Market Power and Incentive-Based Capacity Payment Mechanisms

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Capacity payments are an increasing share of revenue for generation firms in electricity markets around the world

- Three primary sources of revenue for generators
  1. Sales of electricity in the short-term market
  2. Sales of forward contracts
  3. Capacity payments
- Capacity mechanisms in the U.S. have been successful at providing revenue to generators... but less successful in ensuring that capacity is available when required

We will study a special type of incentive-based capacity mechanism based on payments for "firm energy"

- Various names for the mechanism we study: reliability option, peak energy refund, pay-for-performance, firm energy refund
- The mechanism provides a market-based incentive for generators to provide at least their firm energy quantity
- Widely considered to be the best-practice design for capacity payments
- Adopted in Colombia, New England ISO, and Ireland—and under consideration in several other markets

Firm energy mechanism is based on the idea of a "scarcity period" that creates an obligation for sellers of firm energy

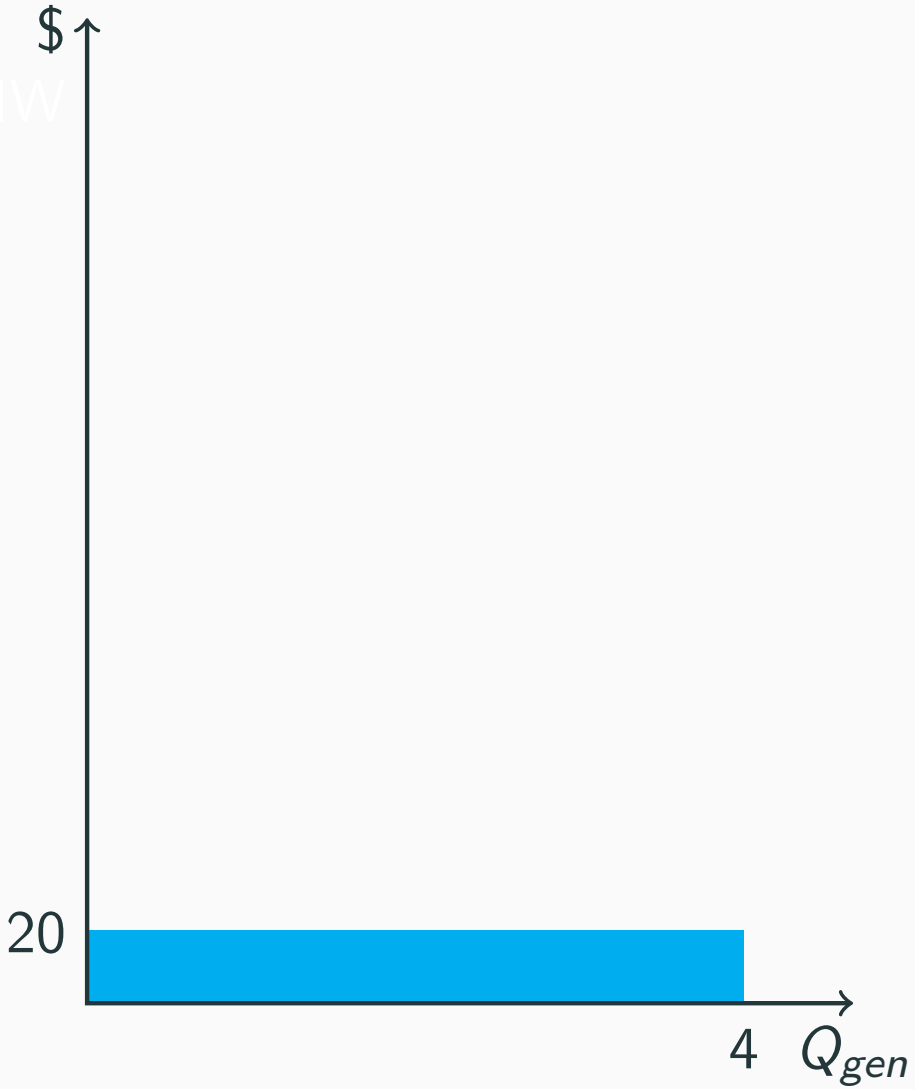
- Administrative formula sets a **scarcity price**
- Scarcity periods occur when the market price exceeds the scarcity price
- During scarcity periods:
  - The price that load pays for electricity is capped at the scarcity price
  - Generators have an obligation to make or pay the difference between the market price and the scarcity price, for the quantity of firm energy they sold
- Generators have an incentive to supply at least their firm energy quantity during scarcity period
- No obligations for generators during non-scarcity periods

We show that the interaction between firm energy and forward contracts creates perverse incentives for generators

- Large generators can **choose** whether or not a scarcity condition exists
- In some hours, it can be optimal for generation firms to withhold generation and create a scarcity condition
- For the example of the Colombian wholesale market, we show that generators recognize and respond to these incentives
- As a result, firm energy mechanism may lead to lower reliability, higher generation costs, and higher prices
- We suggest an alternative based on modifications to the existing forward contract design

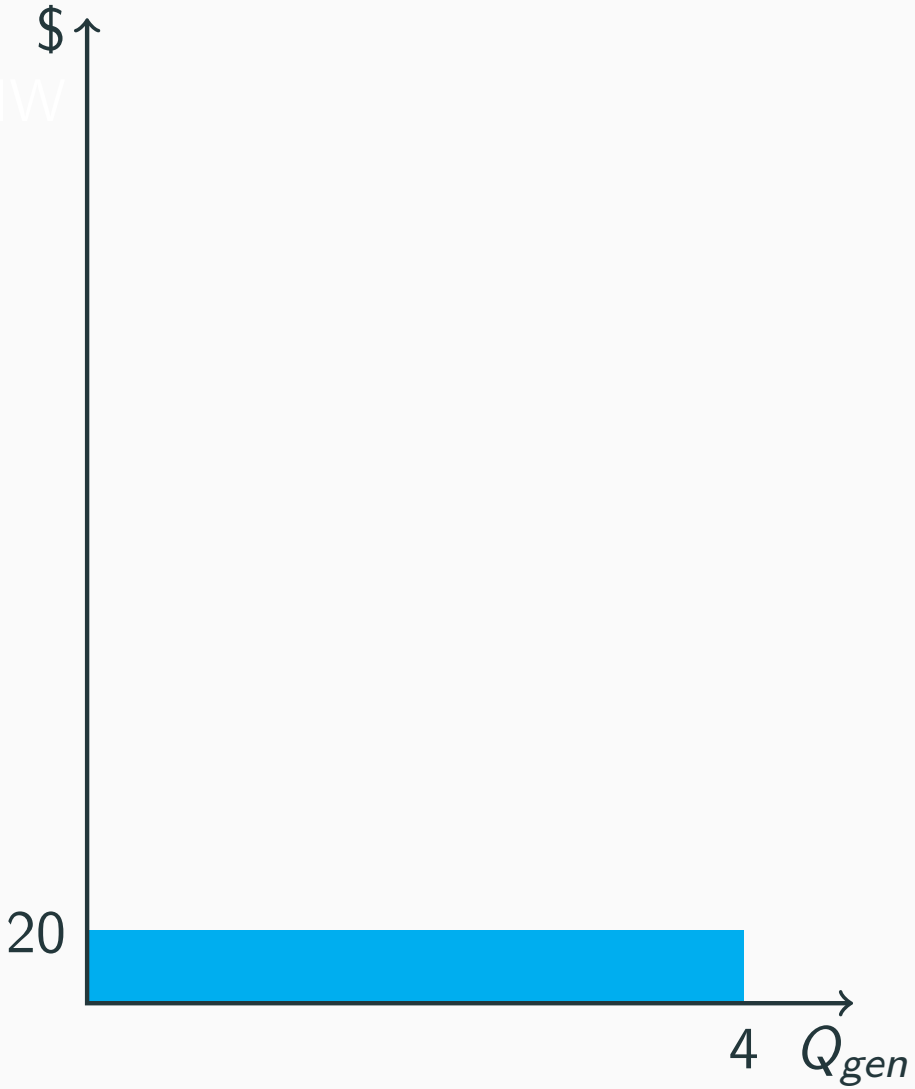
What are forward contracts?

Suppose we have a firm that generates 4 GW in one hour and sells it at the market price of $20/MWh



Forward obligation

Revenue from generation sales for the firm in this hour will be $80,000 (ignore costs for this example)



Generation sales

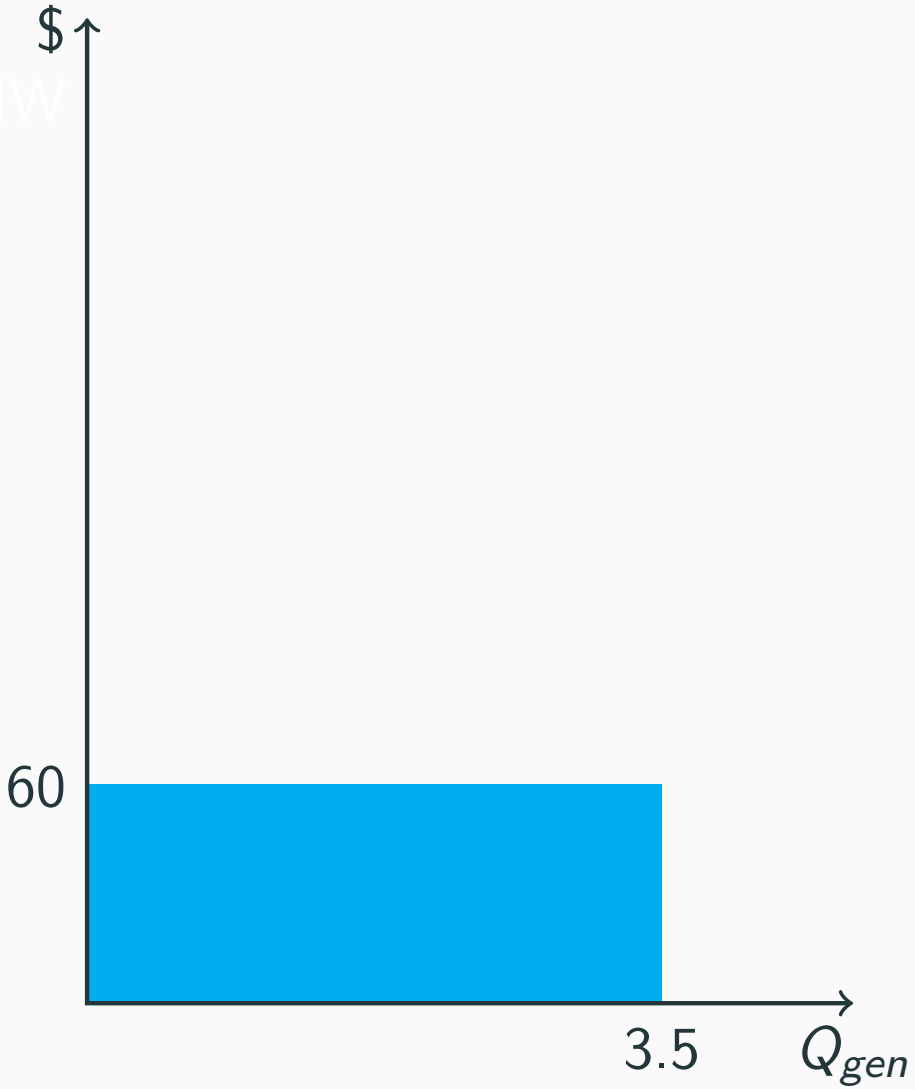
+80

Forward obligation

NET REVENUE

80

By producing a lower quantity, the market price will be higher, and generation revenue will increase



Generation sales

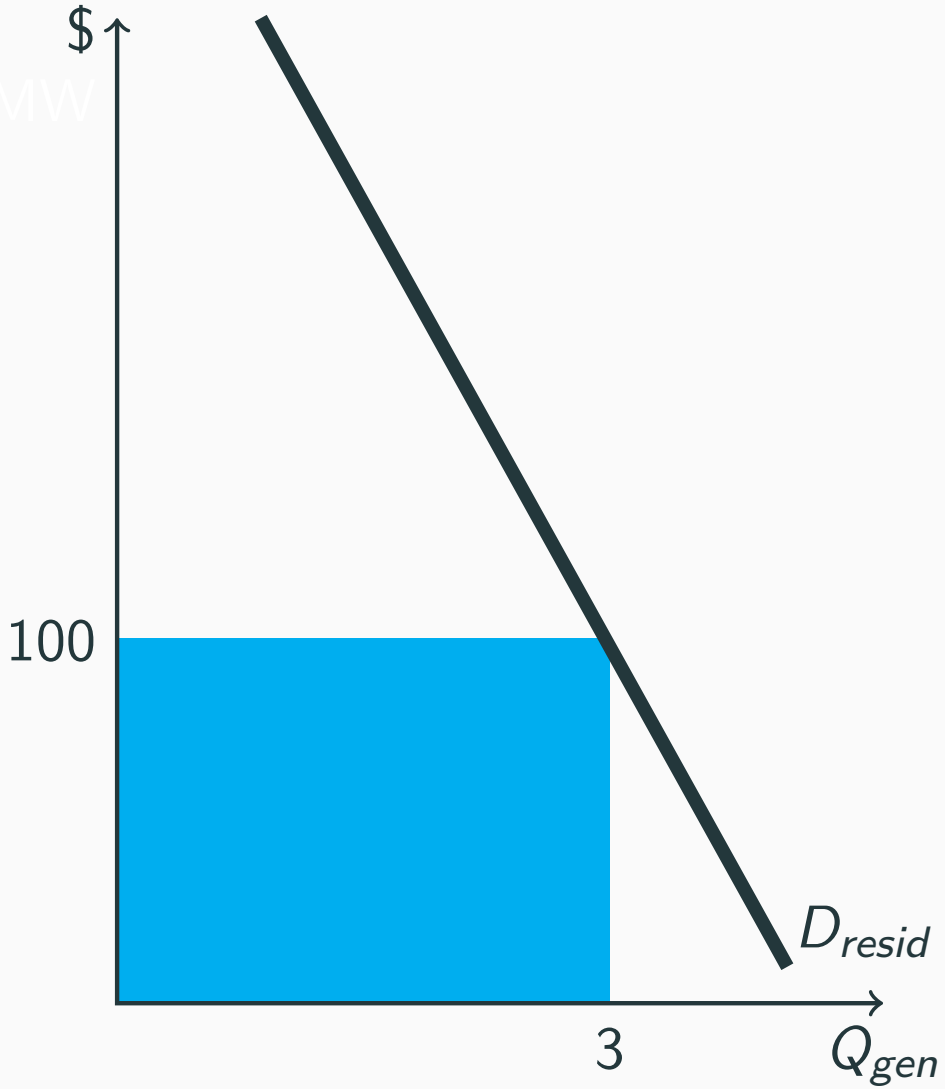
+210

Forward obligation

NET REVENUE

210

Residual demand line traces out the possible combinations of prices and quantities for the firm



