-bid terms.	Public auctions, some with a prequalification round. More recent offshore auctions have been single-round public auctions with no prequalification round. Sealed, pay-as-bid auctions with no price cap.	Single-round with prequalification requirements, pay-as-bid payment for most, uniform clearing price for citizen projects.
Contract details	30-year pay-as-bid PPA for energy-only for large hydro, 20 years for small hydro, solar, wind, and biomass. Brazil's new renewables auction (A-3) requires that the projects be commercially operational within 3 years.	12- to 15-year contract for electricity with pay-as-bid terms.	20-year PPA for a pay-as-bid contract for differences from the electricity spot market. However, citizen projects (those done by electric co-ops) are paid a uniform clearing price.
Participants	Multiple bidders win. Offtake is distributed proportionally by load among the utilities.	One bidder is awarded the whole tender for offshore. The offtaker is the Danish Energy Agency.	Multiple bidders and awardees, one offtaker (Bundesnetzagentur).

Country	Brazil	Denmark	Germany
Combination of resources?	No	Yes for ancillary services	No
Links	**Oxford**	**University of Denmark**, **IRENA**, **EEG**	**German Government**, **IRENA**, **EEG**

Country	Japan	Mexico	South Africa	Spain
Motivation behind procurements (e.g., policy, planning)	Unknown.	Renewable portfolio standard of 50% by 2050.	REIPPP was used to develop renewable energy and introduce more independent power producers in the monopoly Eskom. South Africa was also facing capacity constraints.	Switch from feed-in tariffs to auctions to meet renewable targets.
Procurement type	**Technology-specific solar PV only.**	**Technology-neutral renewable-only auctions** for energy and capacity, and long-term energy auctions for clean energy certificates.	**Multiple technology-specific auctions,** except for the small renewables auction, which is technology-neutral.	First round had technology-specific requirements (onshore wind and biomass), but subsequent rounds are **technology-neutral,** with specific bidding requirements for different technologies to level the playing field.
History and number of rounds	Established in 2017, with 4 rounds so far.	Auctions were introduced in 2013 and are run once per year since 2015.	The REIPPP program started in 2011 and has completed 4 bidding rounds in 2011–15.	Auctions were introduced in 2015, and 3 rounds have been conducted thus far.

Country	Japan	Mexico	South Africa	Spain
Procurement size	First auction was for up to 500 MW, with awards of 140–200 MW. Originally restricted to 2 MW and above for first 3 auctions, but later reduced to 500 kW for round 4.	The size is set based on the volume of the offtaker purchase bids.	Varied by technology. Highest procurements for wind and PV (average over 500 MW awarded in each bidding round), and lowest for biomass (50–200 MW in each bid).	Round 1: 700 MW (500 MW wind, 200 MW biomass). Round 2: 3,000 MW. Round 3: 3,000 MW. So far, 8,373 MW have been procured. The third auction ended up procuring over 5,000 MW.
Number of rounds and payment structure	Single round with prequalification requirements.	Single round with prequalification requirements, pay-as-bid terms.	Single round with prequalification requirements, pay-as-bid terms.	Single round with prequalification requirements, uniform clearing price.
Contract Details	20-year fixed PPA.	15 year pay-as-bid PPA for energy and capacity,	The REIPPP program started in 2011 and has completed 4 bidding rounds in 2011–15.	Auctions were introduced in 2015, and 3 rounds have been conducted thus far.
Participants	20-year contracts for clean energy certificates.	20-year PPA that increases with inflation (indexed to South African Consumer Price Index).	20 year contract for wind and solar PV, 25 years for biomass.	Multiple bidders and one offtaker.
Combination of resources?	No	No	No	No
Links to websites	**IRENA**, **IEA**, **DLA Piper**	**Harvard**, **Oxford**	**IRENA Sub-Saharan Africa**	**EEG**

Appendix B: State Experiences

This appendix summarizes key features of procurement processes in three US states: New Jersey, Massachusetts, and New York. For each state, the table provides a snapshot of the motivation behind procurements, procurement type, history and number of rounds, procurement size, frequency of auctions, delivery year, contract details, participants, and contract prices awarded. The table also indicates whether combinations of technologies are procured.

