Clean Security of Supply in Europe:
Models for Market-Aligned Contracting and Procurement

PREPARED BY
Dr. Andrew W. Thompson
Dr. Kathleen Spees

PREPARED FOR

CLEAN AIR
TASK FORCE

FEBRUARY 2026

Brattle

Notice

This report was prepared by The Brattle Group for the Clean Air Task Force (CATF). It is intended to be read and used as a whole and not in parts. The report reflects the analyses and opinions of the authors and does not necessarily reflect those of The Brattle Group's clients or other consultants.

Contents

Section I: Problems with Power Investments

Problem Statement

The conundrum of power investments is that we need clean energy, and secure supply, which to date have been pursued in disconnected and expensive ways.

- Long-term contracts if poorly designed can undermine short-term market signals and competition
- Non-dispatchable clean energy procurements often do not contribute sufficiently to changing reliability needs
- Current security of supply mechanisms tend to procure reliability at least cost, with limited scope for also supporting clean energy policy goals
- Hard to incorporate market discipline and price transparency with long-term contracts
- Hedging costs via contracting requires dedicated expertise which may limit access for smaller customers
- Many ongoing efforts to improve contract structures for clean energy procurements and security of supply mechanisms, but minimal coordination between the two

How to ensure security of supply for changing system needs while enabling the clean energy transition?

The energy transition will require new ways of system planning

Wind and solar energy will need to scale substantially in Europe over the coming decades to meet net zero targets, substantially altering the energy mix.

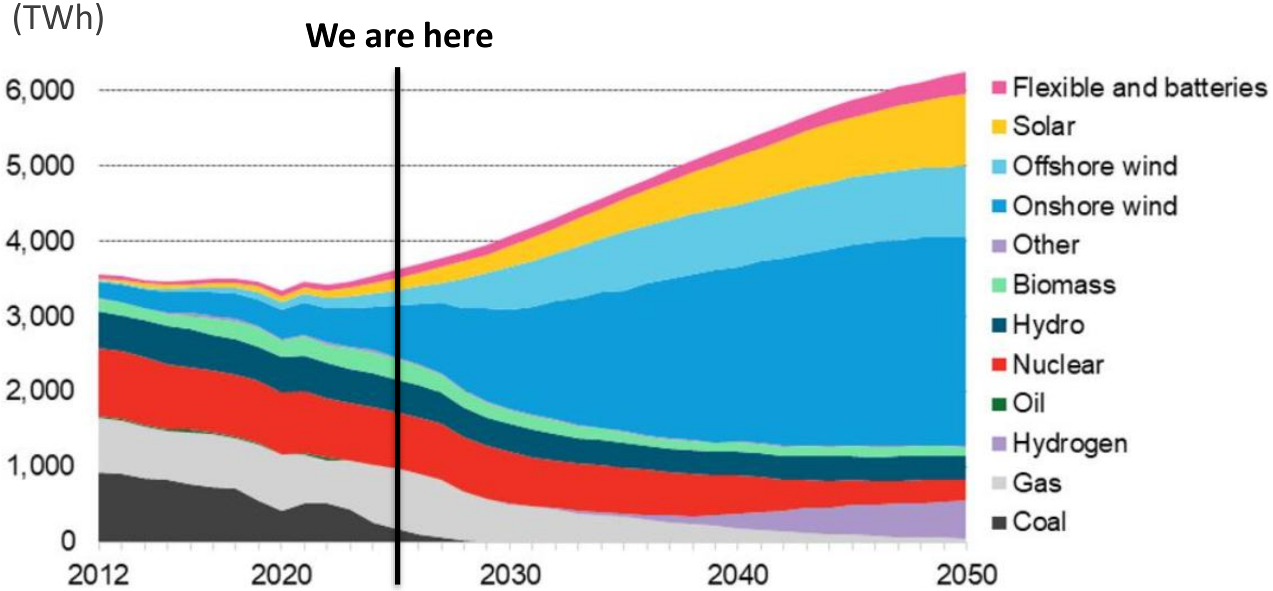
Previously under a fossil-dominated energy mix, **Security of Supply** planning focused on building dispatchable fossil fuel resources to meet peak demand needs and ensuring sufficient reserve margins to address unexpected generation outages and network contingencies.

Driven by improving economics of variable renewable resources and climate policies, the energy transition will result in greater shares of electricity generated by non-dispatchable and weather-dependent resources and energy storage.

Additionally, support schemes and **Clean Procurement** policies aimed at attracting clean or flexible energy resources have been implemented in many European countries.

However, to date security of supply planning and policies for clean procurement have largely been uncoordinated, resulting in overlap and inefficiencies.

Europe Net Zero Transition Scenario
(TWh)



Source: BNEF, Europe's Path to Clean Energy: A $5.3 Trillion Investment Opportunity, April 2022.

PROBLEMS WITH POWER INVESTMENTS

Highly decarbonised systems will have new operational challenges which will alter short-term energy prices

Symptoms

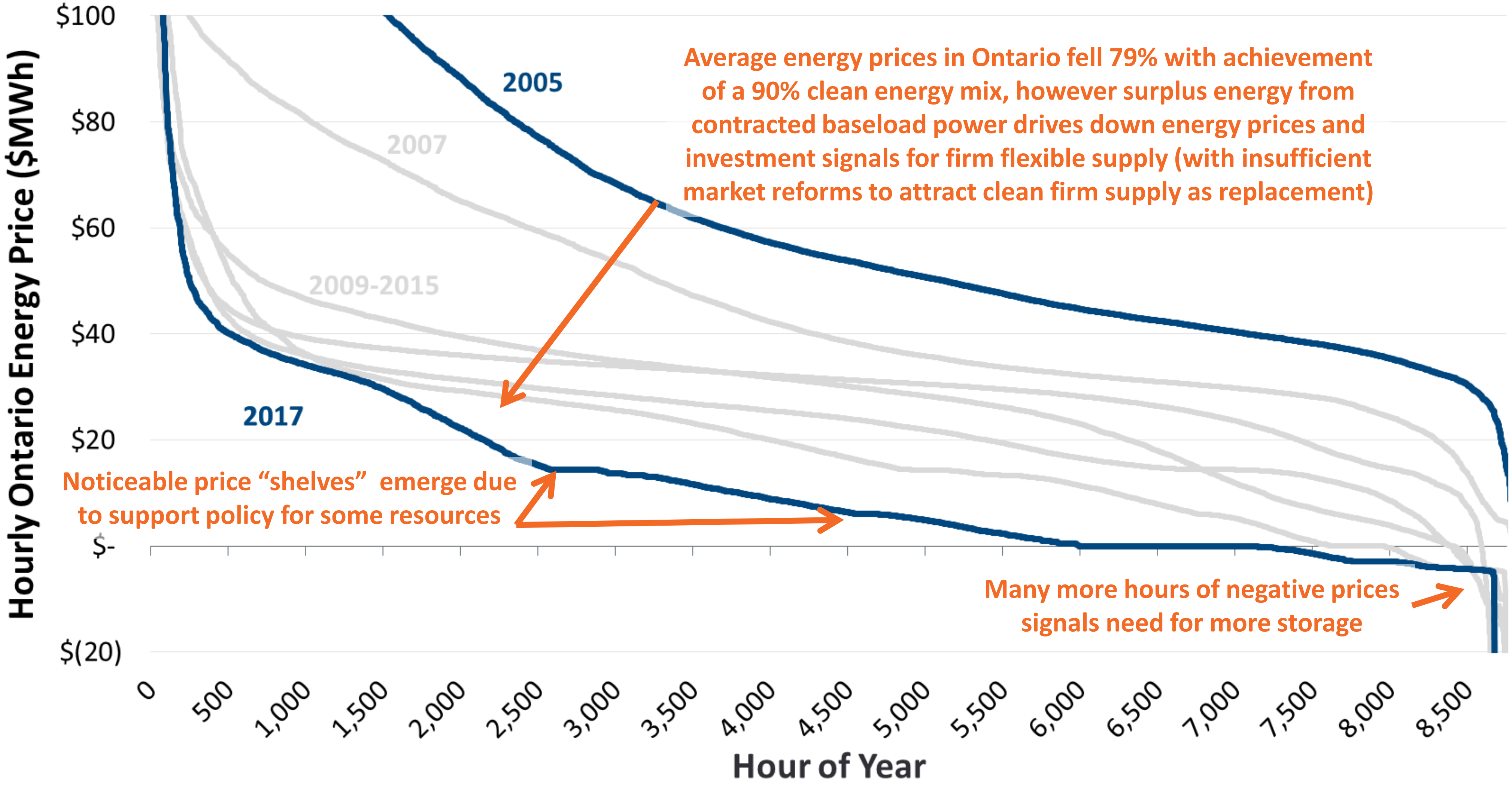
1. Greater extremes of short-term energy prices progressing toward more bi-modal clearing (scarcity vs normal operating conditions) in highly decarbonised systems
2. Potentially greater volatility of short-term energy prices and excessive variable renewable energy curtailments
3. Growing imbalance and redispatching costs
4. Power system instabilities and responses happening at faster timescales

Causes

1. Combination of greater frequency of zero-marginal cost renewable generation meeting all demand and insufficient volume and duration of storage resources or demand-side response
2. Insufficient system flexibility, storage, and demand-side response; lack of locational signals of grid constraints in short-term energy and/or investment signals
3. Greater reliance on weather-dependent resources with imperfect forecasting; lack of locational signals of operational grid constraints in short-term energy prices
4. Reduced system inertia paired with greater volume of resources operating at faster power-electronics timescales (e.g. inverter-based resources) instead of slower control system timescales (e.g. generator droop response); insufficient coordination between Tx and Dx-connected inverter-based resources

Disconnected approaches to clean resource contracting and security of supply can result in additional changes to short-term energy prices

Ontario Energy Price Duration Curves (2005-2017)



Average energy prices in Ontario fell 79% with achievement of a 90% clean energy mix, however surplus energy from contracted baseload power drives down energy prices and investment signals for firm flexible supply (with insufficient market reforms to attract clean firm supply as replacement)