Generation sales

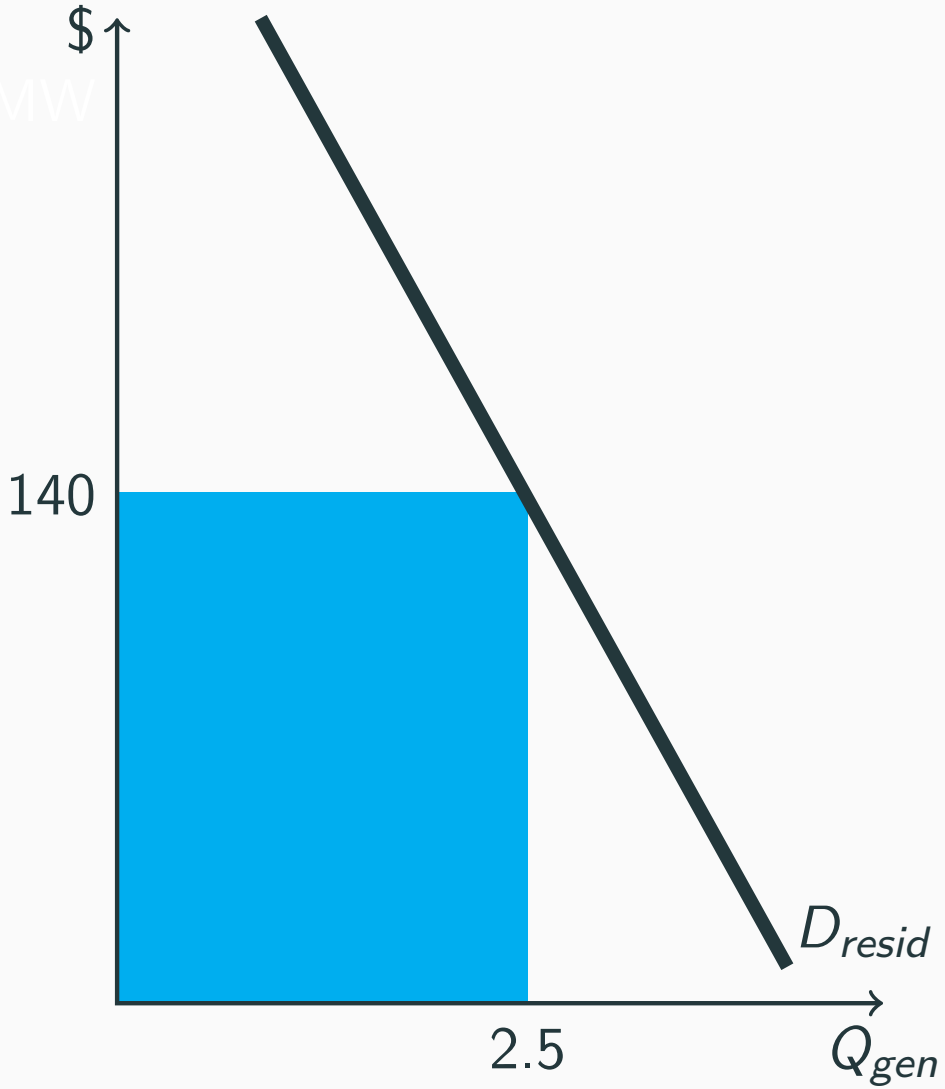
+300

Forward obligation

NET REVENUE

300

Residual demand line traces out the possible combinations of prices and quantities for the firm



Generation sales

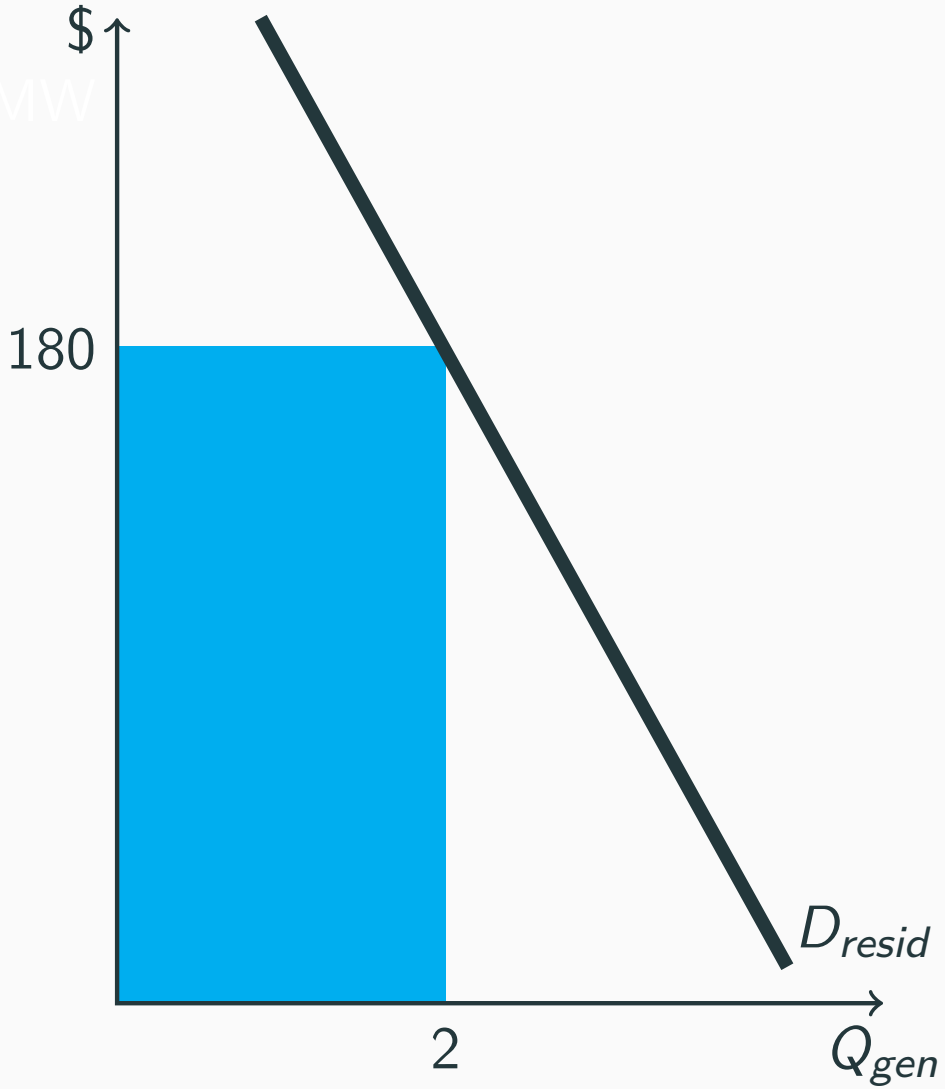
+350

Forward obligation

NET REVENUE

350

Firm will earn the highest possible revenue by reducing its generation to 2 GW and selling at a price of $180

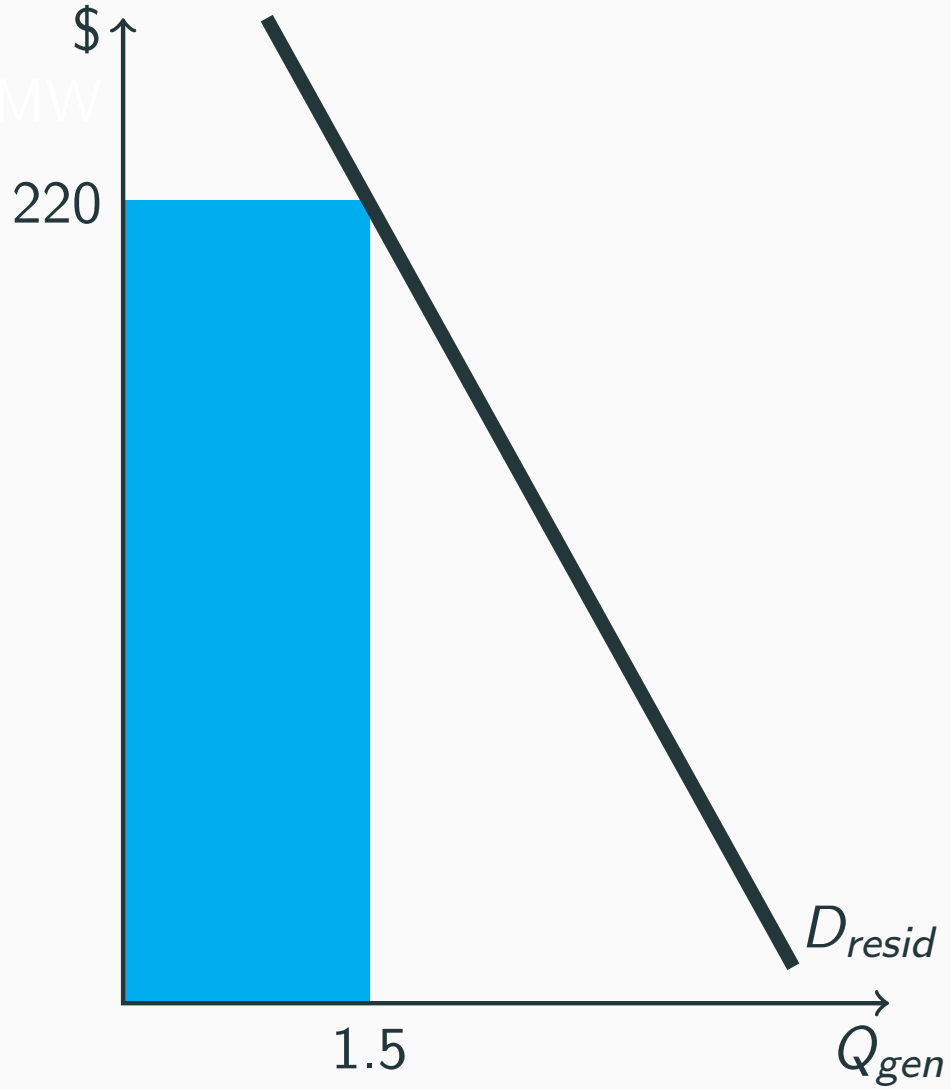


Generation sales
+360

Forward obligation

NET REVENUE
360

Further reductions in generation will lead to higher prices, but revenues will start to fall