State	**New Jersey**	**Massachusetts (large-scale procurements)**	**New York (large-scale renewables)**
Motivation behind procurements (e.g., policy, planning)	State goal of 7,500 MW of offshore wind by 2035 from Executive Order No. 92.	An Act Relative to Energy Diversity (2016).	Governor Cuomo's Green New Deal, requiring 70% renewable by 2030.
Procurement type	Technology-specific **offshore wind procurement** for offshore wind renewable energy certificates (ORECs). Bids can include transmission.	**Technology-specific: 83C contracts** for offshore wind only. **Technology-neutral: 83D contracts** for solar, on-shore wind, and hydro renewable energy credits (RECs) only. These bids can be either hydro only, Class I renewables only (wind or solar), or a combination of hydro and Class I resources, with or without transmission project.	**Technology-neutral procurement** for renewable energy credits only (does not include energy, capacity, or ancillary services). However, there is a limit on any one technology being awarded more than 80% of the winning portfolio. There are also tranches for size, and each tranche is required to have some MWh of energy storage.
Procurement size	1100 MW in 2018. 1,200 MW in 2020 and 2022.	First 83D solicitation from 2017: 9,450,000 MWh of energy and/or RECs. First 83C solicitation from 2017: 1,600 MW of offshore wind by June 30, 2027.	**2017**: 1,380 MW procured (mix of solar, wind, and hydro). **2018**: 1,364 MW procured and 25 MW of utility-scale storage.

State	New Jersey	Massachusetts (large-scale procurements)	New York (large-scale renewables)
Frequency of auctions	Every two years.	83D: Not specified 83C: Every two years. Subsequent auctions must have a lower price than previous auctions. Each auction is for 400 MW but will allow for up to 800 MW.	Thus far, once every year.
Delivery year	Not specified.	83D: Contract year 2022, with preference given to projects able to deliver by 2020. 83C: Contract year 2027.	About 5 years out (2017 awards expected to be online by 2022).
Contract details	Qualified projects secure 20-year fixed OREC contracts (pay-as-bid), which includes all-in costs of the projects minus any other subsidies. In exchange, the project must return any revenues from PJM wholesale markets to ratepayers. ORECs are based on generation per MWh (pay-for-performance). The quantity of MWh that the project can sell is specified in the bid. The OREC price can either be fixed for all 20 years or escalate at a fixed rate over the 20 years (but no high upfront payment).	First 83D solicitation from 2017: 9,450,000 MWh of energy and/or RECs. First 83C solicitation from 2017: 1,600 MW of offshore wind by June 30, 2027.	2017: 1,380 MW procured (mix of solar, wind, and hydro). 2018: 1,364 MW procured and 25 MW of utility-scale storage.

State	New Jersey	Massachusetts (large-scale procurements)	New York (large-scale renewables)
Participants	Multiple bidders allowed (minimum offer size of 300 MW), but only one bidder chosen for the first round. Winners then sell ORECs to electric distribution companies. However, procurement is carried out by the BPU and is a fixed price.	83D: Multiple bidders (minimum bid size of 20 MW), but only one selected for 100% hydro with transmission. The 3 investor-owned utilities each enter into a contract at the same price, but for apportioned quantities of their share of the total. 83C: Few bidders (3 in first auction), one selected. DOER selects winners, but distribution companies responsible for negotiating final contracts.	Multiple bidders, NYSERDA one offtaker.
Contract prices awarded	**$98.10/MWh**, but since projects must return all revenues from wholesale markets to ratepayers, the real cost is estimated to be $46.46/MWh.	83D: levelized cost of **5.9 cents/ kWh** ($59/MWh), estimated to save ratepayers money over the contract term. 83C: undisclosed, but said to be lower than the ceiling price of $**84.23/MWh**.	2017: weighted average of $21.71/REC. 2018: weighted average cost of $18.52/ REC.
Combination of technologies	Yes, transmission can be included in bids.	Yes, transmission can be included in bids.	Yes, energy systems colocated with storage are eligible for additional points.