Noticeable price “shelves” emerge due to support policy for some resources

Many more hours of negative prices signals need for more storage

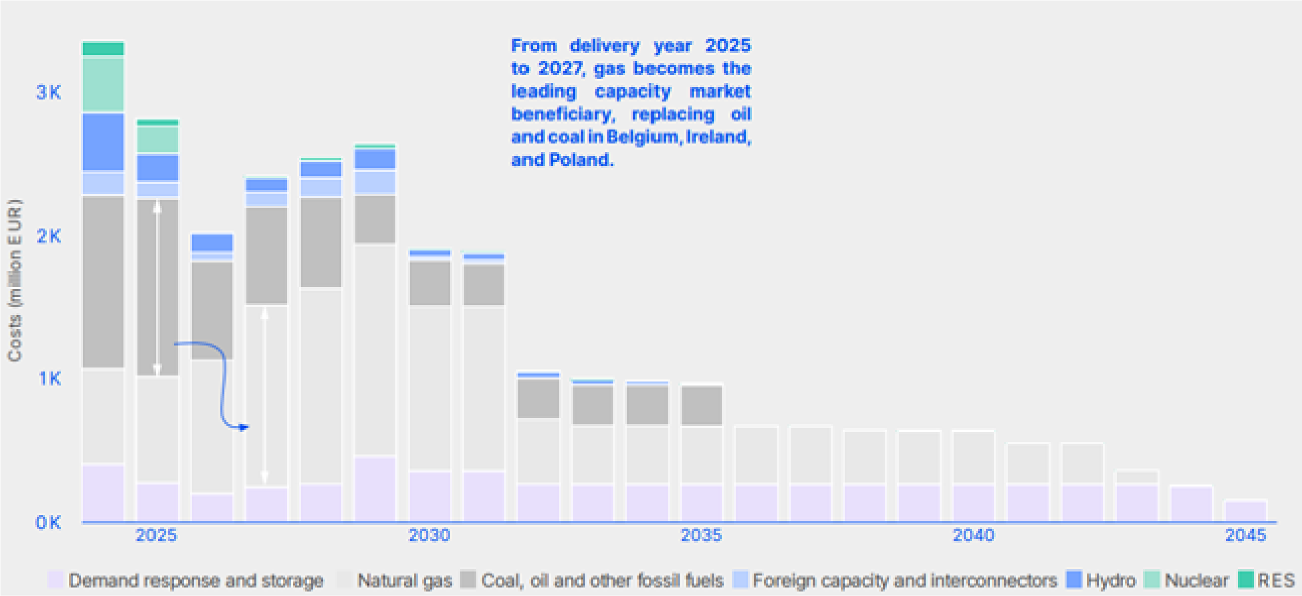
Current capacity mechanisms largely support fossil supply

Capacity mechanisms in Europe to date tend to attract and retain fossil-fuels (least cost for reliability) and do not always result in least cost for reliability + clean energy transition.

ACER expressed concern about potential challenges with capacity markets working at cross purposes with the clean energy transition in the 2025 Security of EU Electricity Supply Report, stating:

- *“Fossil fuels are at the core of EU capacity mechanisms, with a recent shift from oil and coal towards gas. The contracts awarded to gas units have seen their value doubled from 2024 to 2027 delivery years. However, providing long-term financial support for gas units locks them in the market. This could result in electricity prices staying exposed to tensions linked to geopolitical challenges or to the volatility of globalized LNG market.”*
- *“Fossil fuels plants – coal, oil, and gas – currently benefit the most from capacity mechanisms. This impacts CO2 emissions, especially in the case of market-wide capacity mechanisms that provide non-targeted support”*

Aggregated Costs of Long-term Capacity Contracts in France, Ireland, and Poland (2024, million EUR)



From delivery year 2025 to 2027, gas becomes the leading capacity market beneficiary, replacing oil and coal in Belgium, Ireland, and Poland.

Source: ACER, 2025 Security of EU Electricity Supply Report, November 2025.

Can we chart a new path forward for market-aligned contracting and investment models for clean and secure supply?

Section II: Security of Supply

Introduction

There have been many approaches to ensuring Security of Supply in the past, with good lessons learned.

It is useful to understand where and how investment incentives for new supply are structured in power markets across the world, which can broadly be categorised into **energy-only** markets, markets with **capacity mechanisms**, or markets with **centralised planning.**

Any market-based Security of Supply mechanism will require a number of design choices, which must be chosen to balance against inherent trade-offs between reliability outcomes, procurement costs, price volatility, simplicity/transparency, and stability.

Many approaches to security of supply in Europe

Security of Supply measures are at varying stages of development in Europe with no standard approach to date.

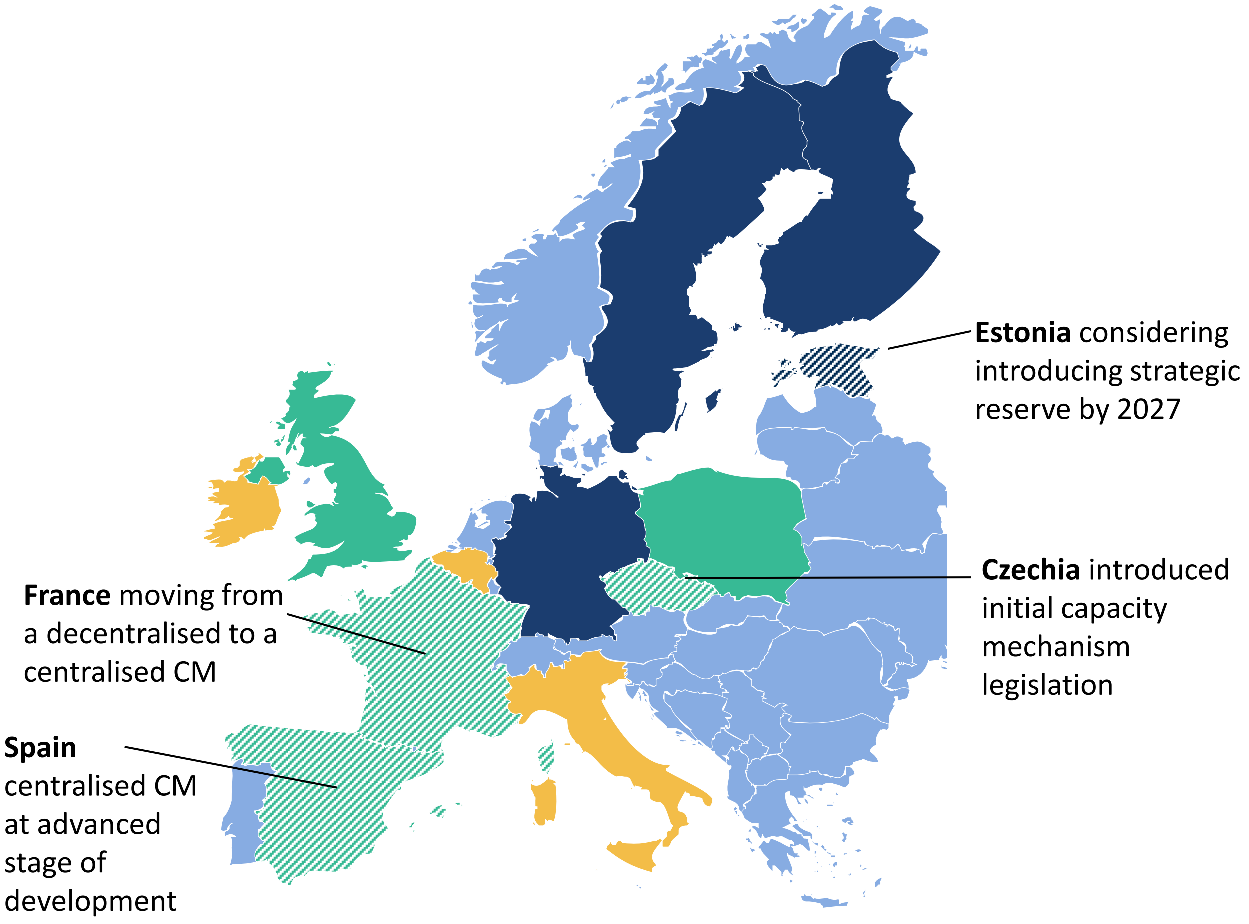
Three primary approaches to security of supply in markets have developed in Europe:

Strategic Reserves: pays generation to be held in reserve outside of the energy market. Targeted to limited supply so results in less distortion to short-term energy and balancing markets in theory. Often do not incentivise investments in new resources or technology and tend to favour existing fossil-fuels.

Capacity Mechanisms (CMs): procures a product for capacity (€/kW) often on a forward-looking basis. Provides an additional revenue stream which improve economics of new resources. Can result in distortionary effects on short-term energy and balancing market signals and high consumer costs if poorly designed.

Reliability Options: similar to CMs but with a payback mechanism to consumers when short-term energy prices are high. Ensures greater consumer protections during extreme prices but capped supplier revenue at strike price may discourage new investment at necessary pace if set too low.

Security of Supply Measures in Europe (2025)