Generation sales

+330

Forward obligation

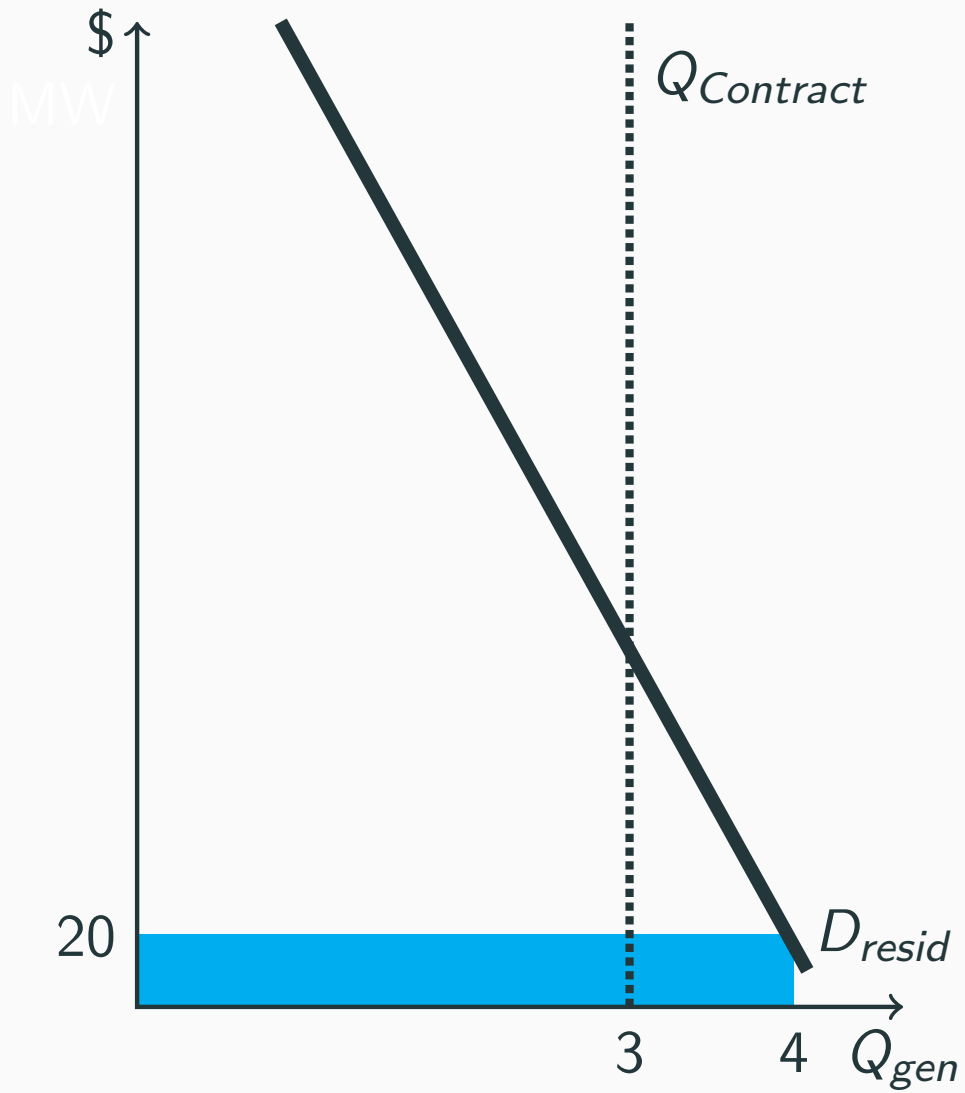
NET REVENUE

330

Now we introduce forward contracts to show how they affect the firm's incentive to push up the market price

- Suppose the firm sells 3 GW of forward contracts for a fixed price of $60/MWh
- This gives constant revenue stream each hour of $180,000
- But the firm has to **buy** 3 GW at the market price to meet its forward contract obligations

Start again by considering a firm that generates 4 GW in one hour and sells it at the market price of $20/MWh



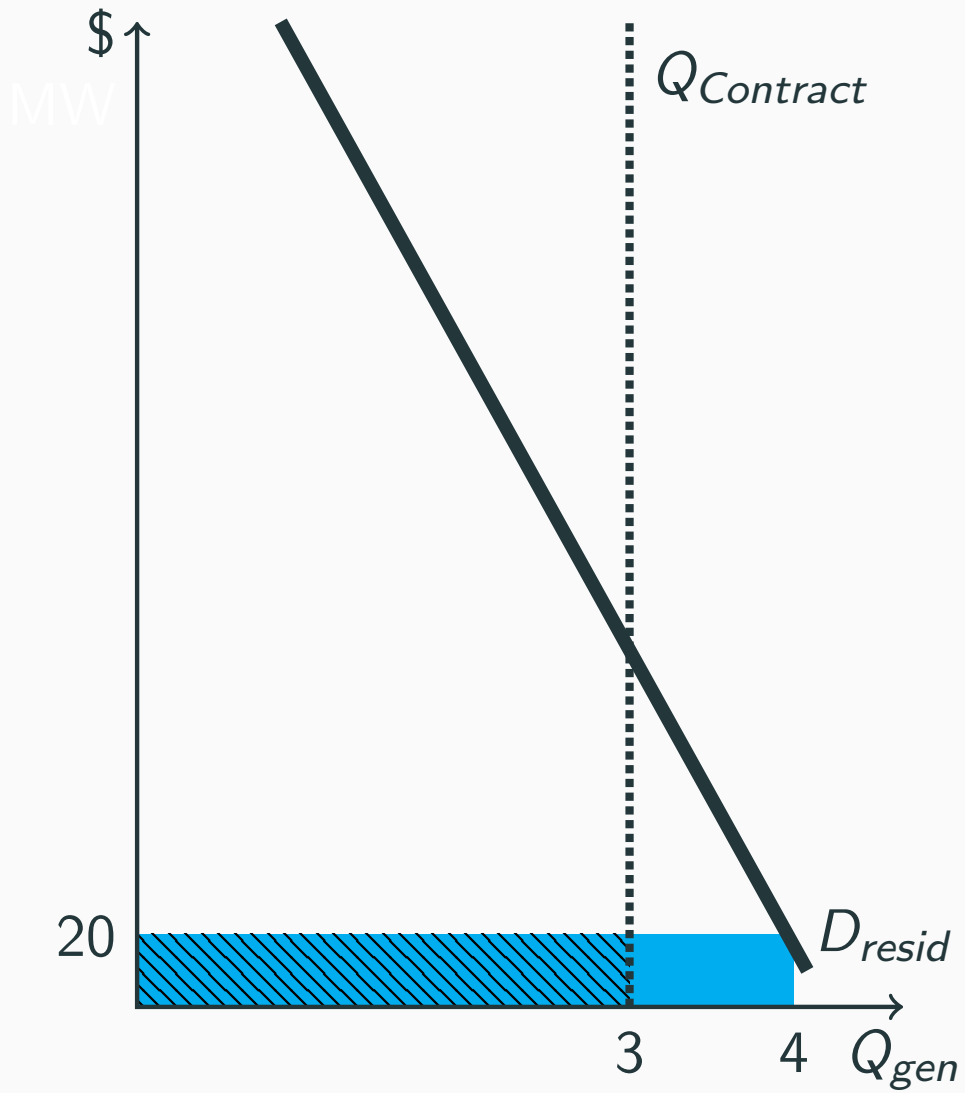
Contract sales
+180

Generation sales
+80

Forward obligation

NET REVENUE

The forward contract obligation requires the firm to buy 3 GW at the market price of $20/MWh



Contract sales

+180

Generation sales

+80

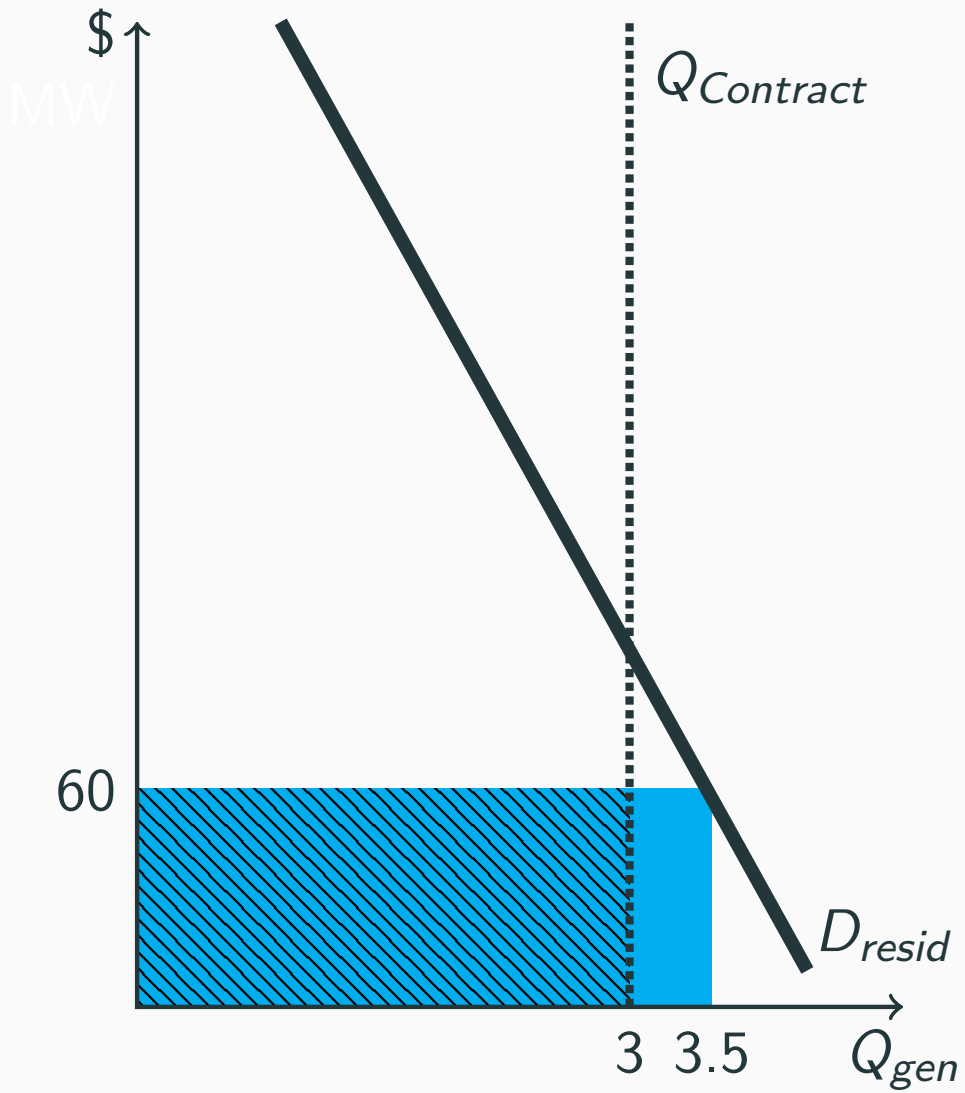
Forward obligation

−60

NET REVENUE

200

Increasing the price will increase the generation revenue but also increase the forward contract obligation



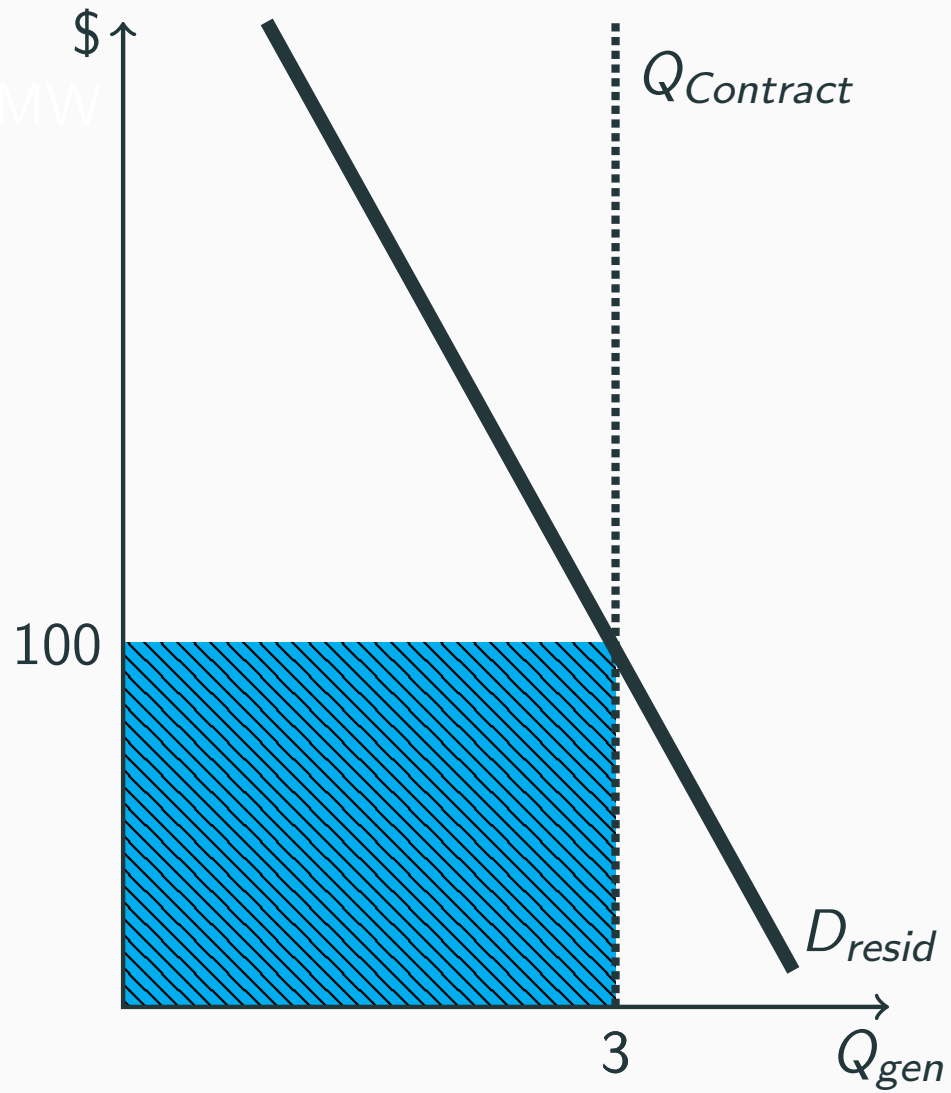
Contract sales
+180

Generation sales
+210

Forward obligation
−180

NET REVENUE
210

If the firm generates exactly its forward contract quantity, then the net revenue will be the revenue from contract sales