Appendix C: California Backgrounder: Integrated Resource Planning and Resource Adequacy

Integrated Resource Planning

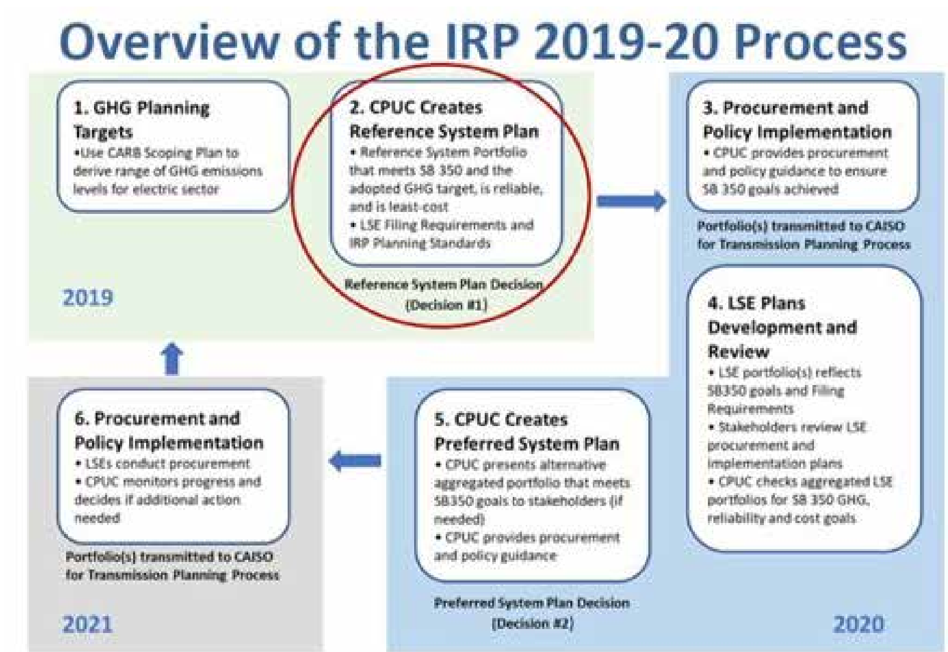
California's clean energy goals are set by Senate Bill (S.B.) 350, which in 2015 established a GHG reduction goal of 40 percent below 1990 levels by 2030 and 80 percent below 1990 levels by 2050.[8] In addition, the 2018 S.B. 100 requires 100 percent of retail electric sales to customers to be zero carbon by 2045.[9] As of January 2020, approximately 30 percent of California's net electricity generation comes from nonhydro renewable resources (EIA 2020).

In California, the CPUC has been granted significant authority over resource planning and procurement to meet clean energy goals. In 2015, S.B. 350 updated 399.13 of the Public Utilities Code to allow the CPUC to require, review, and adopt utility procurement plans that select least-cost and best-fit eligible renewable energy resources to meet California's RPS. S.B. 350 and Public Utilities Codes 454.51 and 454.52 provide additional detail on the establishment of integrated resource planning to "identify a diverse and balanced portfolio of resources … that provides optimal integration of renewable energy in a cost-effective manner." Commission Decision (D.18-02-018) in February 2018 further established a two-year process for IRP development that included state-level planning and would include authorization of procurement over the next one to three years (CPUC 2018). California's two-year process for developing IRPs, which incorporates a state-level assessment of goals and review of aggregated LSE plans, was proposed in 2017, tested in the 2017–18 cycle, and first implemented for the 2019–20 cycle, which is described in Figure 4 (Walton 2019).

8 Clean Energy and Pollution Reduction Act of 2015, S.B. 350, California State Legislature (2015–16).

9 California Renewables Portfolio Standard Program: Emissions of Greenhouse Gases, S.B. 100, California State Legislature (2017–18).

Figure 4. Overview of California's Two-Year Planning Cycle



Source: CPUC 2019d.

In California's two-year IRP process, a large portion of early modeling occurs at the state level, covering the CAISO balancing area. Using GHG emissions targets from CARB developed to meet S.B. 350 targets and demand forecasting from the California Energy Commission's Integrated Energy Policy Report, the CPUC develops a Proposed Reference Scenario Portfolio to guide the IRP plans developed by California's LSEs using a capacity expansion model (RESOLVE) and production cost model (SERVM) in parallel.[10] (In other states, candidate portfolios are developed exclusively by utilities and focus on their own service territories.) This state reference portfolio is developed in year one of the process, and in year two, LSEs develop individual candidate portfolios that reflect the reference portfolio and any justifiable alternatives. In addition to the reference scenario, the CPUC provides LSEs with a GHG planning price to guide consistent assessment of GHG reductions across both supply and demand resources.