Estonia considering introducing strategic reserve by 2027

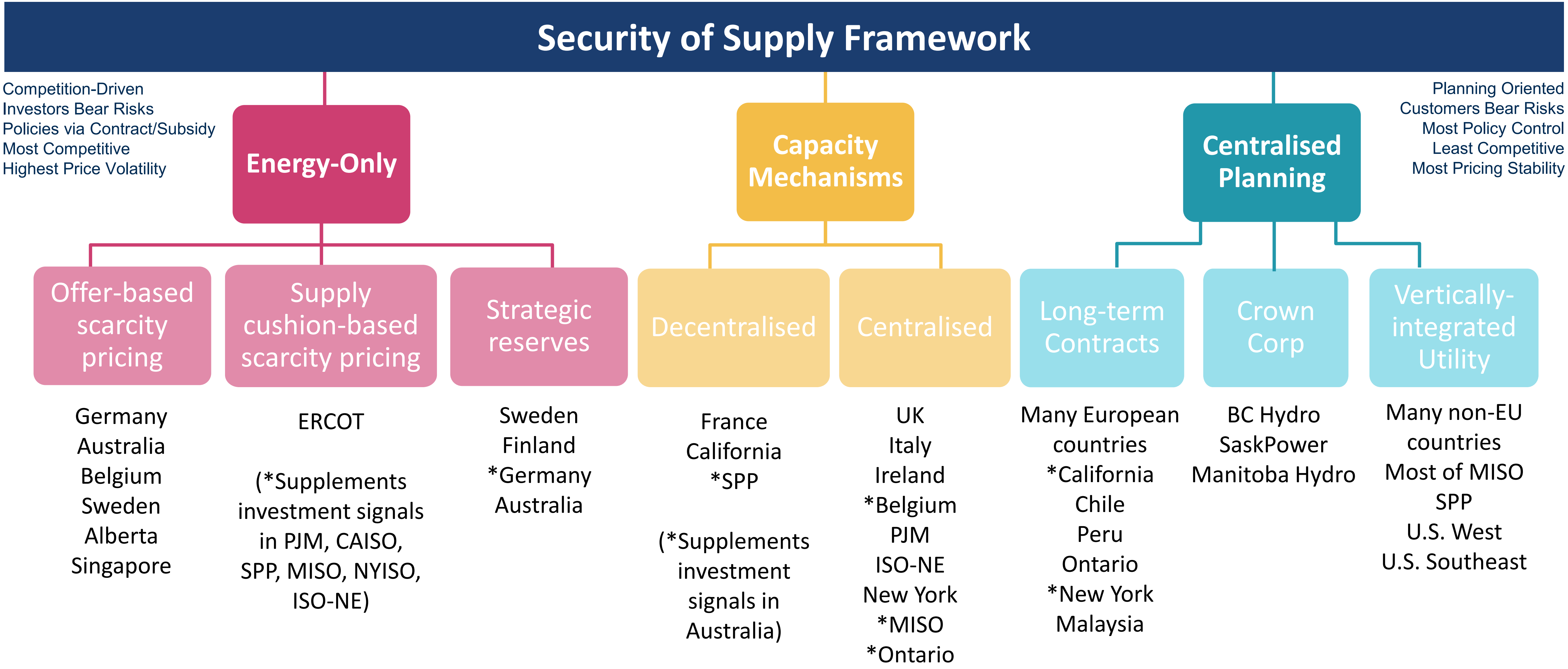
Czechia introduced initial capacity mechanism legislation

France moving from a decentralised to a centralised CM

Spain centralised CM at advanced stage of development

Source: Adapted from ACER, 2025 Security of EU Electricity Supply Report, November 2025.

Security of supply has traditionally been a spectrum of options



Security of Supply Framework

Competition-Driven
Investors Bear Risks
Policies via Contract/Subsidy
Most Competitive
Highest Price Volatility

Planning Oriented
Customers Bear Risks
Most Policy Control
Least Competitive
Most Pricing Stability

Energy-Only

Offer-based scarcity pricing

Germany
Australia
Belgium
Sweden
Alberta
Singapore

Supply cushion-based scarcity pricing

ERCOT

(*Supplements investment signals in PJM, CAISO, SPP, MISO, NYISO, ISO-NE)

Strategic reserves

Sweden
Finland
*Germany
Australia

Capacity Mechanisms

Decentralised

France
California
*SPP

(*Supplements investment signals in Australia)

Centralised

UK
Italy
Ireland
*Belgium
PJM
ISO-NE
New York
*MISO
*Ontario

Centralised Planning

Long-term Contracts

Many European countries
*California
Chile
Peru
Ontario
*New York
Malaysia

Crown Corp

BC Hydro
SaskPower
Manitoba Hydro

Vertically-integrated Utility

Many non-EU countries
Most of MISO
SPP
U.S. West
U.S. Southeast

*Most jurisdictions rely on more than one market-based or planning-based approach to attract new investments (e.g. primarily market-based, with a small share of policy contracts; or regulated planning as influenced by market-price-driven economic incentives and short-term purchases.)

Lessons learned from past approaches

Energy-Only Markets

Energy prices (plus “scarcity pricing” during tight hours) is primary mechanism to attract new investments

Pros:
- More aligned with “pure market” theory
- Investment risks are borne by investors

Cons:
- Insufficiently high price caps in short-term energy markets lead to “missing money” problem
- Investment can depend on investor risk appetite instead of customer risk aversion to outages
- Governments tend to intervene when energy prices spike or remain high

Capacity Mechanisms

Organised market for “capacity” product that reflects sellers’ commitment to deliver supply when needed

Decentralised

Pros:
- Enables continuous trade that is flexible to the timeframes and preferences of sophisticated buyers

Cons:
- Less ability to implement market power mitigation
- Higher transactions costs
- Less price transparency than centralised auctions

Centralised

Pros:
- Competitively attracts range of resource types
- Can better enable cross-border trade and price transparency

Cons:
- Market outcomes can be impacted by modeling
- Rules are complex, changing frequently, and yet sometimes still not fast enough

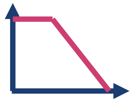
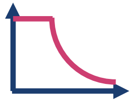
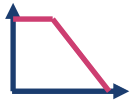
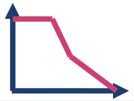
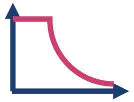
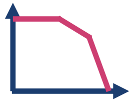
Centralised Planning

Vertically integrated utilities or a government entity does resource planning to build or contract new resources

Pros:
- Greater control of resource mix
- More price stability
- Fewer decision-makers
- Can provide investor certainty

Cons:
- Customers bear investment risks
- Least competitive approach
- Outcomes dependent on complex modelling which is often not transparent
- Can exhibit barriers to entry of innovative new resources
- Potentially greater exposure of investors to regulatory risk since investment is driven by policy

Capacity mechanisms require a number of design decisions

	Forward Period	Seasonality	Delivery Period	Capacity Auctions	Price lock-in	Derating Factor	Demand Curve
CAISO	2 months (annual) 45 days (monthly)	J F M A M J J A S O N D	Monthly x 24 slice of day	None (Bilateral Market)	Varies	Thermal: historic performance Wind/solar: exceedance	none
Ontario	4 Months	Summer Winter	Seasonal (2 Seasons)	Centralized auction for residual need only	6-months	Thermal: forced outage Wind/solar: historic performance	
MISO	1.5 Months	Sum Fall Win Spring	Seasonal (4 Seasons)	Mandatory Auction (Net of Self-Supply)	4-months	Approximated average probabilistic during critical hours	
NYISO	0-6 Months	A M J J A S O N D J F M	Monthly & 6-Month Strip	Voluntary & Mandatory Auctions	Up to 6-months	Marginal probabilistic	
PJM	3 Years	Annual	Annual	Mandatory Auction (opt-out possible)	1-year	Marginal probabilistic	
ISO-NE	Prior: 3 Years Plan: Non-Forward	Annual	Annual Plan: Seasonal	Mandatory Auction	1-year	Marginal probabilistic	
UK	T-1: 1 year T-4: 4 Years	Annual	Annual	Mandatory Auction	Existing: 1-year New: 15-years	Average probabilistic	

Sources and Notes: Kathleen Spees, Are Resource Adequacy Markets Adequate?, Energy Bar Association 2025 Annual Meeting & Conference.

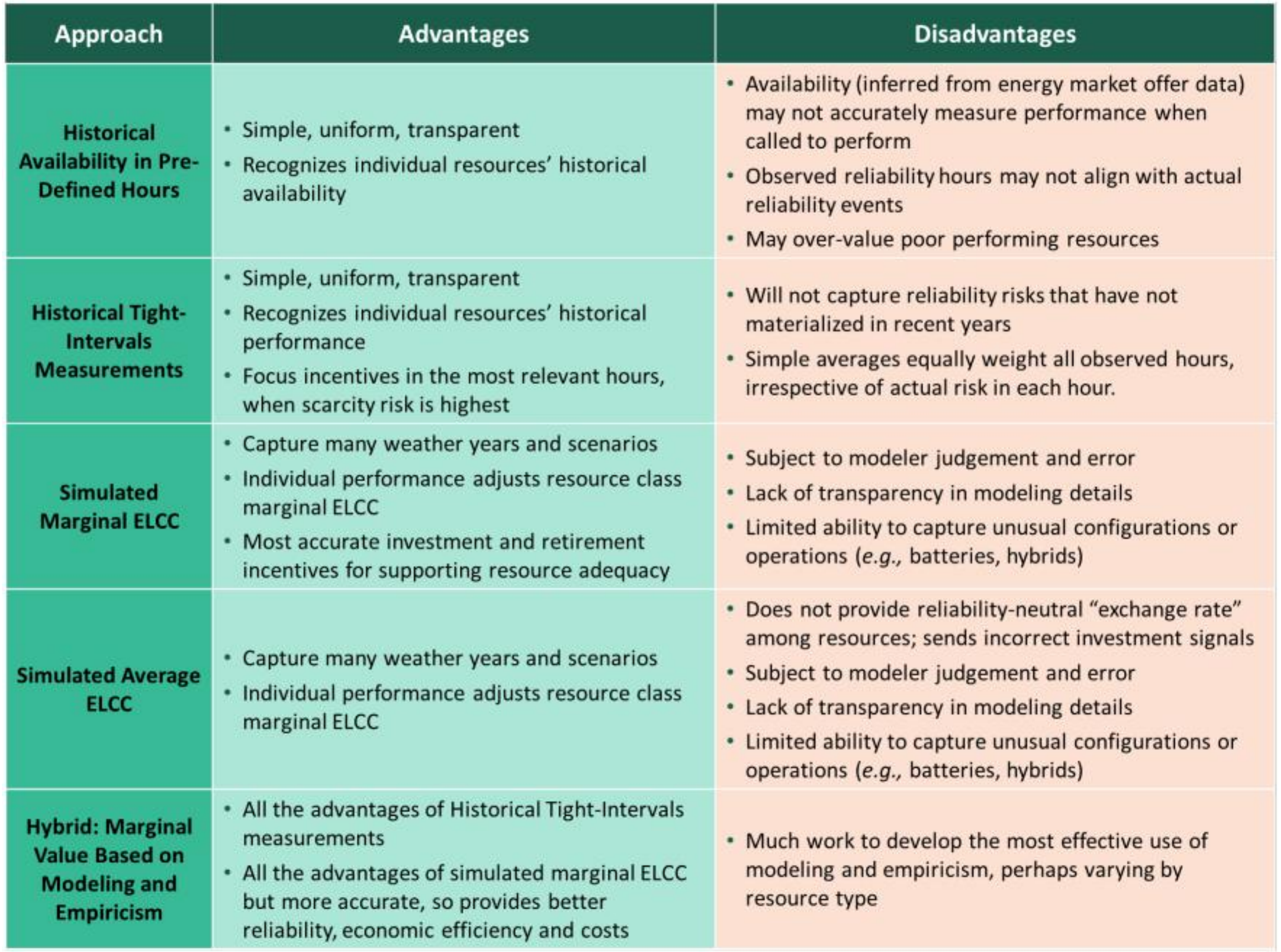
Example of one design element: derating factors

Derating factors are one design decision for CMs and are necessary to translate from a resource's physical capacity ("installed capacity") into what a resource can be relied on to deliver energy when needed ("derated capacity").