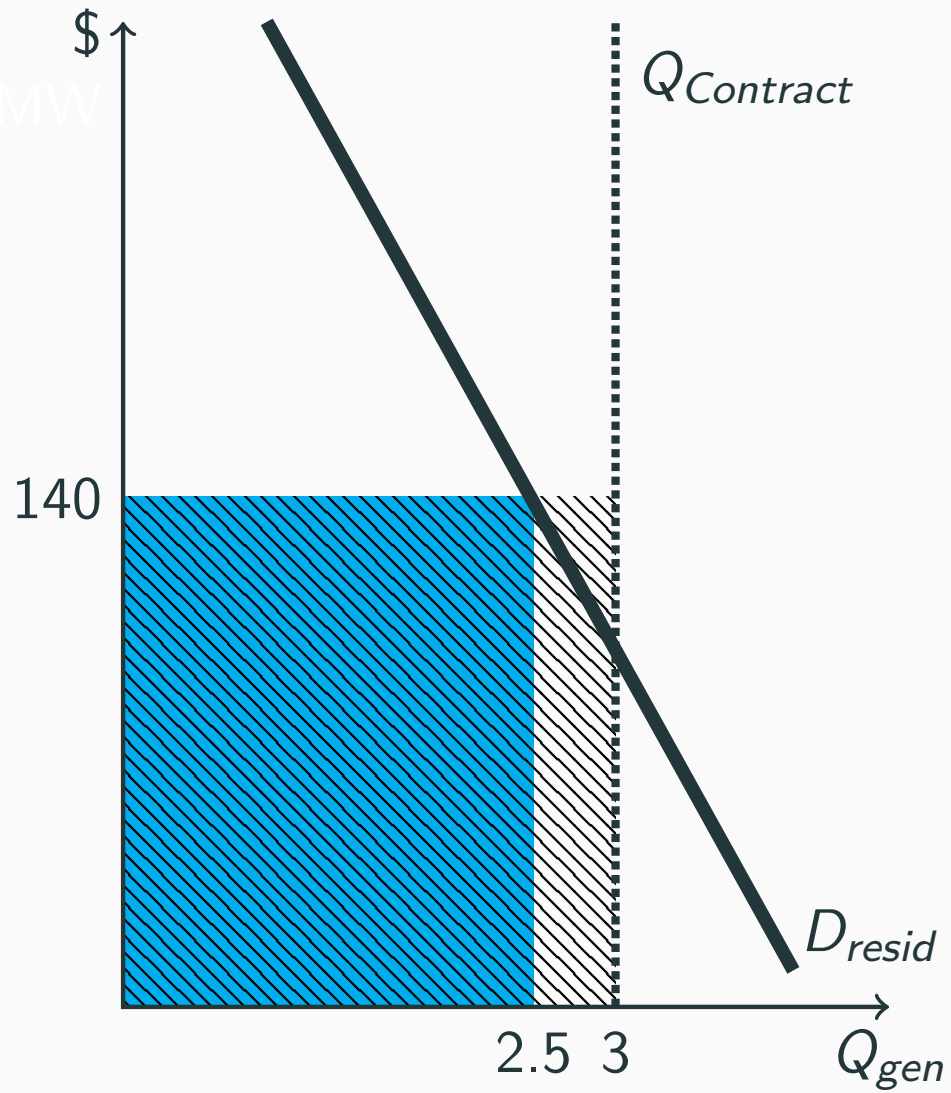
Contract sales
+180

Generation sales
+300

Forward obligation
−300

NET REVENUE
180

Reducing the generation quantity further means that the firm is a net buyer—at a price that continues to increase



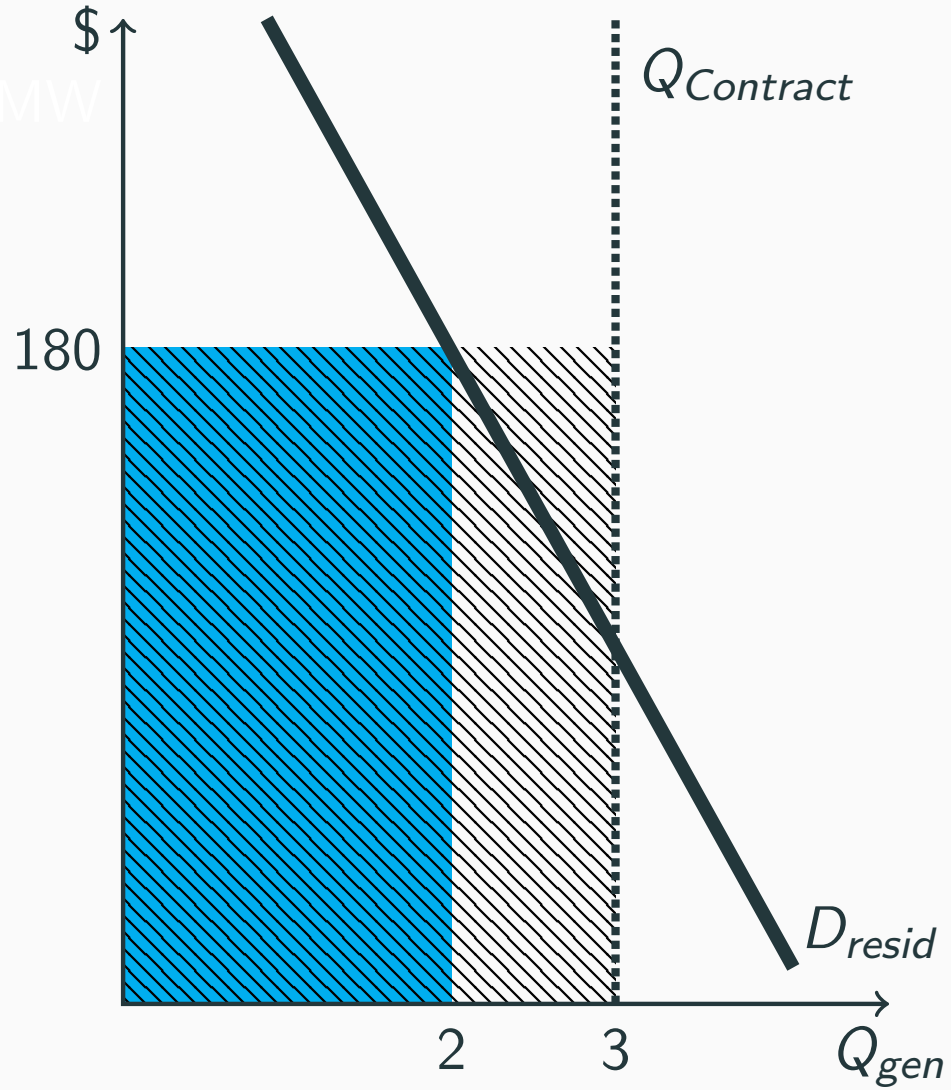
Contract sales
+180

Generation sales
+350

Forward obligation
−420

NET REVENUE
110

Reducing the generation quantity further means that the firm is a net buyer—at a price that continues to increase



Contract sales

+180

Generation sales

+360

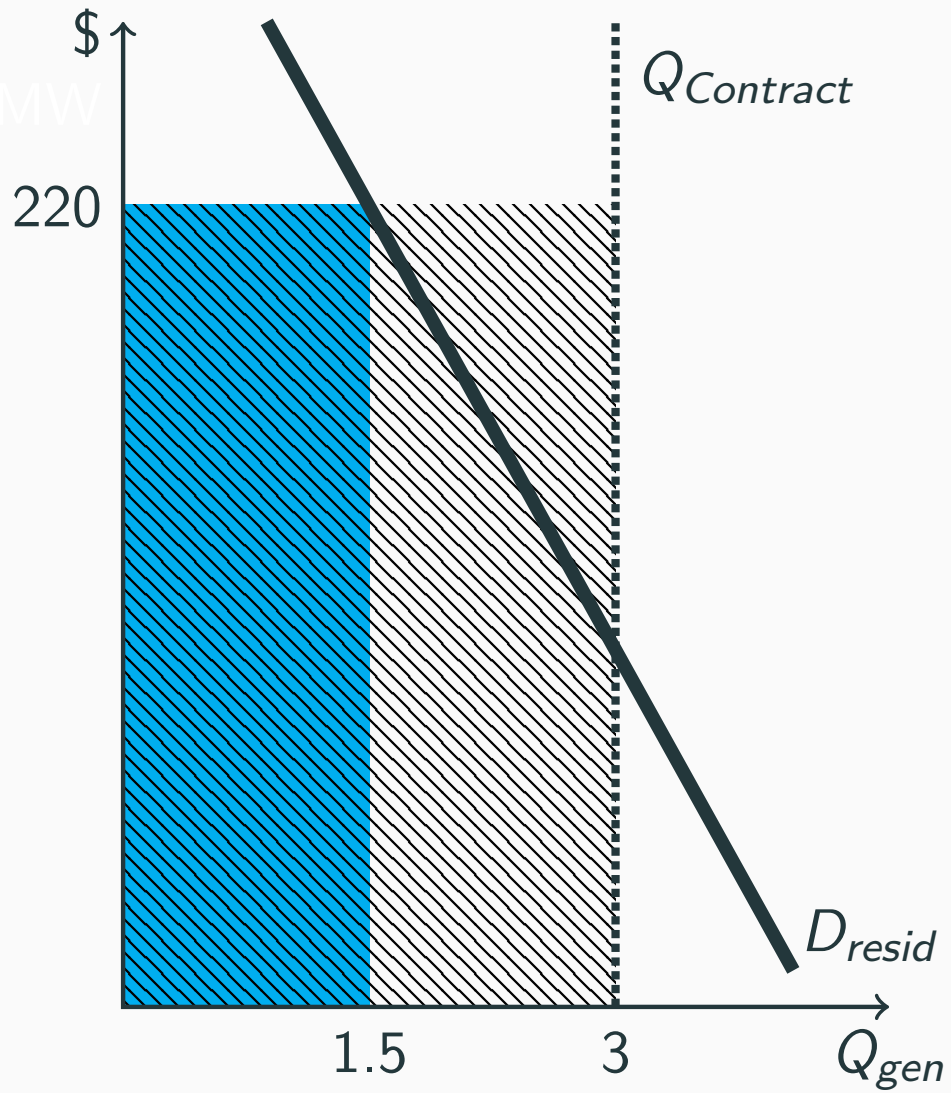
Forward obligation

−540

NET REVENUE

0

Net revenue can even go negative, if the firm has to buy a sufficiently large quantity to cover its forward obligations



Contract sales
+180

Generation sales
+330

Forward obligation
−660

NET REVENUE
−150

Selling forward contracts gives a powerful incentive to the firm not to withhold generation and push up the market price

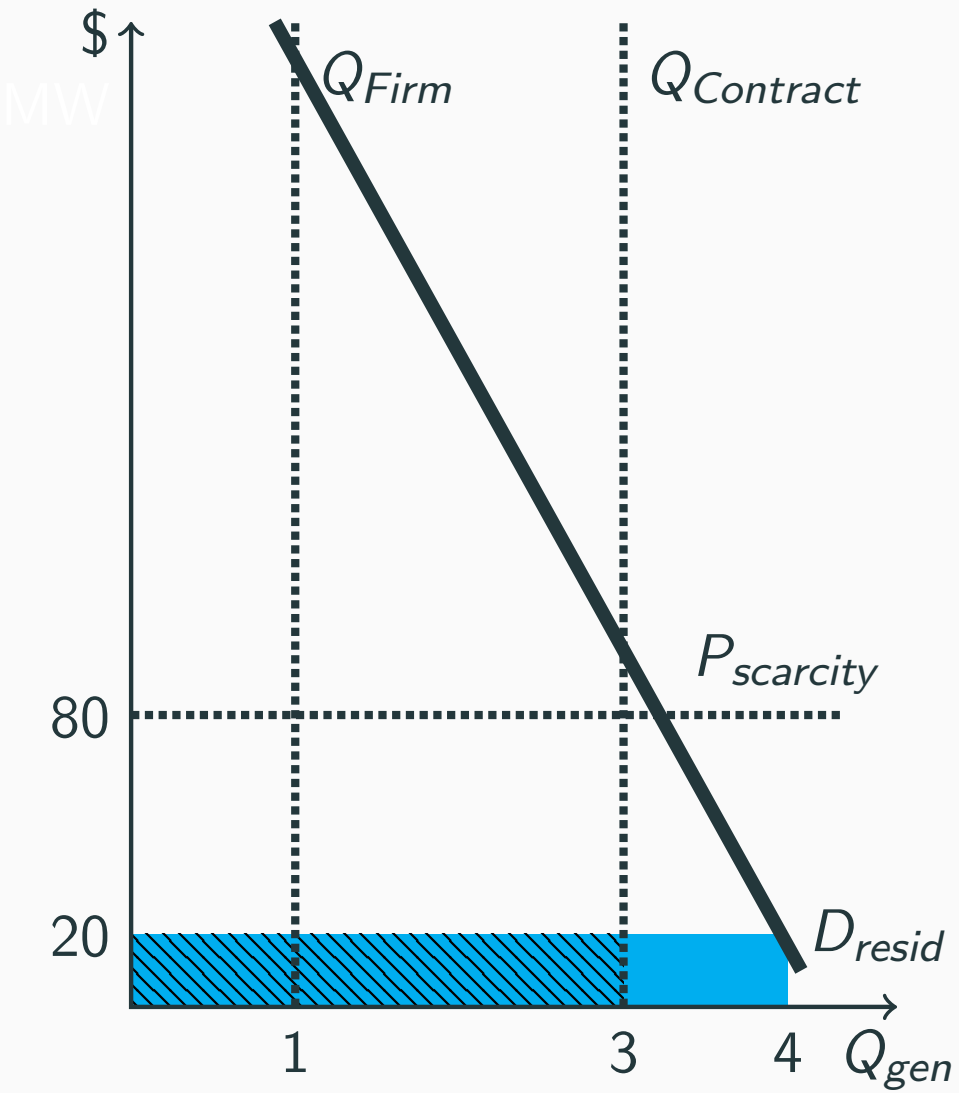
- In this example, net revenue is highest when the firm generates a quantity of 3.5 GW
- No longer profitable to withhold generation and increase the market price—because this will also increase the size of the forward contract obligation

What will change when we introduce firm energy contracts?