The RESOLVE model is designed to compare various strategies for large-scale renewable integration and is used in the IRP to select new resource portfolios that meet policy goals reliably at least cost.[11] RESOLVE co-optimizes investment and dispatch within the planning territory over the planning horizon, incorporating optimization of dispatch outside of the planning region as needed. Modeling starts with a review of existing resources and then chooses from candidate resources,

10 California's LSEs include investor-owned utilities, community choice aggregators, publicly owned utilities, co-ops, and retail electric providers. The previous resource planning process, long term procurement planning, applied only to investor-owned utilities.

11 RESOLVE: Renewable Energy Solutions Model, **https://www.ethree.com/tools/re-solve-renewable-energy-solutions-model/**.

including demand side, behind-the-meter PV, behind-the-meter batteries, and load shed demand response, to be optimized into future portfolios. RESOLVE selects resources for candidate portfolios based on fixed and variable costs and also considers system benefits: hourly energy and reserve value, contribution to clean energy goals, resource adequacy, and local capacity requirements (CPUC 2019d). SERVM is a probabilistic system reliability planning and production cost model used in California's IRP to validate reliability, operability, and emissions of resource portfolios. It does so by modeling the hourly economic unit commitment and dispatch for one year of a candidate portfolio over several future sensitivities, including subhourly balancing, ancillary service provision, and unit constraints.

In year two of the California IRP processes, the LSEs develop their individual IRPs and portfolios that conform to the Reference System Portfolio or alternative portfolios that deviate from it. The LSEs' preferred portfolios, conforming or alternative, are then aggregated by the CPUC into the Hybrid System Portfolio, which is evaluated to see if it is aligned with California policy goals. In the last step, the CPUC finalizes the Preferred System Portfolio to guide procurement and policy. From here, LSEs are able to move forward with program-specific procurements and issue all-source requests for offers.

In 2017–18, the CPUC found significant issues with the individual IRPs submitted by LSEs. The CPUC concluded that when aggregated into the Hybrid System Portfolio, they "collectively did not result in a diverse and balanced portfolio of resources needed to ensure a sufficiently reliable or environmentally beneficial statewide electricity resource portfolio" (CPUC 2019a).

Through the 2017–18 IRP process overall, several trends were identified. Market participants reported tightening of the bilateral market, and the CPUC has noted a decline in the robustness of competitive solicitations, reducing potential supply. With natural gas resources expected to retire in 2020, the CPUC warned that the state could become overly reliant on out-of-state imports (Walton 2019). The Hybrid System Portfolio highlighted that while CCAs drove the majority of new resource buildout, overall the IRPs they submitted were not useful to regulators, as they were unclear on whether resources were planned or aspirational and were also difficult to aggregate (CPUC 2019a, 89 and 101).

Resource Adequacy

Resource adequacy (RA) requirements for utilities in California are determined by the CPUC in partnership with CAISO, as specified by Public Utility Code Section 380(a)). This statute connects the resource adequacy requirements with the CPUC responsibility to ensure "reliability of electrical service in California while advancing, to the extent possible, the state's goals for clean energy, reducing air pollution, and reducing emissions of greenhouse gases." The CPUC has set up RA requirements as a compliance program that uses bilateral contracts and obligates resources with RA contracts to offer bids into one or more CAISO markets.[12]

12 RA Program Orientation Slides

The CPUC's RA program sets three different types of requirements (system, local, and flexible) for which the LSE is required to procure sufficient resources three years in advance. System requirements are based on the California Energy Commission's 1-in-2 monthly load forecast, plus a 15 percent planning reserve margin.[13] System requirements are also split into maximum cumulative capacity buckets, defined by resource availability and meant to ensure LSEs do not rely heavily on resources with run-time limitations (CPUC 2019c). Local RA requirements are calculated based on the CAISO's annual local capacity requirement studies. Since 2015, RA also includes flexible capacity needs, which represent the quantity of resources needed by the CAISO to manage grid reliability during the greatest three-hour continuous ramp in each month.

In Rulemaking 17-09-020, Decision Adopting Local Capacity Obligations for 2019 and Refining the Resource Adequacy Program, the CPUC began to consider what reforms to the resource adequacy program could overcome current challenges. The recent growth of CCAs has led to load migration not captured in the year-ahead RA process, creating deficiencies in RA that are shifted to investor-owned utilities. The CPUC has cited challenges in cost-effective and efficient coordinated procurement and equitable cost allocation. At the same time, the CPUC also highlighted the growing need to balance procurement of local preferred resources with the retention of state jurisdiction over preferred resources.