Design principles for derating factor approaches:

- Balance of transparency and ease of implementation with need to capture realistic system adequacy needs and resource operations
- Need to incorporate new resource performance data relatively quickly to avoid locking-in derated capacity out-of-sync with actual adequacy contributions
- Should be adaptable to changing system conditions, reflecting the marginal contribution of each resource to system adequacy
- Assess resource contribution over all hours of a year (8760 hrs) and over many weather-years, including extreme weather and low renewable output scenarios
- Should apply same derating factor approach to all resource types with the aim to be technology neutral
- Must capture impact of weather-driven and correlated outages (e.g. cold weather reducing availability of gas, cloudy conditions reducing solar output over a wide area, etc.)

Advantages and Disadvantages of Different Derating Factor Approaches



Approach	Advantages	Disadvantages
Historical Availability in Pre-Defined Hours	• Simple, uniform, transparent • Recognizes individual resources' historical availability	• Availability (inferred from energy market offer data) may not accurately measure performance when called to perform • Observed reliability hours may not align with actual reliability events • May over-value poor performing resources
Historical Tight-Intervals Measurements	• Simple, uniform, transparent • Recognizes individual resources' historical performance • Focus incentives in the most relevant hours, when scarcity risk is highest	• Will not capture reliability risks that have not materialized in recent years • Simple averages equally weight all observed hours, irrespective of actual risk in each hour.
Simulated Marginal ELCC	• Capture many weather years and scenarios • Individual performance adjusts resource class marginal ELCC • Most accurate investment and retirement incentives for supporting resource adequacy	• Subject to modeler judgement and error • Lack of transparency in modeling details • Limited ability to capture unusual configurations or operations (*e.g.*, batteries, hybrids)
Simulated Average ELCC	• Capture many weather years and scenarios • Individual performance adjusts resource class marginal ELCC	• Does not provide reliability-neutral "exchange rate" among resources; sends incorrect investment signals • Subject to modeler judgement and error • Lack of transparency in modeling details • Limited ability to capture unusual configurations or operations (*e.g.*, batteries, hybrids)
Hybrid: Marginal Value Based on Modeling and Empiricism	• All the advantages of Historical Tight-Intervals measurements • All the advantages of simulated marginal ELCC but more accurate, so provides better reliability, economic efficiency and costs	• Much work to develop the most effective use of modeling and empiricism, perhaps varying by resource type

Notes and Sources: ELCC: Effective Load Carrying Capacity; Class ELCC refers to probabilistic modeling that assesses the *average* adequacy value of all resources of the same type; Marginal ELCC assesses each individual resource's *marginal* contribution to system adequacy. See Newell, Spees, Higham, Capacity Resource Accreditation for New England's Clean Energy Transition, June 28, 2022, and Newell, Levitt, Sreenath, Developments in Capacity Accreditation, June 5, 2025.

Plenty of work on capacity mechanisms to be done:

Need to ensure all clean resources can compete and become operationally useful

Have accurate accounting of traditional and emerging reliability needs embedded in mechanism (e.g. via good derating factors and expression of system demand for capacity throughout the year)

Regionalised, transparent, and consistent definitions of security of supply “product” and reliability value of resource types will enable cross-border trade

Section III: Clean Procurement

Introduction

Procurements and contracting can ensure revenue sufficiency to cleaner and capital-intensive technologies to mobilise timely investment.

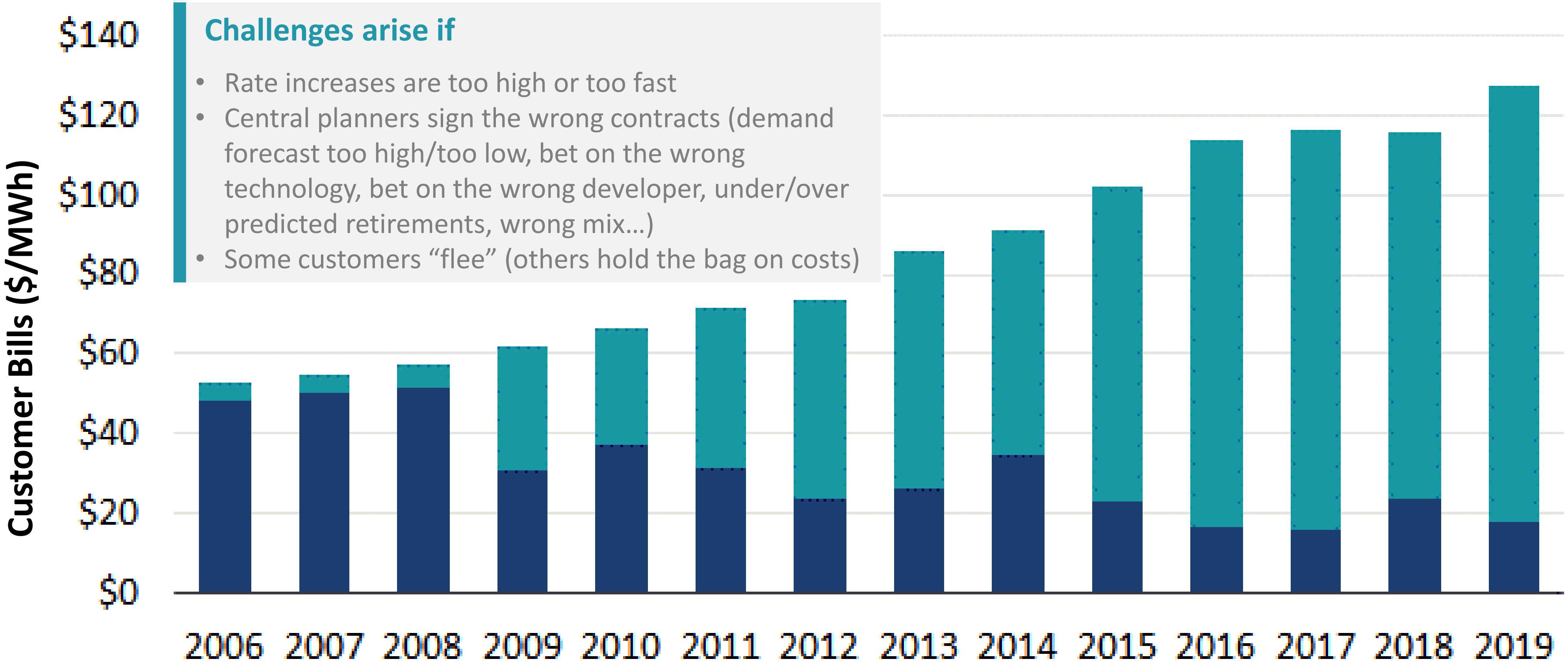
However, these need to be designed to minimise interference, particularly in the short-term energy markets.

Known issues of clean support schemes/contracts:

- Blunt non-market aligned procurements can result in bad outcomes (e.g. incorrect supply mix for future reliability needs, imbalanced allocation of risks between buyers and sellers, high overall consumer costs)
- Lack of locational signals and marginal incentives reflected in contract or support schemes result in resources operating out-of-sync with system needs (e.g. injecting energy when prices are negative or in areas that are constrained)

Low energy prices do not always translate to low customer costs

Long-term contract-based investment model that is not sufficiently market aligned can mean customers pay investment costs as pass-through



Challenges arise if

- Rate increases are too high or too fast
- Central planners sign the wrong contracts (demand forecast too high/too low, bet on the wrong technology, bet on the wrong developer, under/over predicted retirements, wrong mix…)
- Some customers “flee” (others hold the bag on costs)

Contract Payments
Portion of fixed costs increase due to achievement in clean policy goals but with capacity oversupply relative to demand, and excess baseload in the mix (contributing to clean energy curtailments)

Energy Cost

Source: Ontario Independent Electricity System Operator, Global Adjustment Components and Costs.

Some contracting lessons learned (Dos and Don’ts)

Do: Emulate Others’ Successes

- **Do: Maintain focus on strong and accurate market signals** for all system needs (energy, capacity, ancillary, environmental value) at all timeframes (especially closer to near-term and real time)
- **Do: Include locational price signals** that reflect transmission limits
- **Do: Ensure all resources have “skin in the game”,** i.e. meaningful exposure to short-term energy prices so they will seek to maximise value relative to near-term and real-time system needs
- **Do: Maximise competition across suppliers and technologies** by ensuring equal playing field (focus mechanism design on *needed services*, rather than *specific technologies*)
- **Do: Structure procurements to minimise reliance on planners’ forecasting accuracy and qualitative judgements**
- **Do: Allocate risks where they belong**. Developers can and should bear the risks under their ability to manage and control (e.g.: uneconomic technology, delayed schedules, poor operational performance, fuel prices, supply chain interruptions)
- **Do: Let customers self-supply** (but without free riding on system reliability). They may find cheaper alternatives
- **Do: Eliminate barriers to entry and participation** for new technologies that can be activated to “do more”

Don’t: Make the Common Mistakes

- **Don’t: Discourage participation in real-time energy markets** and distort or mute efficacy of short-term energy price signals
- **Don’t: Pay sellers for injecting power where or when it has no value** (zero or negative price intervals, places where injections are curtailed)
- **Don’t: Offer contracts for 100% of resource capacity and 100% of asset life**– need to leave room for market discipline to correct for planners’ forecasting uncertainties
- **Don’t: Believe the “base case” forecast.** Long-term planning is about decision-making in uncertainty (“least regrets” resource mix will outperform the best “base case” resource mix)
- **Don’t: Let sellers get lazy with “contract and forget” structures**
- **Don’t: Put all the eggs in one basket** (going all-in on one technology or high-risk megaproject) without putting it to the “market test” (put out the call: can anyone else solve the same problems at a lower cost?)
- **Don’t: Shift investment risks to customers** unless there is a good reason (e.g.: identified market failure, systemic risks, inefficient regulatory risk)
- **Don’t: Underestimate what creative companies and customers can do.** They will nearly always find an easier, better, or cheaper answer to a well-defined problem

Additional reading: Chapter III of South Carolina Market Reforms Study; Chapter 3 of EU Market Review Study.