In addition to the forward contracts, we introduce firm energy contracts to see how incentives will change

- Suppose the generator **also** sells 1 GW of firm energy contracts at a price of $20/MWh
- Suppose the system operator sets a **scarcity price** of $80/MWh
- The firm energy contracts create two changes:
  - The price for the forward contract obligation is capped at $80/MWh
  - When the market price exceeds $80/MWh, there is a 1 GW firm energy obligation for the difference between the market price and the scarcity price

When the market price is below the scarcity price, everything is identical to before, except for the firm energy revenue



Contract sales

+200

Generation sales

+80

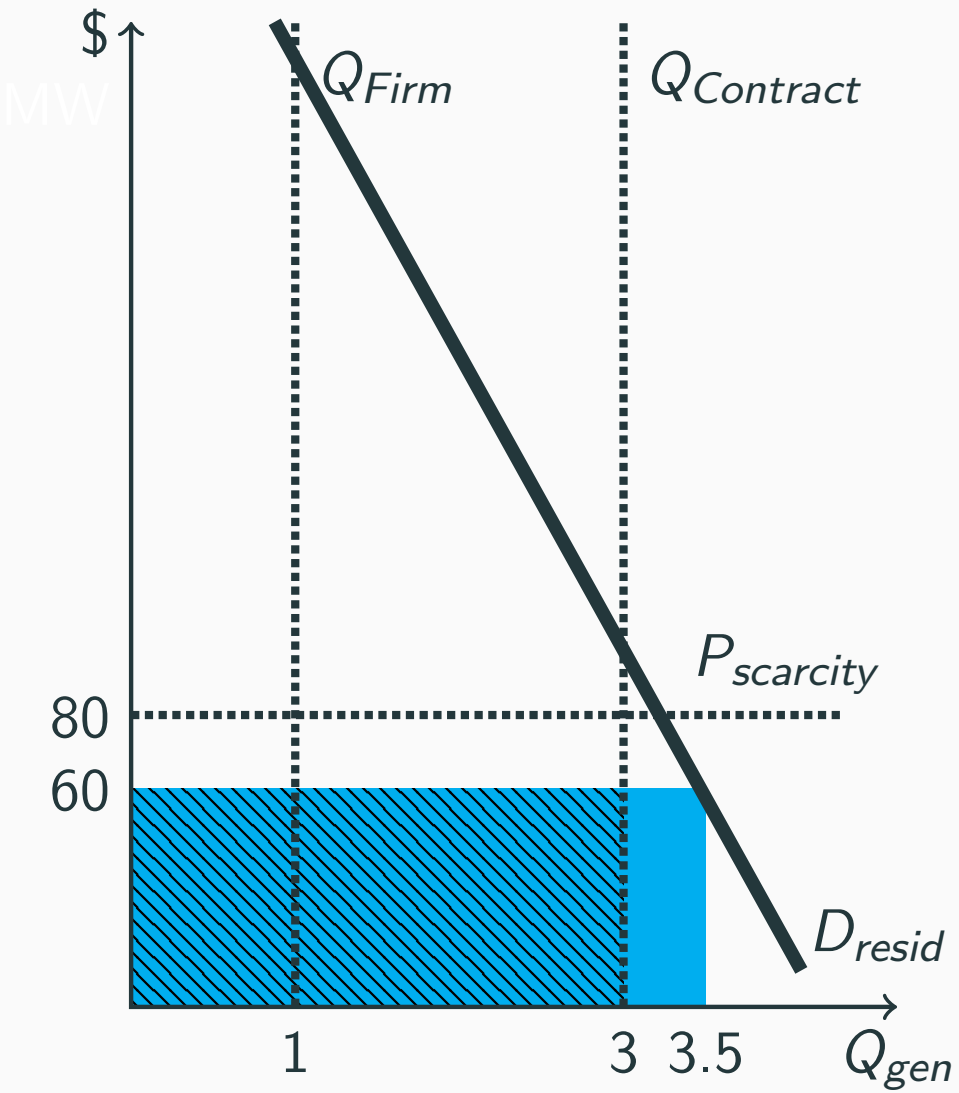
Forward obligation

−60

NET REVENUE

200

When the market price is below the scarcity price, everything is identical to before, except for the firm energy revenue



Contract sales

+200

Generation sales

+210

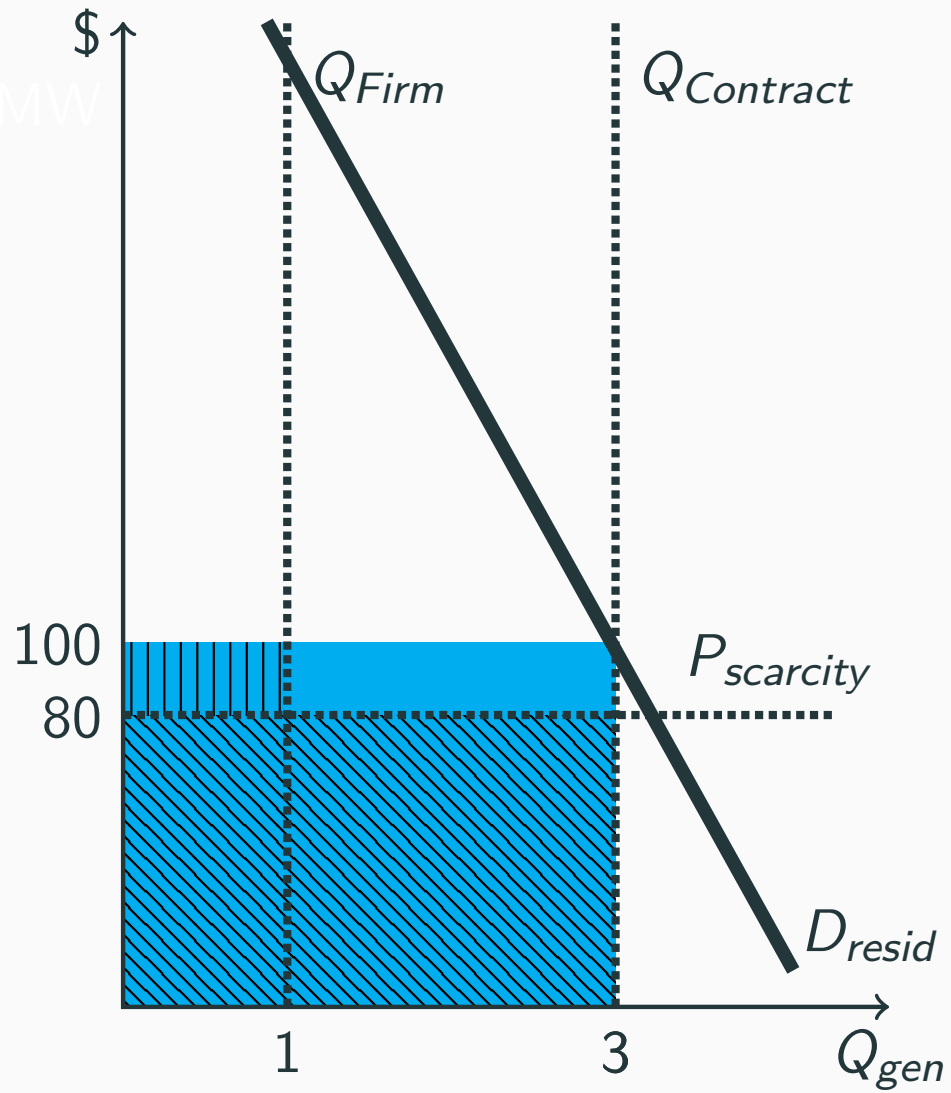
Forward obligation

−180

NET REVENUE

210

When the price is above the scarcity price, the firm must pay the difference, but only for the firm energy quantity



Contract sales
+200

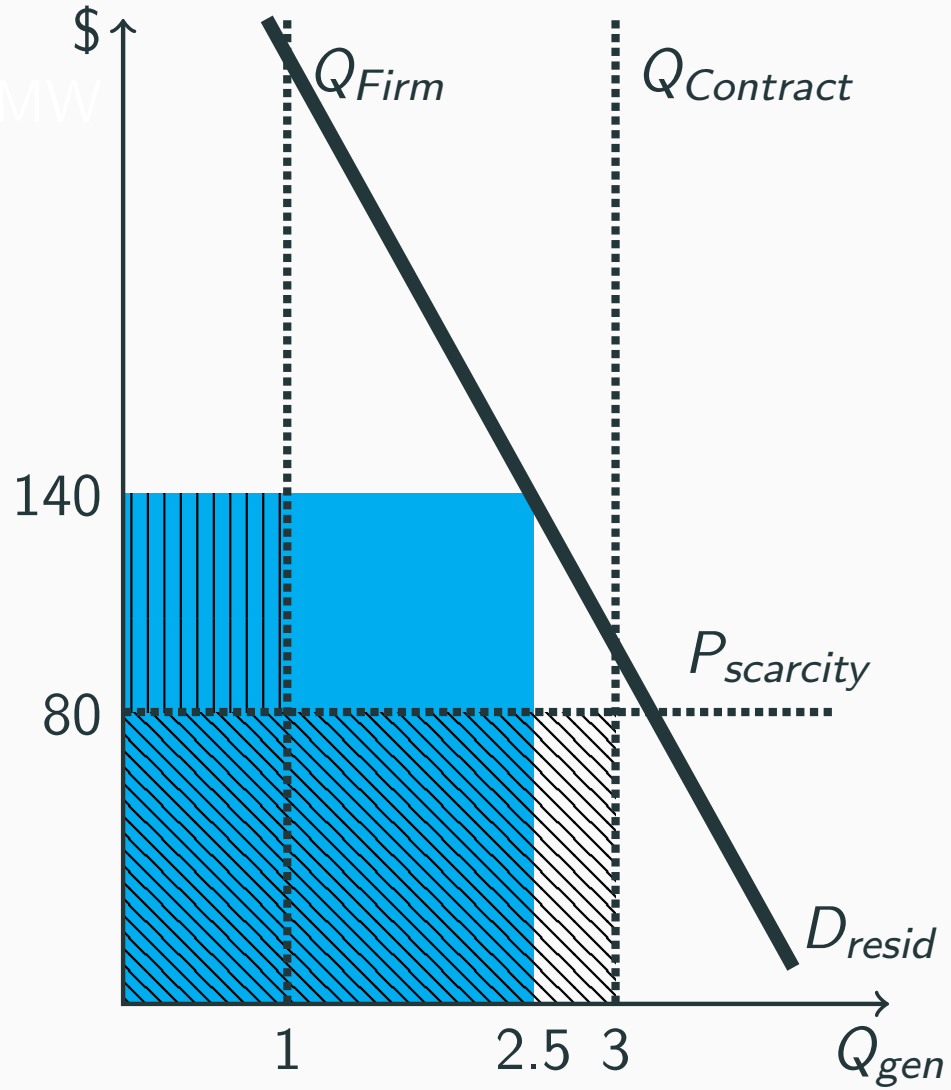
Generation sales
+300

Forward obligation
−240

Firm obligation
−20

NET REVENUE
240

With firm energy, the generator will find it optimal to withhold generation to below the forward contract quantity