13 The 1-in-2 peak estimate is the estimate of peak load with a 1 in 2 probability that the peak will actually be higher than the estimate. The 1-in-10 peak estimate is the estimate of peak load with a 1 in 10 probability that the peak will actually be higher than the estimate.

Appendix D: Colorado Backgrounder: Xcel Energy Electric Resource Planning and All-Source RFP

In 2010, HB10-1001 increased Colorado's Renewable Energy Standards to 30 percent renewable energy by 2030 (CEO 2020). Xcel Energy recently announced ambitious goals to reduce carbon emissions 80 percent by 2030 with renewable and carbon-free energy and 100 percent by 2050, compared with 2005 levels (Xcel 2020). Xcel's Colorado Energy Plan specifically targets 55 percent renewable energy by 2026 and carbon reductions of 60 percent from 2005 levels. This plan will retire 660 MW of coal-fired generation early and will not include future natural gas investments. As of 2017, Xcel's Colorado territories have been served by 23 percent wind and 3 percent solar resources (PSCo 2018).

Colorado's IRP process produces Electric Resource Plans (ERPs), which the Colorado Public Utility Commission has authority to accept or deny. A proceeding is currently underway at the commission to update the ERP rules to align utility planning with climate goals and increase the connection to transmission and distribution planning (Wilson et al. 2020). The current ERP process is organized into two phases: one year of IRP-style planning, followed by a little over a year for all-source RFP and similarly a little over year for the commission to grant approval of purchases through a certificate of public convenience and necessity (CPCN).

In phase 1 of planning, the utility determines its future needs based on load forecasts and reserve margin, available resources, carbon costs, and the findings of separate studies on demand-side resources (Wilson et al. 2020). This phase uses capacity expansion and production cost modeling but does not result in a preferred portfolio of resources. Instead the commission approved several scenarios for which the utility may issue an RFP to seek solutions. This is different from other IRPs, where the commission typically approves a future portfolio with set MW amounts of specific resource types. In phase 1, the commission also reviews the utility's "model contracts, modeling assumptions that will be used to conduct the all-source RFP bid evaluation, the process by which transmission costs are factored in to bids, the surplus capacity credit (how to handle bids that aren't perfectly matched to need), backfilling (how to compare bids of various length) and other procurement policy matters" (Wilson et al. 2020).

Phase 2 moves more fully away from planning to procurement with the development of an all-source RFP. Xcel established bidding for intermittent, dispatchable, and semi-dispatchable resources that would all pass an "all-in" levelized energy cost screen, and then specific screening criteria for bids within each category. Selected bids would then be included in the system planning model analysis. Using these market data and IRP planning models, Xcel selects portfolios and tests them across sensitivities. After a preferred portfolio is selected and approved by the commission, Xcel can translate this directly into contract negotiations. A recent review of Colorado's process concluded that it demonstrated “how utility regulators can proactively ensure that resource procurement follows from utility planning.” It also noted that the infusion of market-based insight was able to influence the resources selected in phase 2, which differed from those targeted in the first round of traditional IRP planning (Wilson et al. 2020).

Appendix E: Hawaii Backgrounder: Commission “Inclinations” and HECO Integrated Grid Planning and Planning Reforms

In 2015, H.B. 623 established a renewable energy goal of 30 percent by 2020 and 100 percent by 2045 for Hawaii utilities.[14] For HECO, the state’s largest utility, 28 percent of electricity sales are provided by renewable energy, with almost 50 percent of these resources coming from customer-sited projects (EIA 2020b and HECO 2020a).