Design process for clean contract incentives

Design principles for long-term contracting and incentives for clean and secure supply:

- Design process to meet policy goals very similar to other market design processes focused on reliability or security (but rather than starting with reliability needs, begin with policy goals)
- Initial focus (step 1) is to clarify policy goals in clear units of measure, and then translate goals into a clear product definition (step 2), as this creates the central basis for many other aspects of efficient investment & operational incentives
- If all resources (contracted and not contracted) can access the same monetisable value in the operating timeframe for green, reliability, and other values, then markets & contracts can be mutually informative and reinforcing

DESIGN PROCESS

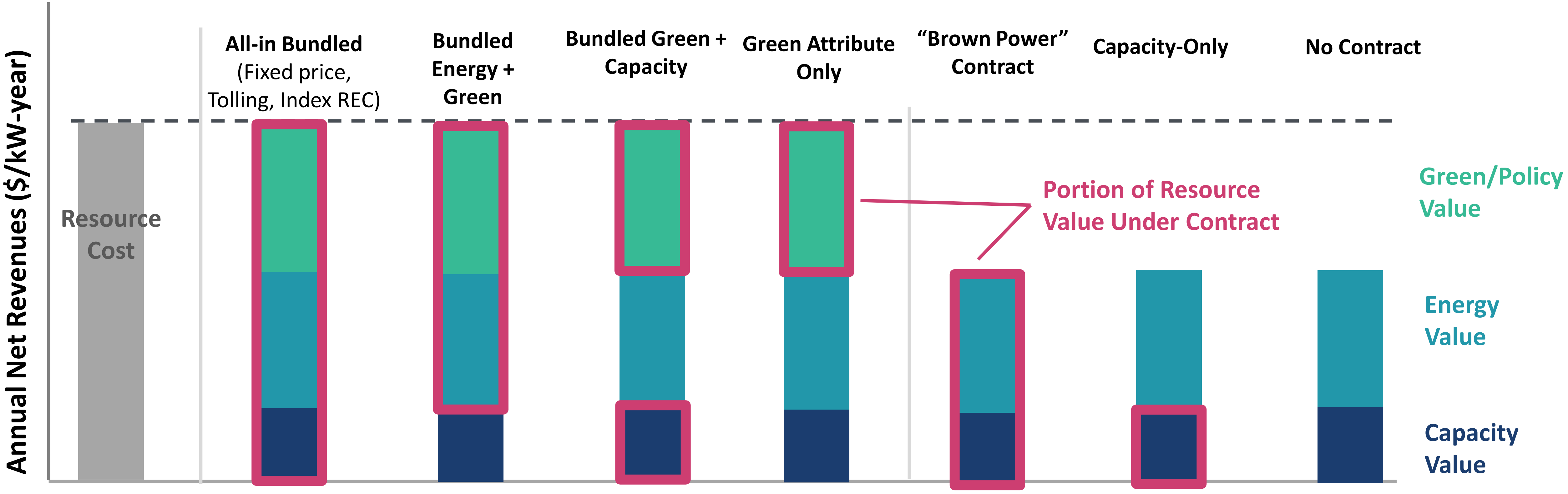
1. Set policy objectives/targets to be achieved
2. Translate objectives into primary product definition (units of measure toward meeting objective)
3. Identify regulatory entity responsible for meeting objective, and mechanism to enforce compliance (defines buy side of the market/contracts)
4. Measure how different resources contribute to (or detract from) meeting policy objectives (defines the sell side of the market)
5. Create a spot market (or contract-based operating incentives) that incentivise buyers & sellers to pursue the policy objective
6. Identify investment market or contract procurement model that will attract resource development, retrofits & retention
7. Assign costs (if cost allocation is not inherent)
8. Enable self-supply and lower-cost solutions

Design choices for clean policy or procurement

Design Step		Design Options
1	Policy Objectives	GHG Target Clean Energy or Renewables Target
2	Product Definition	GHGs Emitted (tonnes of emissions) Renewables Produced (Guarantees of Origin/Green certificates) Emissions Rate Produced or Delivered (kg/MWh)
3	Enforcement on Compliance Entity	Fossil Generation Charged for emissions (or emissions above defined rate) DSOs or Retailers Charged if under-procuring clean MWs (or if delivered emissions rate is too high) Government Agency or Independent Regulator Entity
4	Supply Contributions	GOs produced, MWh produced during high-emission intervals, ensure batteries can do both!
5	Spot Market	GO market, GHG value embedded in energy market price, combination of GO + GHG value
6	Investment Model	Clean energy market, competitive contract solicitations, pure merchant (renewable targets or GHG price)
7	Cost Allocation	Retailer pays (costs passed to customers), non-bypassable charges for contract/subsidy payments, GHG passed via energy price (allowance auction revenues returned to customers), self-funded (fossil gens pay clean), costs shifted to taxpayer
8	Enabling Self-Supply & Innovative Solutions	Enable emerging technologies, allow customers and retailers to identify lower-cost options

GO = Guarantees of Origin, GHG = Greenhouse Gas, DSO = Distribution System Operator.

Contracts have different allocations of risks between buyers and sellers



Green Power Contracts

Include a subsidy above expected market prices, which is needed to attract "preferred" resource types. Can place more risk on customers (left) or sellers (right).

Brown Power Contracts

Hedge against market volatility, but do not include any subsidy above expected market prices.

Market-aligned contracts drive efficient incentives

The formula under which contract revenues are paid matters as much as the total price paid. Traditional, fixed-price contracts for differences “CfDs” can create unhelpful incentives when pursued at scale, while a “index REC” contract structure can leverage market forces to get cheaper and better results

	Traditional CfD Not Market-Aligned, Weakens Short-term Market Signals	**Index REC Contract** Market-Aligned, Maintains Short-term Market Signals
Strike Price	$100/MWh (for bundled energy + RECs)	$100/MWh (for bundled energy + RECs)
Payment Structure	Seller earns: • **Energy market revenue**, calculated in each dispatch interval • **+ Contract top-up payments:** $100/MWh minus **seller’s realised energy market price** • **=Total revenue:** $100/MWh x MWh produced (same price regardless of when power is produced)	Seller earns: • **Energy market revenue**, calculated in each dispatch interval • **+ Contract top-up payments:** $100/MWh minus **monthly customer-average energy price** • **=Total revenue:** $100/MWh x MWh produced if the output profile matches customer demand profile. Higher total revenues if output is focused in high-value hours (lower total revenue if output is in low-value hours)
When is the Seller Incentivised to Produce Power?	• Natural output profile (seller is equally incentivised to inject power in high-value scarcity hours vs. negative price hours when surplus supply is curtailed)	• Incentive to focus output in highest-price hours (and avoid output in zero or negative price hours) • If market price profiles are strong enough, sellers are incentivised to retrofit with battery storage
Does the Customer Receive Strong Hedging Value?	• **Inconsistent.** Some hedging value, but only to the extent that seller’s output profile aligns with average or high-price hours	• **Yes.** Customers receive a hedge that guarantees a consistent delivered price for the contracted volume

Notes: Note that asymmetric CfDs, those that preserve seller protections for downside risk while allowing sellers to retain the upside during high spot prices, solves part of the issues with CfDs. The variation of an index REC contract noted above is an example of a market-aligned contract, but other variants exist. For example, the same structure can be used for a simpler energy-only contract without a bundled REC. The key feature of the contract in either case is that the contracted resource has the marginal incentive to optimise output relative to real-time energy market pricing signals

Clean procurement mechanisms should:

Incorporate best practice, market-aligned incentives (with operational incentives preserved)

Unbundle products (e.g. even clean supply contracts should have separate line items for energy, capacity, and green energy value)

Shift to contract structures that maintain operating incentives from short-term markets (e.g. “indexing” structures, rather than asymmetric CfDs)

Section IV: Models for Clean Security of Supply

Introduction

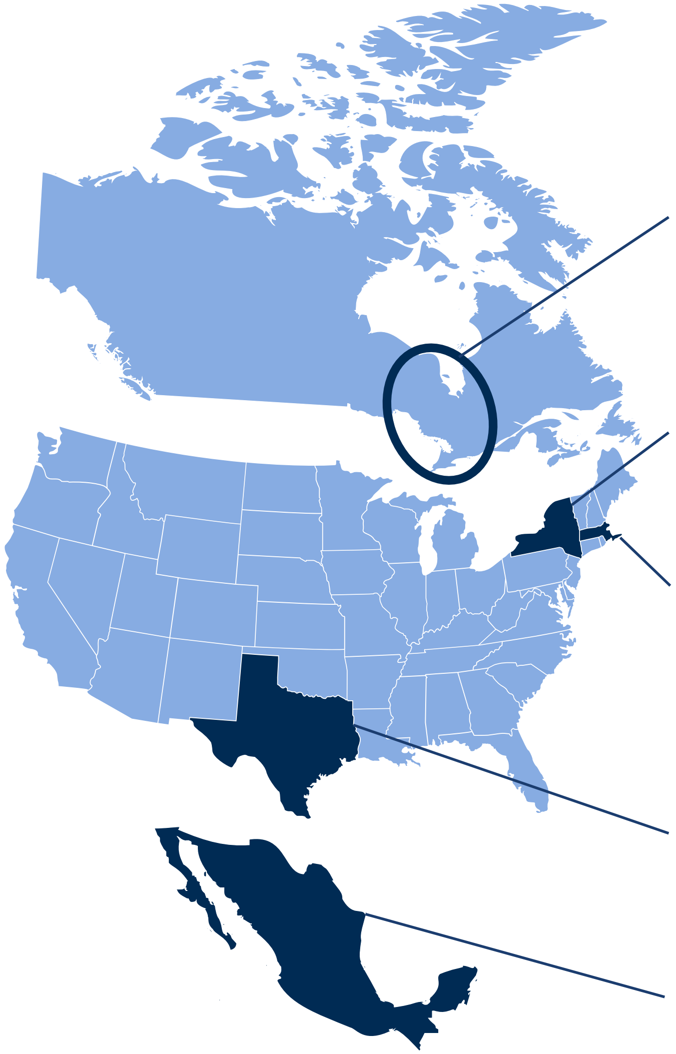
Many jurisdictions have integrated clean energy resources with security of supply to varying degrees and show a compelling spectrum of options.