Contract sales
+200

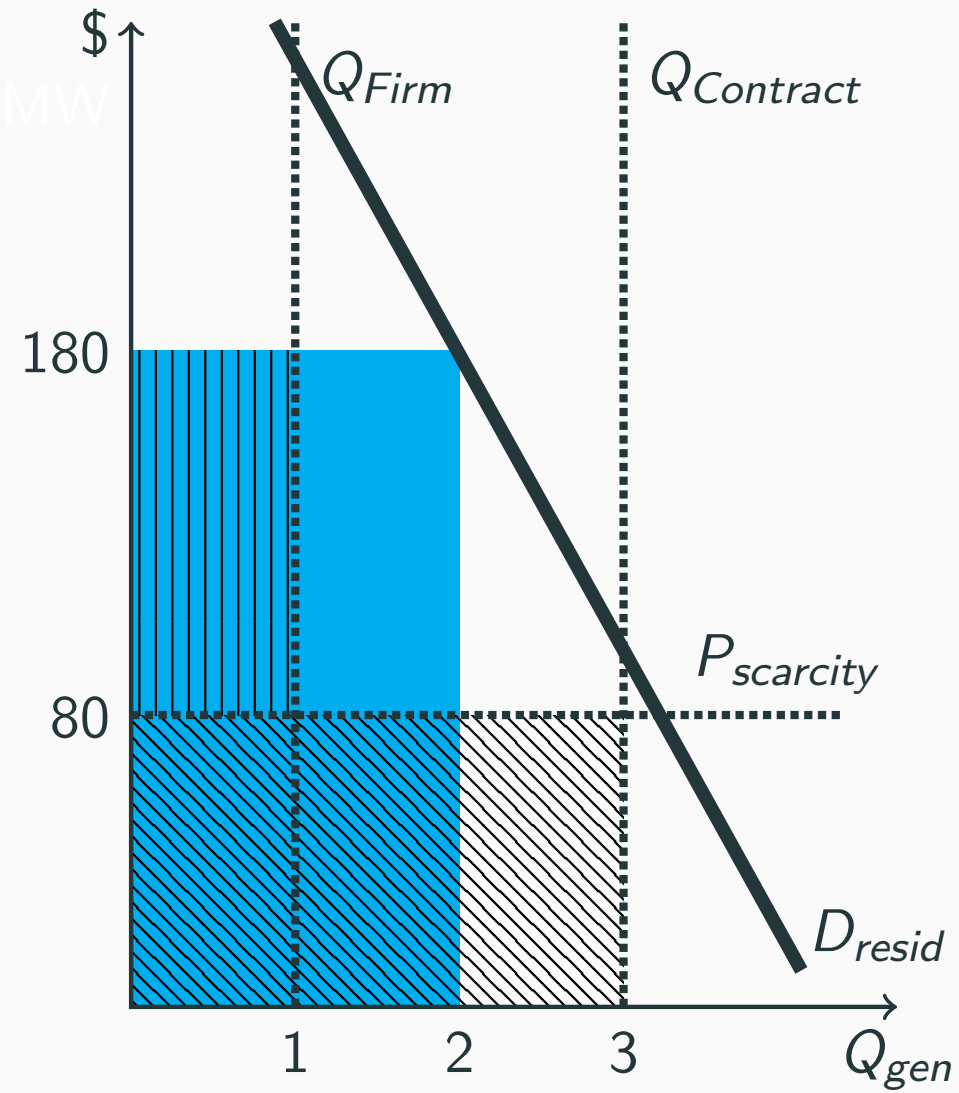
Generation sales
+350

Forward obligation
−240

Firm obligation
−60

NET REVENUE
250

The forward contract obligation is capped at the scarcity price, reducing the disincentive to push up the market price



Contract sales
+200

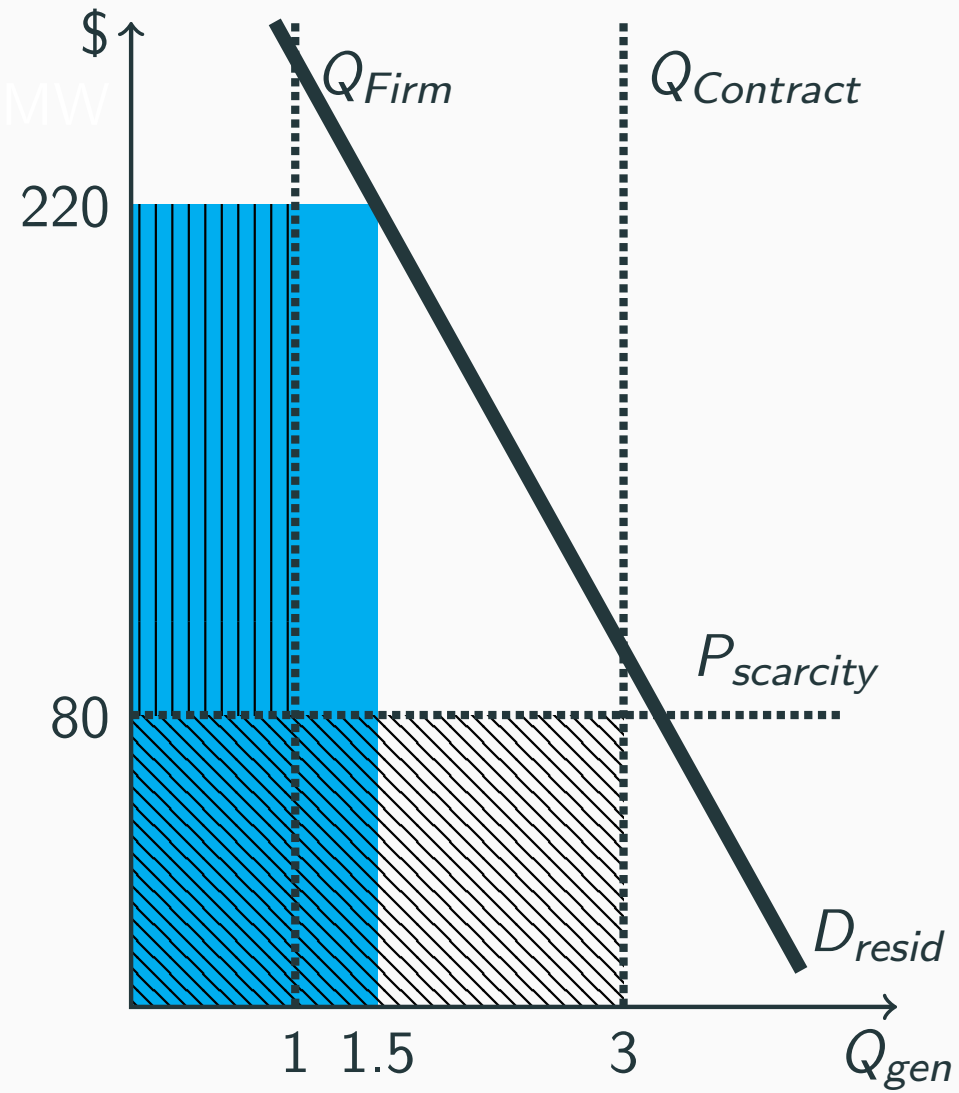
Generation sales
+360

Forward obligation
−240

Firm obligation
−100

NET REVENUE
220

The forward contract obligation is capped at the scarcity price, reducing the disincentive to push up the market price



Contract sales
+200

Generation sales
+330

Forward obligation
−240

Firm obligation
−140

NET REVENUE
150

With firm energy contracts, the generator has an incentive to withhold generation capacity

- In the example with forward contracts **and** firm energy, optimal generation quantity was 2.5 GW
- With only forward contracts, the optimal generation quantity was 3.5 GW
- Although consumers pay for the firm energy contracts, they receive higher prices and lower generation availability

Is it realistic to assume that the firm energy contract quantity is below the forward contract quantity?

- Math relies on firm energy quantity being lower than forward contract quantity

Is it realistic to assume that the firm energy contract quantity is below the forward contract quantity?

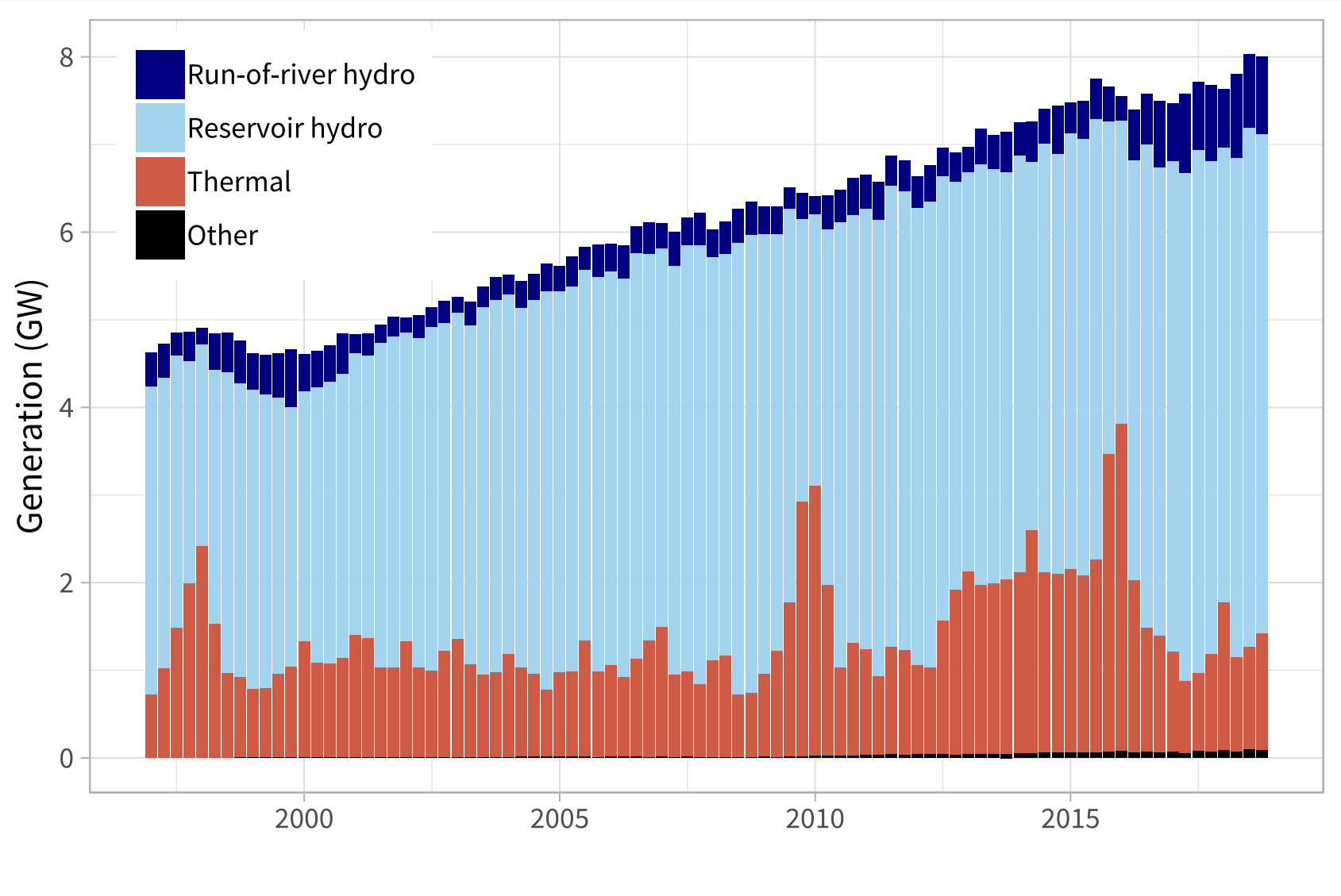
- Math relies on firm energy quantity being lower than forward contract quantity
- With intermittent renewable generation, this will usually be the case
- System operator assumes a "worst case" scenario for calculating firm energy

Do generators recognize the firm energy incentive?

We study the performance of the firm energy mechanism in Colombia, where it was introduced in 2006

- Colombian wholesale market is bid-based (similar to U.S. market design)
  - Generation firms bid hourly quantities and daily prices into the wholesale market
- In addition, there are long-term auctions for firm energy every 4 or 5 years
- Price in this auction sets the price that all plants (not just new ones) receive for their firm energy
- Scarcity price is determined by an administrative formula linked to fuel oil prices

Hydro is the dominant form of generation in Colombia but is subject to periodic shortfalls due to El Niño climate pattern



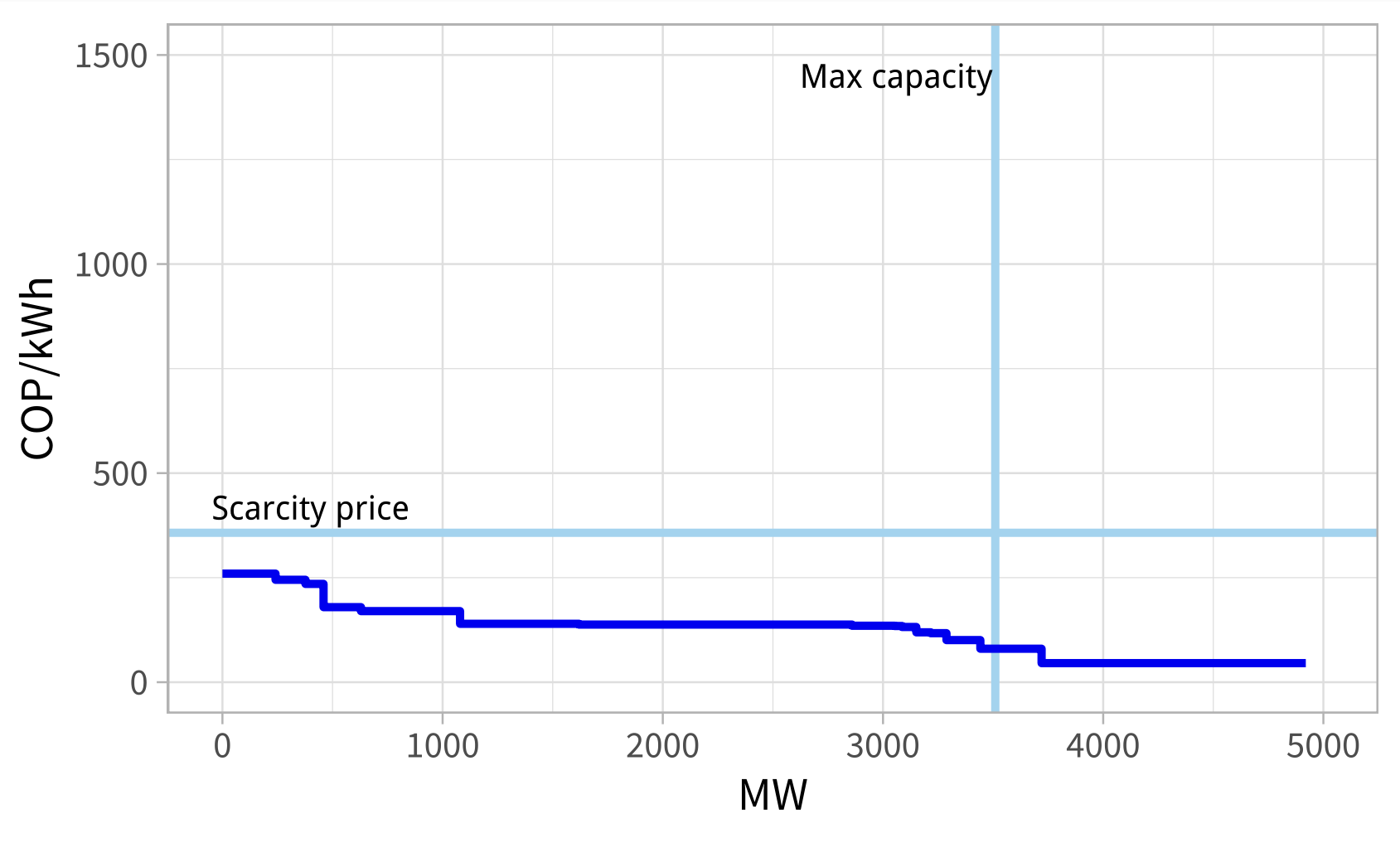
We use hourly data from the Colombian system operator XM to study the performance of the firm energy mechanism