The HPUC has authority to approve or reject utility IRPs and near-term actions plans, as well as to monitor analysis and implementation to ensure they meet customer needs and state energy goals while maintaining reliability. Hawaii’s current IRP process has been under a lengthy reform process that began in 2011, when the HPUC proposed reforming integrated resource planning into a more comprehensive process. The HPUC noted that HECO’s capital plans seemed unaligned with the challenges facing the utility, lacked strategy, and lacked long-term value (HPUC 2013). In 2014, the HPUC rejected HECO’s IRP on the grounds that planning had not improved. The HPUC also stated that modeling had not accurately addressed the feasibility or cost of incorporating the high amounts of variable renewable energy targeted in the final resource plans and action plans. Parties also claimed HECO’s IRP lacked transparency in plan development and selection. Within the order rejecting HECO’s plan, the HPUC included Exhibit A: Commission’s Inclinations on the Future of Hawaii’s Electric Utilities, which outlined a vision for Hawaii that included high levels of low-cost, utility-scale solar supported by grid flexibility investments, retirement of inefficient plants, increased visibility into economic dispatch, and utilization of transparent competitive bidding for procurement. It also noted the need for modern transmission and distribution, as well as regulatory reforms to the utility role and business model (HPUC 2014).

Following the failed IRP, the HPUC required HECO to develop PSIPs for its affiliate utilities, intended to provide a near-term action plan and long-term analysis on how the utility would achieve Hawaii’s renewable energy goals. By the third round, HECO’s PSIPs were approved based on their advanced analysis, integration of stakeholder input, and increased transparency (HPUC 2017). In the subsequent grid modernization plan outlining how HECO would upgrade the grid to enable a high renewable energy future, the utility proposed building out the approaches and tools used for the previous PSIP into an IGP (HECO 2017).

HECO’s new IGP process (Figure 5) uses advanced modeling and was designed to better incorporate market data into planning. RESOLVE is used as a capacity expansion model, and PLEXOS is used for production cost modeling for initial analysis, with cost assumptions as inputs. Together with transmission modeling, the IGP identifies both

14 Relating to Renewable Standards, H.B. 623, 28th Hawaii State Leg. (2015).

grid resources and grid services needed. Grid needs are defined in a technology-neutral manner and are used to solicit market data through RFIs. Data is also collected on what potential land use needs may arise. Based on these data, transmission or distribution needs are assessed and included in RFPs. (Nonwire alternatives are allowed in bids.) The RFP responses provide additional data that account for project size and location, grid integration costs, and project innovation.

Figure 5. HECO's IGP Process

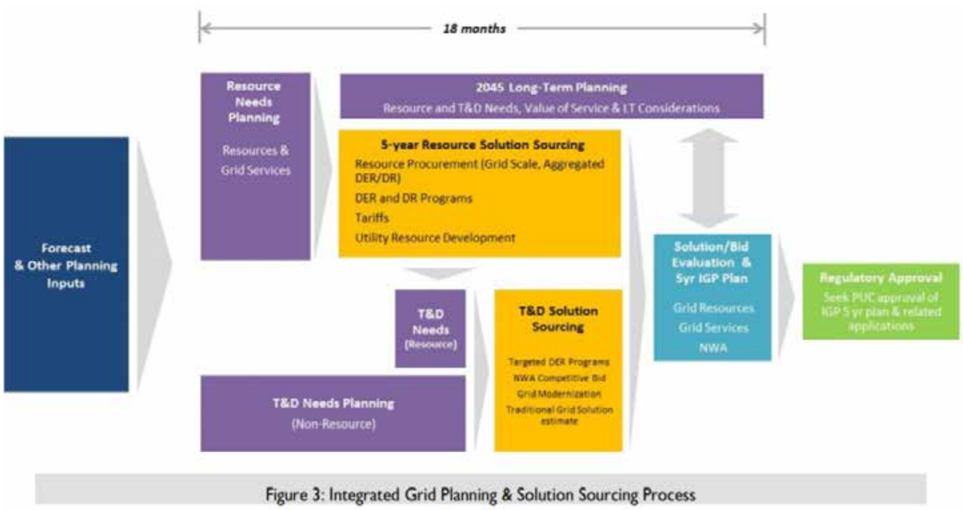


Figure 3: Integrated Grid Planning & Solution Sourcing Process

Source: HECO 2020b.

IGP condenses the planning process, which was previously 30 months, to reduce the risk that assumptions would change and procured resources would not be optimized as planned. Analysis of these bids is formulated into an optimized plan at the end of 18 months. Optimization is accomplished through a second round of modeling, which also uses RESOLVE and PLEXOS, with market data as inputs. Outputs are translated into the five-year action plan, as well as long-term vision to be used in future planning.

IGP was also structured to align planning across the customer, bulk power resource, transmission, and distribution levels. HECO acknowledged that planning processes across these domains could not be done separately and then stacked on each other without missing the key interdependencies and the net value of a solution.