Novel approaches that explicitly value and co-optimise procurement of energy, capacity, and clean resource value have shown promising results and cost savings.

There have been a range of responses to incentivise clean security of supply:

- **Economist answer is "simple"**: introduce GHG emissions cap or carbon price high enough to internalise policy goal, but this tends to be politically infeasible in most places (and undermines electrification goals if not economy-wide)
- **UK & European State Aid Guidelines:** GHG emissions cap for fossil capacity to qualify for capacity market
- **New England USA**: Some states pushing for Forward Clean Energy Market (FCEM) and similar proposals for regional clean energy or clean capacity markets
- **Australia**: Capacity investment scheme for clean capacity only
- **Many places**: targeted subsidies or long-term contracts for firm clean supply like battery storage, demand response, long-duration energy storage (though often not structured to enable cross-technology competition or focus on a defined capacity product)

Integrated models for clean and secure supply: a spectrum of options



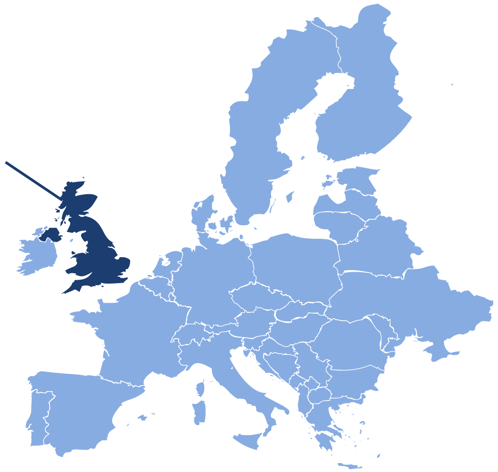
Ontario: centralised planning model with 90% clean supply mix and government playing central role

New York: mix of markets and targeted centralised procurements for clean supply with strong policy goals

New England Forward Clean Energy Market (FCEM): novel approach to incorporate clean energy goals into markets

Texas: energy-only market with scarcity pricing and substantial uptake of clean resources despite no policy support

Mexico: Long-term auction design that resulted in world-record low costs for clean supply



Great Britain: mix of markets and long-term procurements for clean supply

Australia: energy-only market with clean energy certificate market and rapid uptake of clean supply

MODELS FOR CLEAN SECURITY OF SUPPLY

Planning oriented

↕

Competition-driven

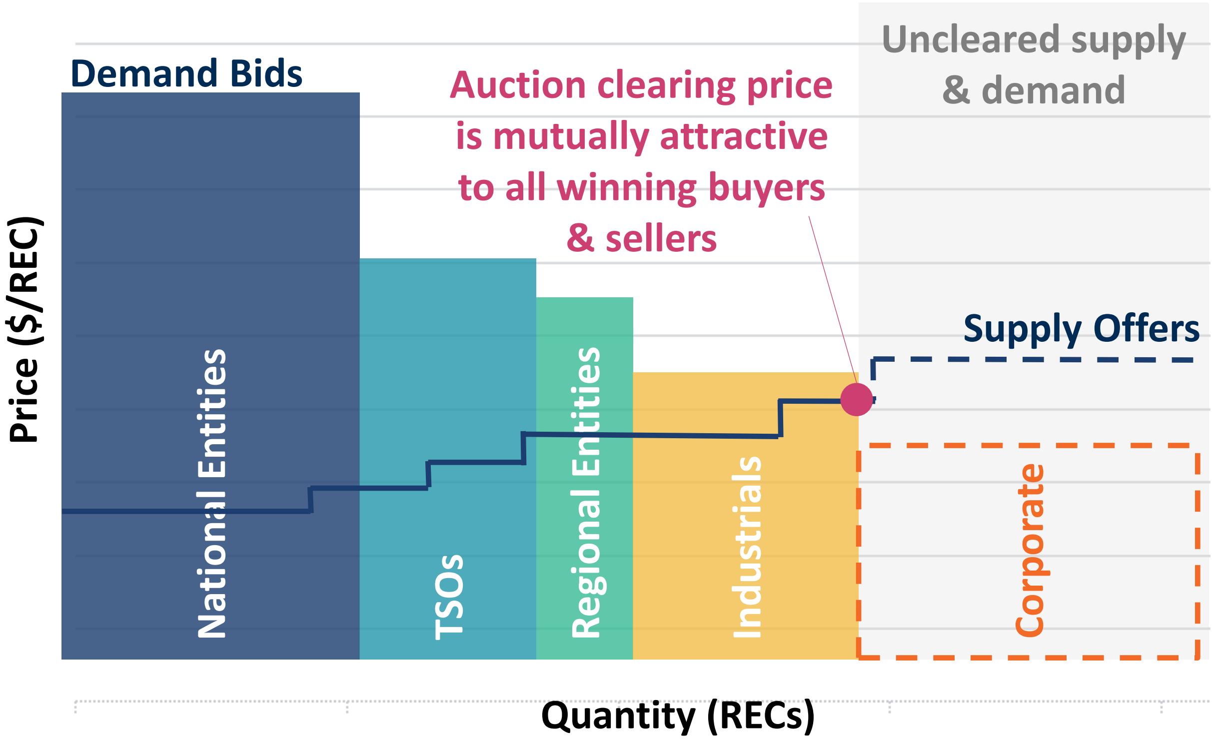
	Market or Clean Support Scheme	Product(s)	Term	Eligible Resource(s)
ONTARIO	**Planning:** Centralised procurement **Market:** Energy + capacity market for residual needs not met through central planning	Energy and capacity	New/existing capacity: between 5 to 20-year contracts	All new generation; recontracting of existing generation
GREAT BRITAIN	**Market:** Energy + capacity market **Clean Support:** centralised auction for low-carbon Contracts for Differences (CfDs)	Energy and capacity	New capacity: 15-year lock-in Existing capacity: 1-year lock-in CfDs: 15-20-year contract	All new and existing generation, storage, and demand response; low-carbon only for CfDs
NEW YORK	**Market:** Energy + capacity market **Clean Support:** centralised procurement/auctions for clean resources and long-term contracts for renewable and zero-emissions credits (RECs/ZECs)	Energy, capacity, RECs, ZECs	New/Existing capacity: 6 months max REC/ZECs: 15-20-years	All new and existing generation, storage, and demand response; renewable or zero-carbon only for REC/ZECs
MEXICO (pre-2019 reform)	**Market:** Auctions of energy, capacity, and clean energy certificates (CELs)	Energy, capacity, and CELs	New: 15-20 year contracts	Capacity all new generation; energy and CEL payments only to new clean generation (includes nuclear and co-gen)
FORWARD CLEAN ENERGY MARKET (FCEM)	**Market:** Energy + auction of capacity and clean attributes	Energy and bundled capacity + clean energy certificates (clean energy/REC, clean capacity, & GHG abatement)	New: 7-15 year price lock-in Existing: 1-year price lock-in	All new and existing generation, storage, and demand response
AUSTRALIA	**Market:** Energy scarcity pricing + renewable energy credits (RECs) **Clean Support:** Capacity investment scheme (CIS)	Energy, CIS revenue underwriting agreements, RECs	CIS: 10-15 year contracts	Renewable generation and firming clean capacity (storage)
TEXAS	**Market:** Energy scarcity pricing + voluntary market for RECs **Clean Support:** None	Energy, voluntary RECs	N/A	N/A

FCEM: Design structured to attract clean investment at competitive prices

Fills the unmet needs of nations and consumers that want more control over resource mix and pace of decarbonisation, while leveraging the benefits of competitive markets

- **Products:** Regional REC (MWh of RECs) and clean capacity products (MW of TSO capacity commitments), plus option for nations to list national products
- **Term:** 1 year for existing resources, 7-15 year commitments for new supply
- **Buyers:** Submit demand bids as price-quantity pairs expressing volume, maximum willingness to pay ($/REC), eligible technologies. Can submit different prices for new resources under multi-year term vs. existing resources
- **Sellers:** Submit minimum price & volume
- **Clearing Price:** Set at the intersection of supply & demand. Co-optimised clearing to maximise benefits of trade across multiple products, and reduced the joint cost of RECs+capacity
- **Schedule:** Annual auction, held 3 years in advance of delivery

FCEM AUCTION CLEARING

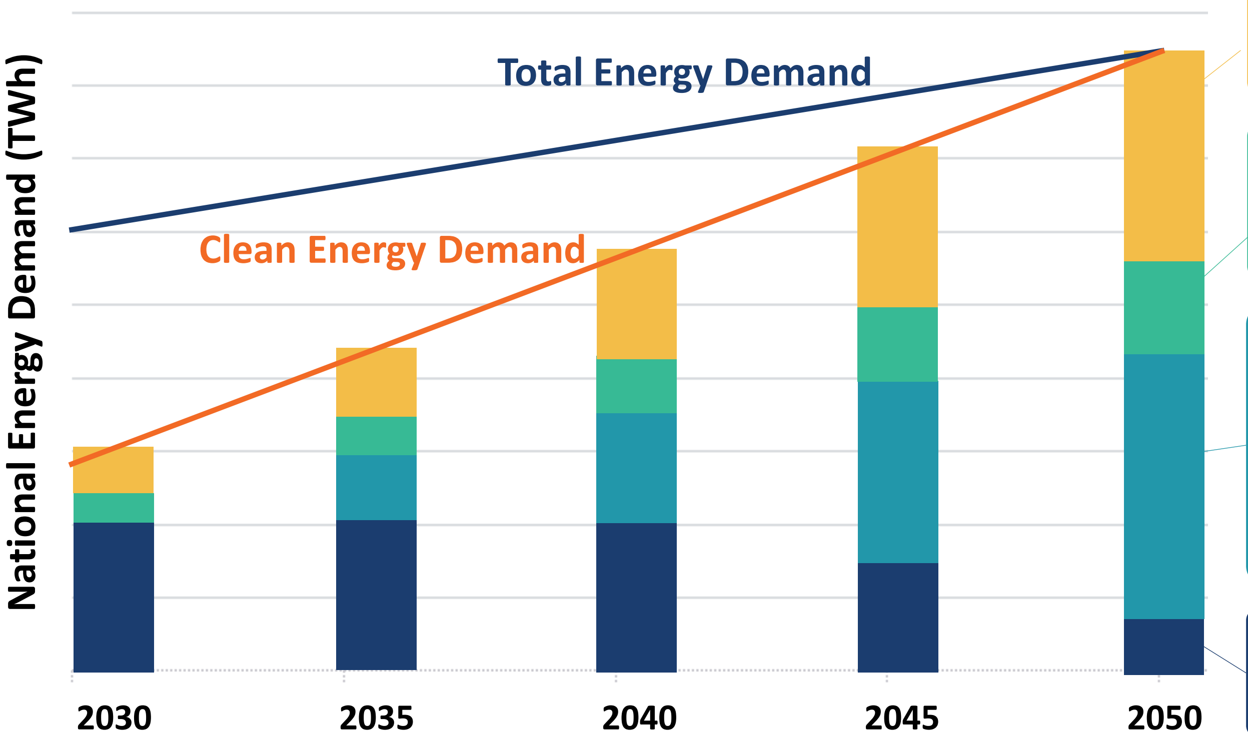


FORWARD CLEAN ENERGY MARKET (FCEM)

What is the role of FCEM compared to other policies and contracts?