- We have data on plant-level generation, bids, fuel prices, and contract positions
- Focus on three largest firms: EPM, Emgesa, Isagen
  - These firms own more than 60% of the system capacity
  - Most of their generation is hydro
- Many small owners of thermal generation plants—we treat these as competitive

We first show that the large generation firms have the ability to choose whether there is a scarcity condition

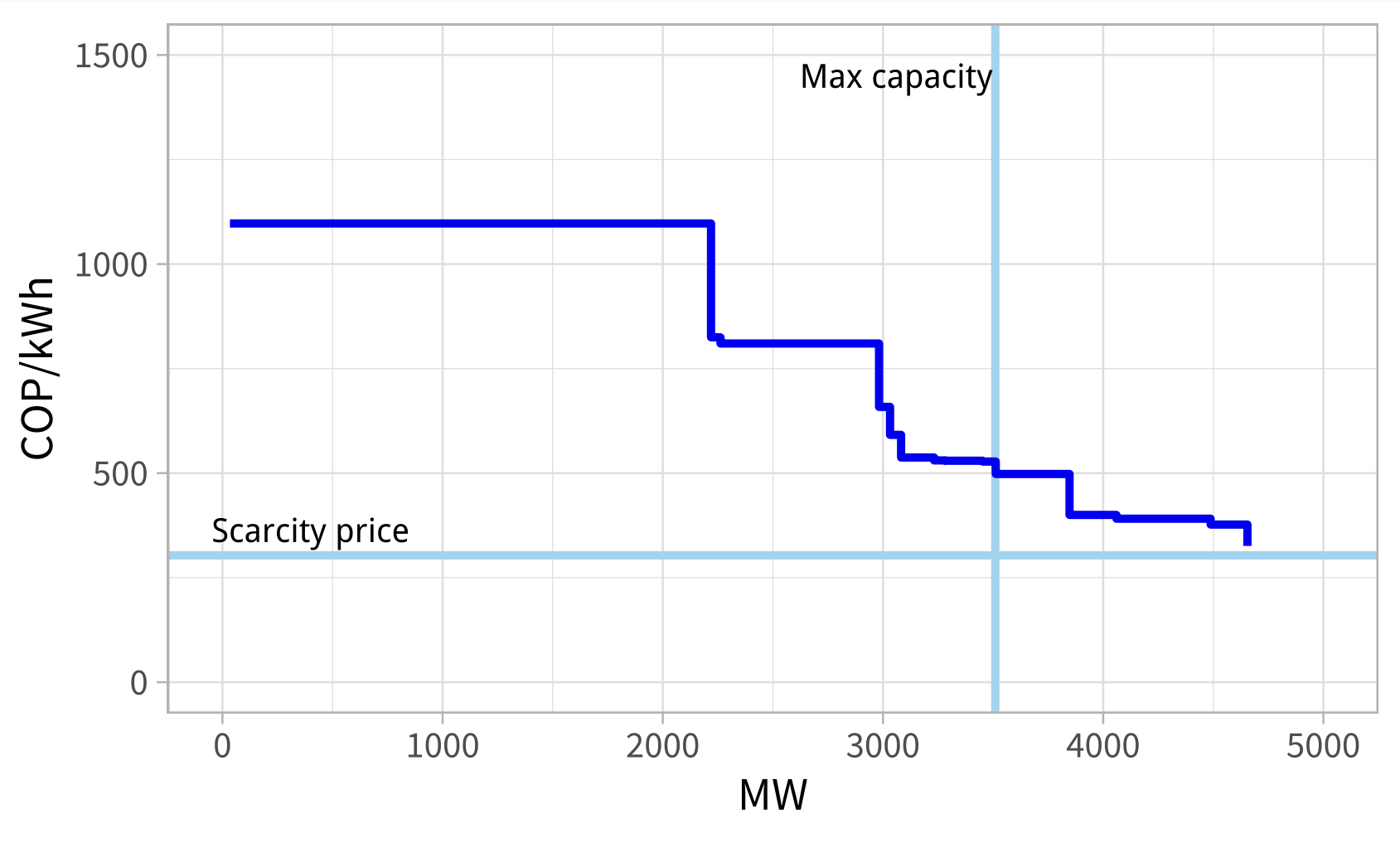
- For each firm and hour, we calculate the residual demand that it faces
  - This is the market demand, less the bids of all of the other firms
- Generation firm can choose combination of price and quantity along its residual demand curve

When residual demand lies below the scarcity price, generator does not have ability to create scarcity condition



Residual demand for EPM on 25 July 2015, at 6:00 PM.

When residual demand lies completely above the scarcity price, scarcity condition will occur for any generation quantity

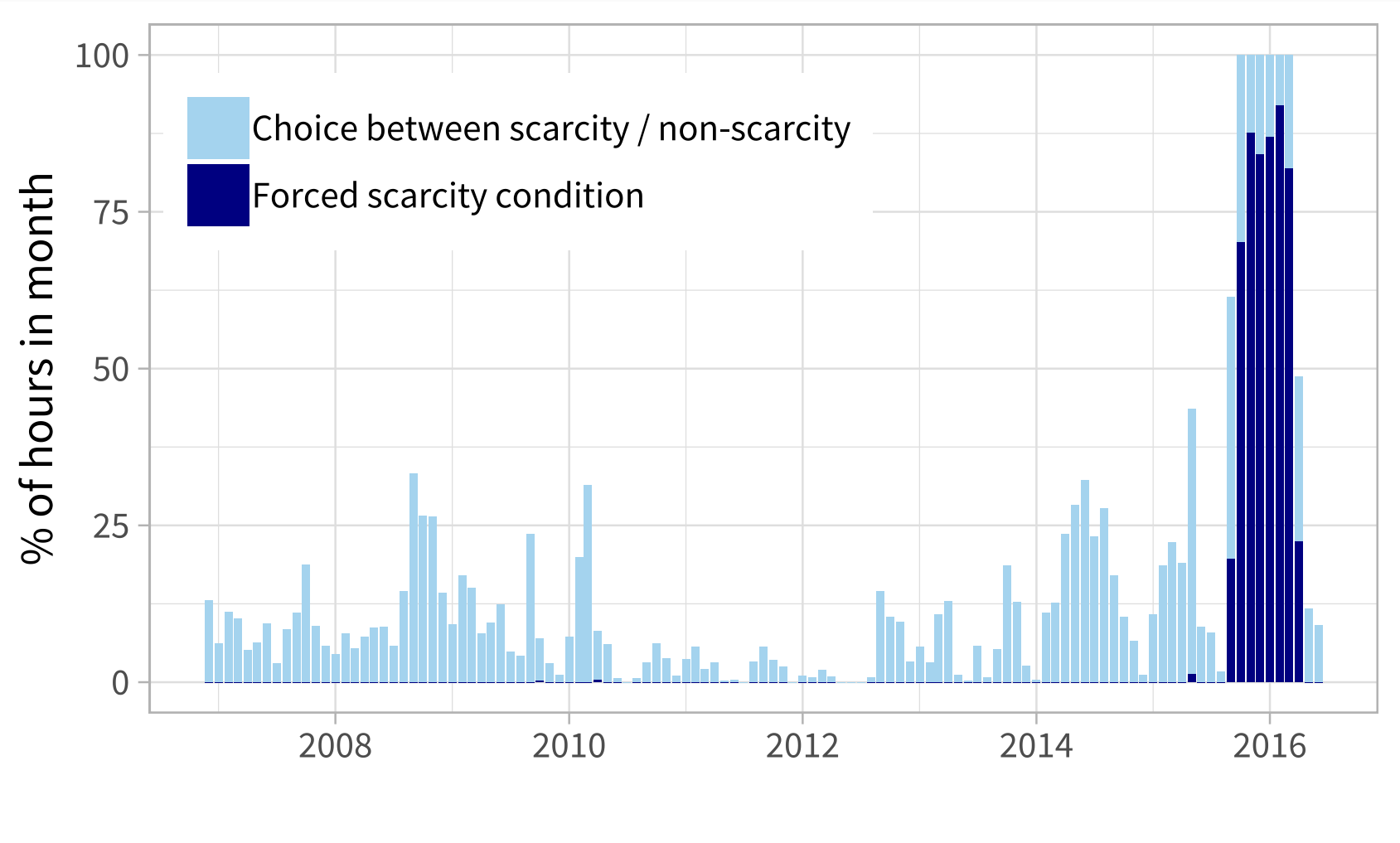


Residual demand for EPM on 25 November 2015, at 6:00 PM.

When residual demand crosses the scarcity price, then the firm can choose to induce scarcity condition or not

Residual demand for EPM on 25 May 2015, at 6:00 PM.

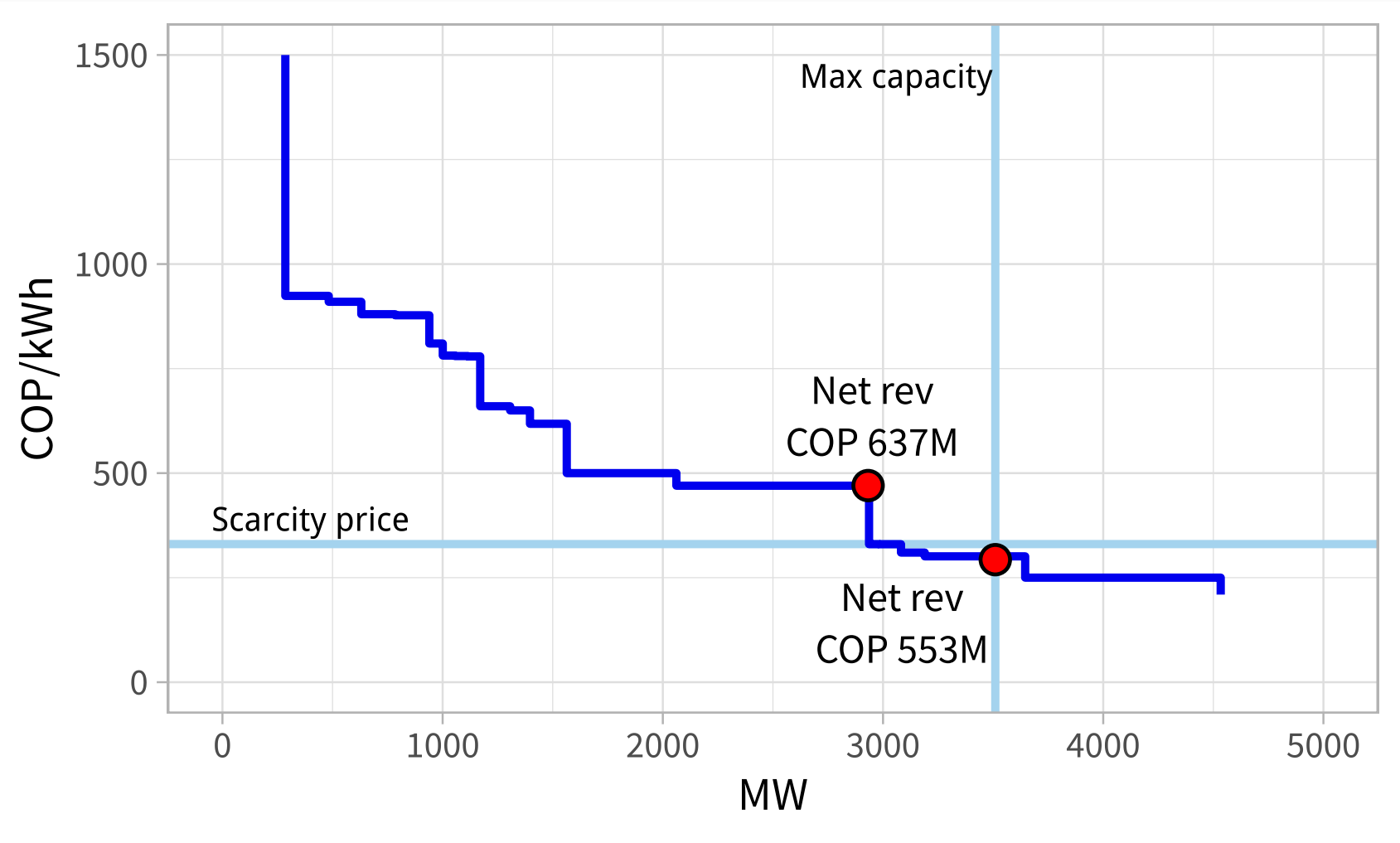
For EPM, in 10% of hours in the sample (18% during 2015) it had the ability to choose between scarcity and non-scarcity



Focusing on hours when the firms can make a choice, when would they want to create a scarcity condition?