Platform would be flexible for nations to rely on FCEM purchases either in a small way (e.g. topping up needs from existing supply), or could be scaled up as the primary means of attracting large-scale clean energy investment and managing fleet transition

EXAMPLE: A NATIONAL CLEAN ENERGY SUPPLY PLAN



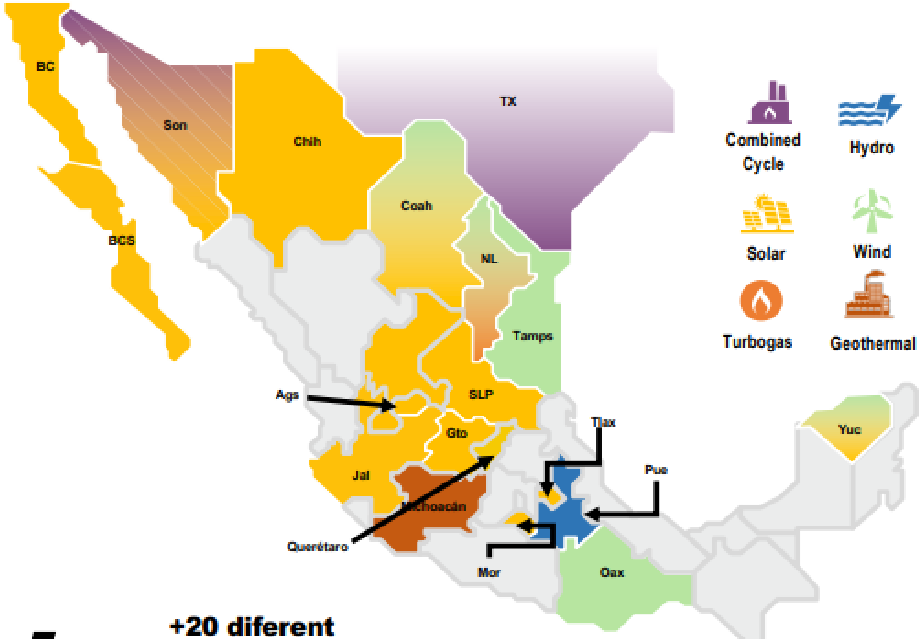
FCEM Purchases (New or Existing)	Nation determines share of clean energy supply needs to procure via FCEM, potentially increasing reliance over time as market gains maturity
FCEM New Resource Purchases	A share of FCEM purchases can be earmarked for 7-15 year new resource commitments (transitions to eligibility as existing supply after initial term)
Other National Contracts & Policies	New contracts and national policies will continue to be used, e.g. to pursue objectives not addressed by FCEM such as local employment and protecting vulnerable consumers (transparency in FCEM can inform better resource selection & pricing)
Existing Contracts	As existing contracts expire, resources become eligible to compete in FCEM

See: Massachusetts Forward Clean Energy Market design proposal for New England; and associated stakeholdering materials.

MEXICO LONG-TERM AUCTIONS

Competitive format attracted many investors and achieved successively lower prices for new investment in capacity

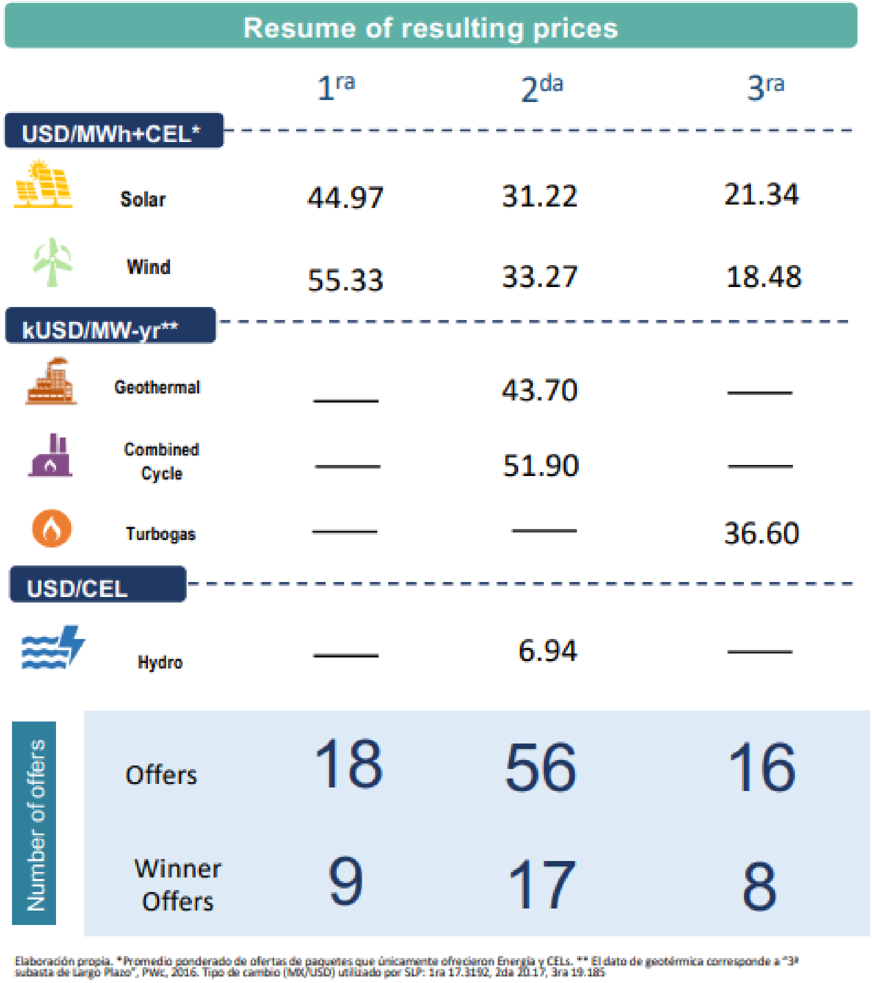
Locations of winning technology types and clearing prices in Mexico's long-term auction scheme (2015-2017)



+20 diferent companies
Companies from more than 11 countries, including Mexico

8.9 billion USD of investment in the coming years

Increase of **7.6 GW** to the current generation capacity in Mexico



Resume of resulting prices

		1ra	2da	3ra
USD/MWh+CEL*				
	Solar	44.97	31.22	21.34
	Wind	55.33	33.27	18.48
kUSD/MW-yr**				
	Geothermal	—	43.70	—
	Combined Cycle	—	51.90	—
	Turbogas	—	—	36.60
USD/CEL				
	Hydro	—	6.94	—
Number of offers	Offers	18	56	16
	Winner Offers	9	17	8

Elaboración propia. *Promedio ponderado de ofertas de paquetes que únicamente ofrecieron Energía y CELs. ** El dato de geotérmica corresponde a "3ª subasta de Largo Plazo", PWc, 2016. Tipo de cambio (MX/USD) utilizado por SLP: 1ra 17.3192, 2da 20.17, 3ra 19.185

USD/MWh for energy plus green attributes

USD/kW-yr Capacity

USD/MWh green attributes

Sources and Notes: CEL = certificado de energía limpia. Comision Reguladora de Energia, The Electricity Market in Mexico, A Recent Market & Regulatory Design for an Era of Low-Cost Renewables and Empowered Consumers, 5th GO15 & ICER Workshop Meeting, October 11, 2018.

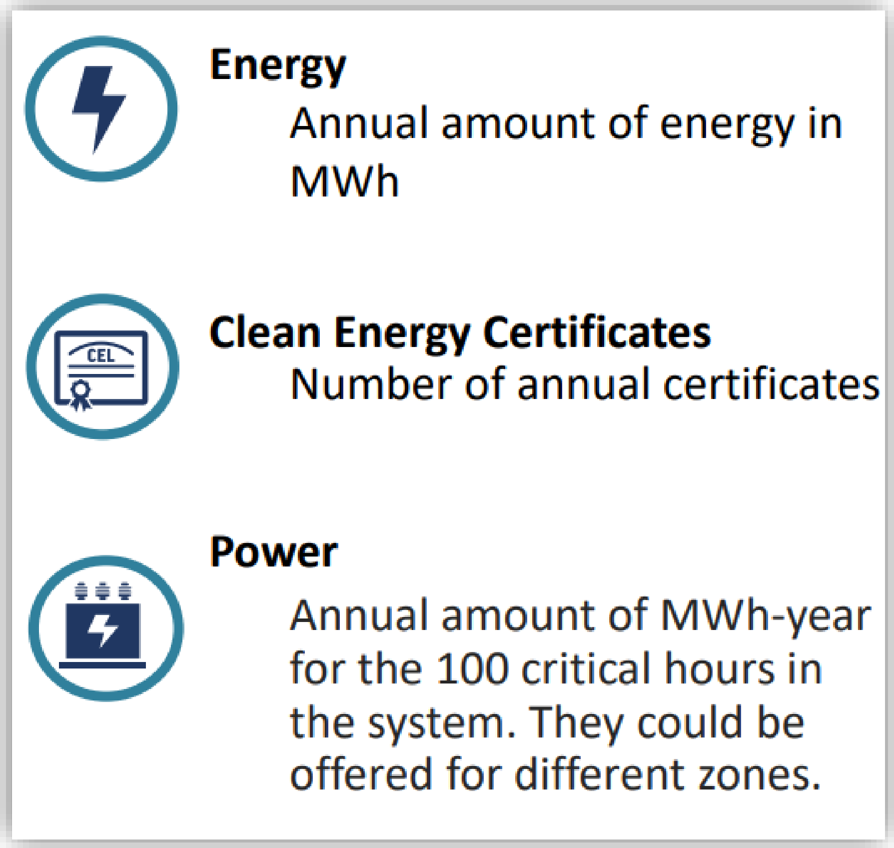
Concept: Co-optimise Long-Term Procurements

Mexico's long-term auctions aimed to procure 3 separate products, with needs defined in an unbundled fashion:

- **15-year: Energy (MWh)**
- **15-year: Capacity (MW)**
- **20-year: Clean Energy Certificates (CECs or CELs*), 1 MWh = 1 CEL**

Auction design:

- Demand for each product from voluntary demand, plus default service provider requirements for: (1) clean energy requirements in each future year, (2) requirements for portion of electricity need that should be contracted (declines with forward period), and (3) portion of needs already contract
- Supply bids in all-in price to supply three products
- Auction administrator applies adjustments to competitive bids to adjust for forecasted differences in zonal energy prices and output time profile (these factors also apply to settlements above/below auction clearing price)
- Meet demand for three products so as to maximise social surplus (similar to minimising total procurement price)
- Separate prices for all 3 products (winning bidders earn revenue stack at clearing price times cleared volume across all three products, for 15/20 years)



Energy
Annual amount of energy in MWh

Clean Energy Certificates
Number of annual certificates

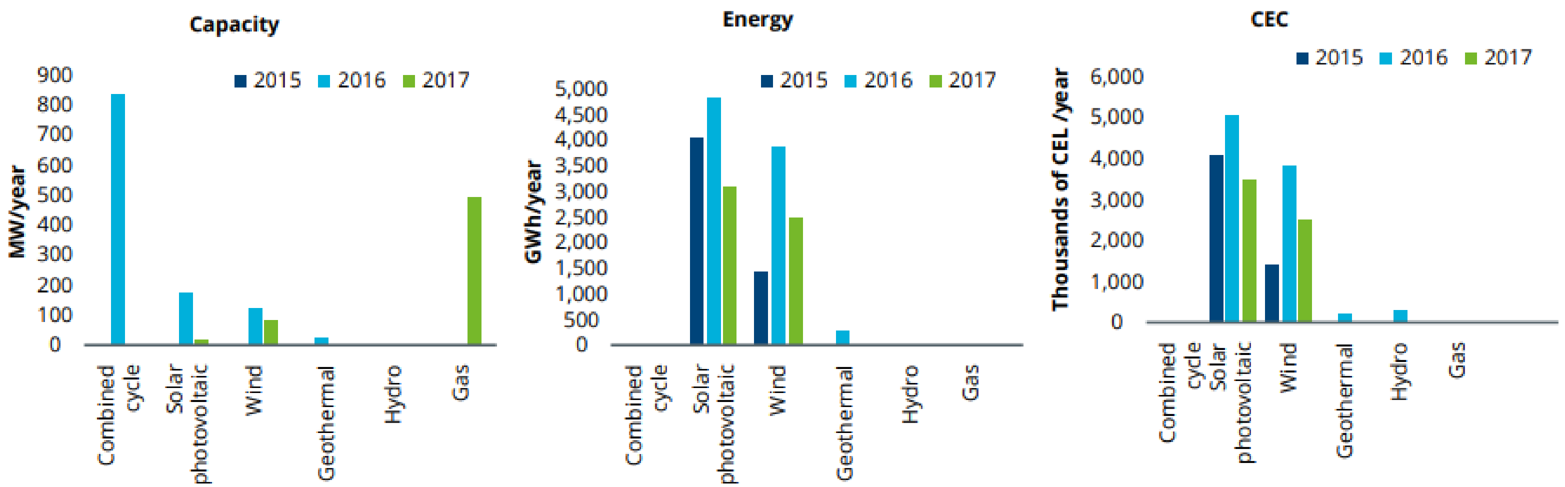
Power
Annual amount of MWh-year for the 100 critical hours in the system. They could be offered for different zones.

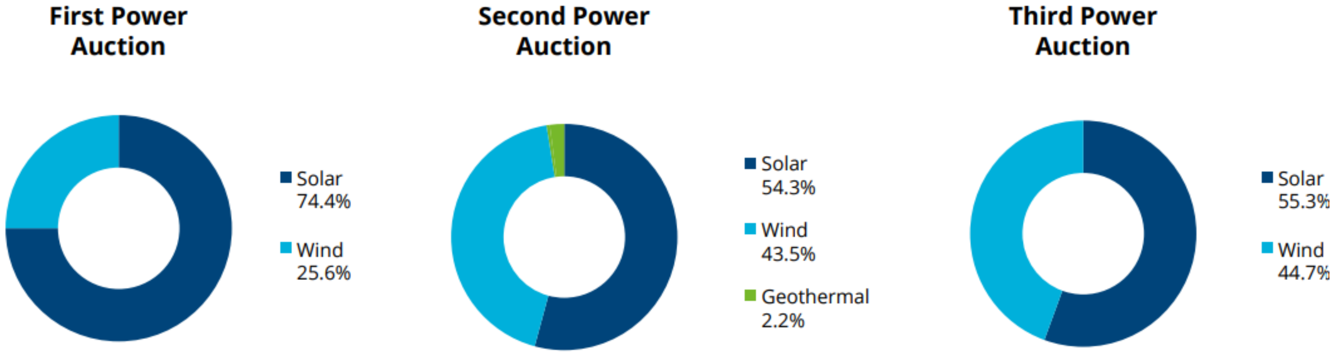
Sources and Notes: *CEL = certificado de energía limpia. Federal Ministry for Economic Affairs and Energy of Germany (BMWi) and Ministry of Energy of Mexico (SENER), The German-Mexican Energy Partnership, [Mexico's New Energy Era](), May 2018, pp. 49+.

MEXICO LONG-TERM AUCTIONS

While fossil plants provided majority of capacity they did not clear for energy or CEC, result was a shift towards a cleaner energy mix

Procurement volumes and prices by resource type in Mexico's long-term auction scheme (2015-2017)





Average price: USD 47.78 per package (MWh+CEC)

Average price: USD 33.47 per package (MWh+CEC)

Average price: USD 20.57 per package (MWh+CEC)

Bundling procurement of energy/capacity/and clean attributes enabled Mexico to achieve world-record low prices for new clean supply

Sources and Notes: Federal Ministry for Economic Affairs and Energy of Germany (BMWi) and Ministry of Energy of Mexico (SENER), The German-Mexican Energy Partnership, Mexico's New Energy Era, May 2018, pp. 49+.

Some jurisdictions have done a better job of creating more integrated approaches to clean security of supply, but many of the concepts are novel, in proposal stage, or have been implemented for a limited time.

Still, better coordination of these objectives simultaneously within markets is needed to achieve Europe's clean energy future

Section V: A Better Path Forward

There is a spectrum of options for market-aligned contracting and procurement models for clean security of supply. Different approaches may be taken but all of these models have key features of better aligning investment needs to serve GHG reductions, as well as maintaining the role of competition and operating incentives to serve complex grid needs.

Competition-driven ⟷ **Planning oriented**

	Energy-Only		Capacity Mechanism		Multi-product Market	Centralised Planning
	+ Strong Carbon/Clean Credit Pricing	+ Clean Supply Requirements	+ Clean Supply Requirements	+ GHG Rate Reductions	Forward Clean Energy + Capacity Mechanism	Clean Policy-driven Planning
Security of Supply	Energy scarcity pricing		Energy + centralised capacity market		Centralised multi-product markets for procuring clean energy + (clean) capacity 1-year for existing capacity and ~15-year contracts for new capacity	Integrated planning, with all source procurements and market-aligned contract structures
Clean Policy	Strong carbon pricing or a tradable clean-energy-credit market	Decentralised model where each TSO must procure portion of national clean energy target through clean-energy certificates or PPAs	Long-term contracts for given amount of clean supply set by government	Targeted procurements of clean resources + GHG rate reductions set on generators		Clean policy determines resource types procured
How to Ensure Success?	Carbon or clean energy credit price must be high enough to reflect social value of clean supply	Need entity for accountability and given enforcement powers of clean energy targets	Transparent and consistent methods for derating factors in capacity market paired with "least-regrets" system planning to set procurement volumes for clean resources through long-term contracts		Co-optimised procurement of distinct products for clean energy, clean capacity, and GHG reductions on a forward basis; enable participation from greater range of customer types, not just TSOs	Ensure contracts are exposed to short-term energy market to ensure pricing discipline

Contact information

Dr. Andrew W. Thompson

ENERGY ASSOCIATE | MADRID

Andrew.Thompson@brattle.com

Dr. Thompson is an energy economist with a background in electrical engineering and expertise in wholesale electricity market design, regulatory economics, and policy analysis of network industries, particularly in the energy sector. Dr. Thompson has supported clients and diverse stakeholder groups – including electricity system operators, energy regulators, governments, clean energy advocacy groups, market participants, institutional investors, and utilities – in several international jurisdictions. He earned a Ph.D. in Economics from the Université Paris-Saclay (France), an MS in Energy Economics from the Pontificia Universidad Comillas (Spain), an MSc. in Engineering and Policy Analysis from TU Delft (The Netherlands), and a BSc. in Electrical and Computer Engineering from Rowan University (USA).

Dr. Kathleen Spees

PRINCIPAL | WASHINGTON DC

Kathleen.Spees@brattle.com

Dr. Spees is a Principal at The Brattle Group with expertise in wholesale electricity markets design and carbon policies. Her expertise focuses on wholesale electricity market design, environmental policy, economic analysis, and modeling. For market operators she supports implementation and development of wholesale markets including energy, ancillary services, capacity, FTRs, clean energy attribute markets, and integration of emerging technologies. She supports stakeholders to develop GHG reduction policy alternatives, conduct power sector and economy-wide modeling of GHG abatement pathways, and assess benefits/costs in the context of policy reforms for clean energy transition. Dr. Spees earned her PhD in Engineering and Public Policy within the Carnegie Mellon Electricity Industry Center and her MS in Electrical and Computer Engineering from Carnegie Mellon University. She earned her BS in Physics and Mechanical Engineering from Iowa State University.