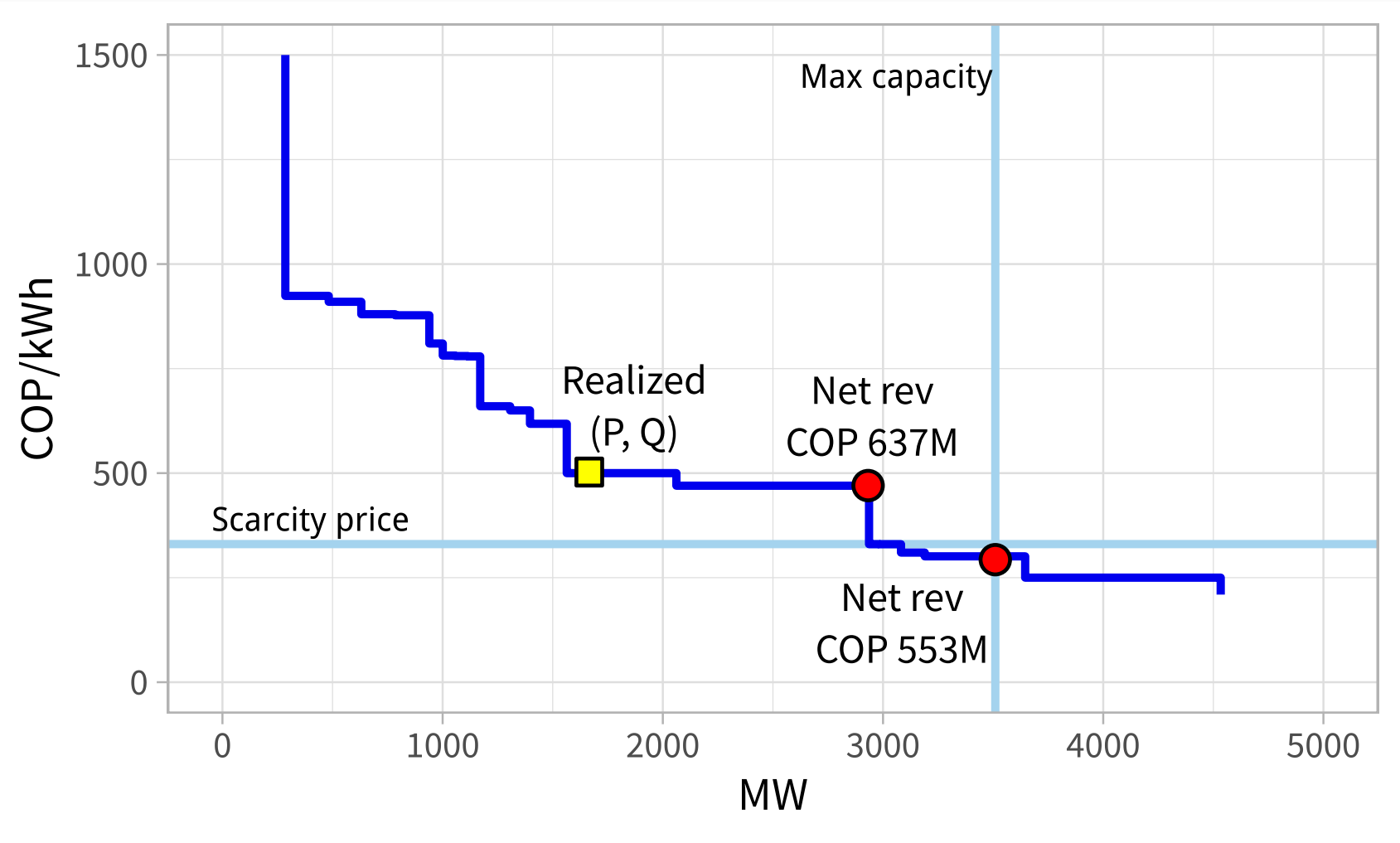
- Search along non-scarcity section of residual demand curve to find the optimal price and quantity
- Search along scarcity section of residual demand curve to find the optimal price and quantity
- Which of the two options would lead to higher net revenues?

Example of a residual demand in which scarcity condition would have maximized net revenues for EPM



Residual demand for EPM on 15 May 2015, at 8:00 AM

Market price was 500 pesos/kWh on this hour and day, above the threshold for a scarcity condition



Residual demand for EPM on 15 May 2015, at 8:00 AM

Optimal choice for the firm between scarcity and non-scarcity periods predicts the observed market outcomes

- Focus on the hours when generators can choose to trigger the scarcity condition
- For EPM, there were about 400 hours when choosing scarcity was **optimal**

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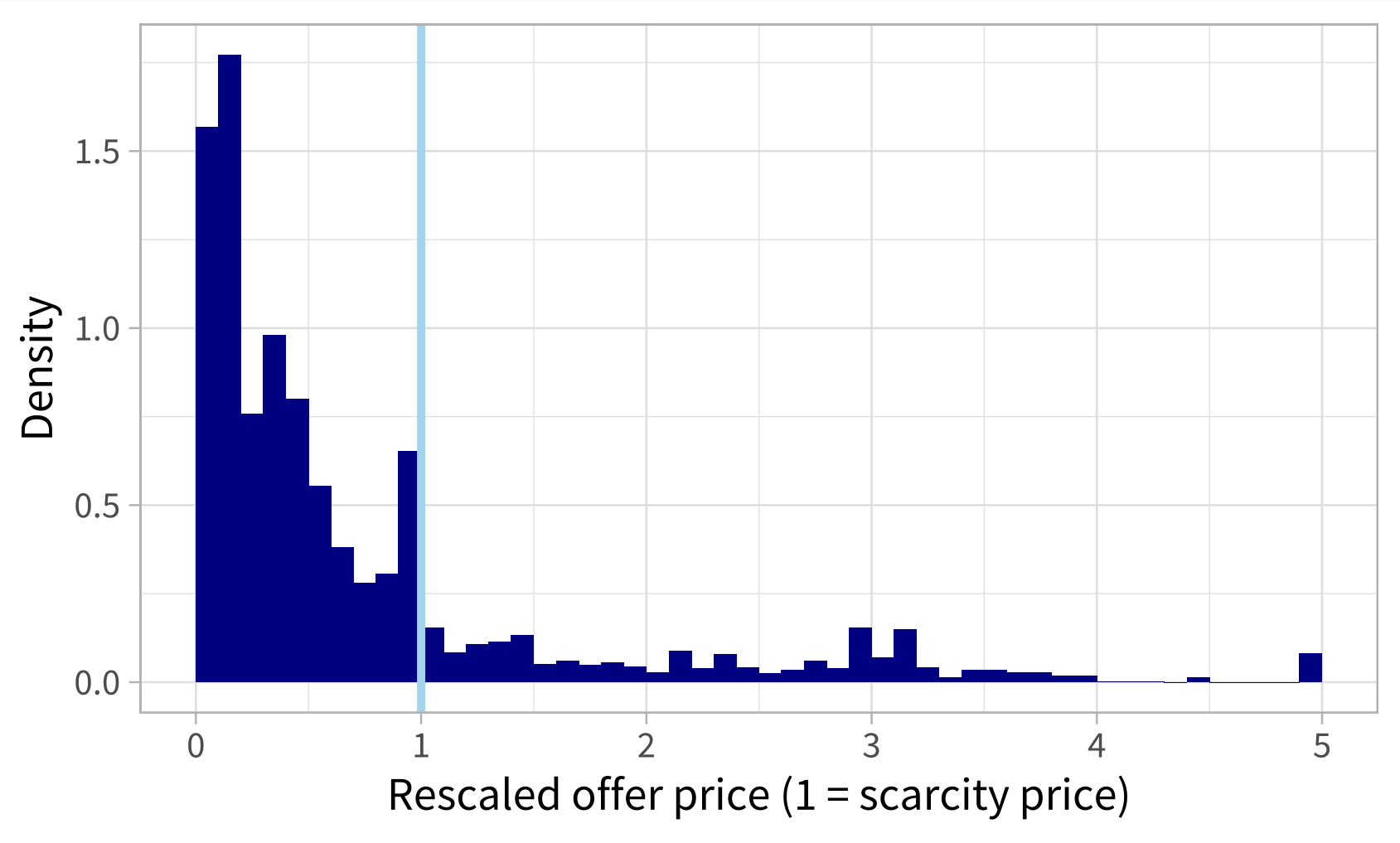
Optimal choice for the firm between scarcity and non-scarcity periods predicts the observed market outcomes

- Focus on the hours when generators can choose to trigger the scarcity condition
- For EPM, there were about 400 hours when choosing scarcity was **optimal**
  - Scarcity condition triggered in **99%** of these
- For EPM, there were about 9,000 hours when scarcity was **not optimal**
  - Scarcity condition was **not** triggered in **92%** of these
- We see similar results for Isagen and Emgesa

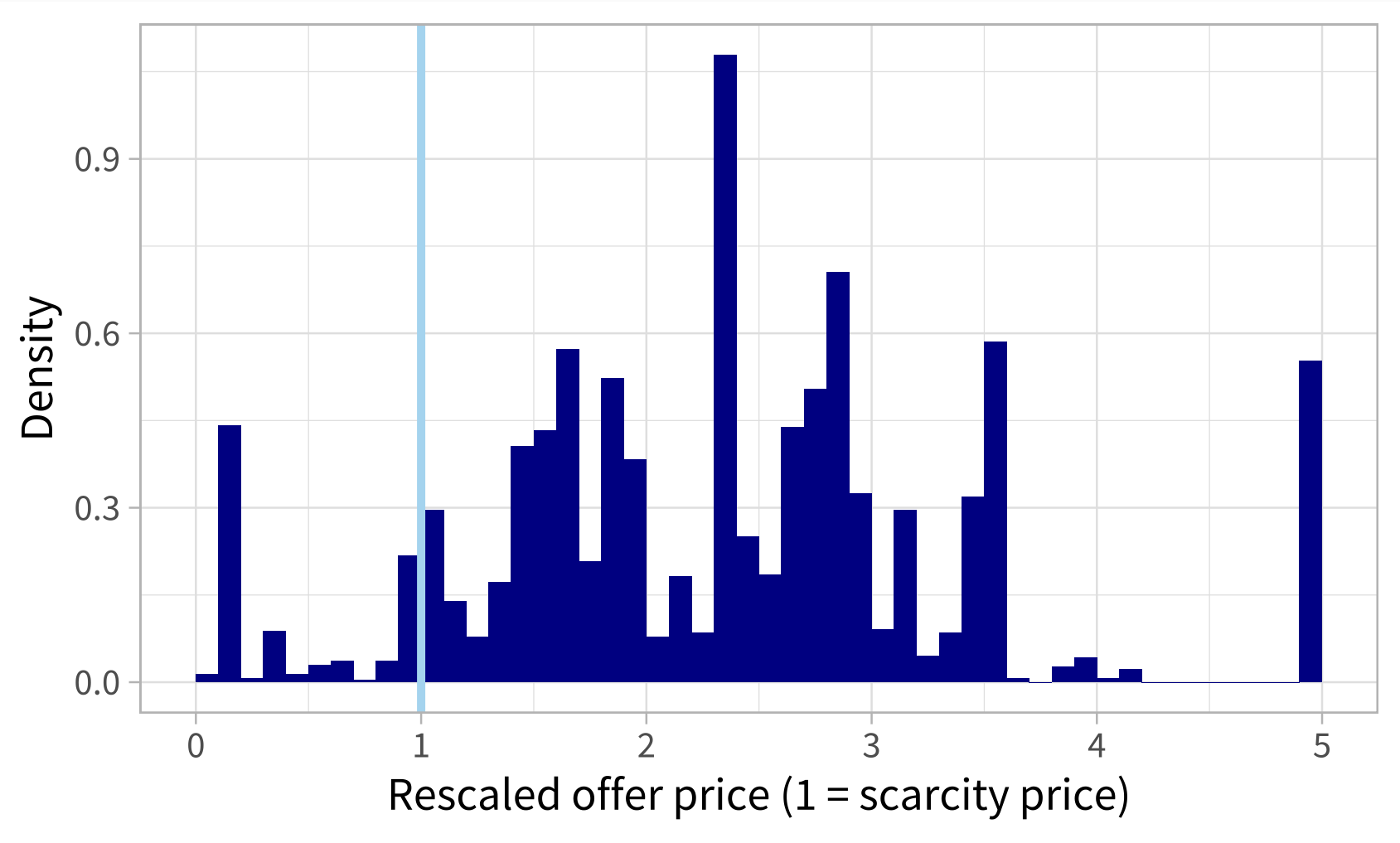
Are these differences in the optimality of the scarcity condition reflected in the bidding behavior of the firm?

- Does the firm bid differently when it would be optimal for it not to trigger the scarcity condition?
- Do the bids in those hours lie below the scarcity price?

For hours when non-scarcity is optimal, generation price offers for EPM exhibit bunching just below the scarcity price



For hours when scarcity condition would be optimal, most generation price offers for EPM lie above the scarcity price

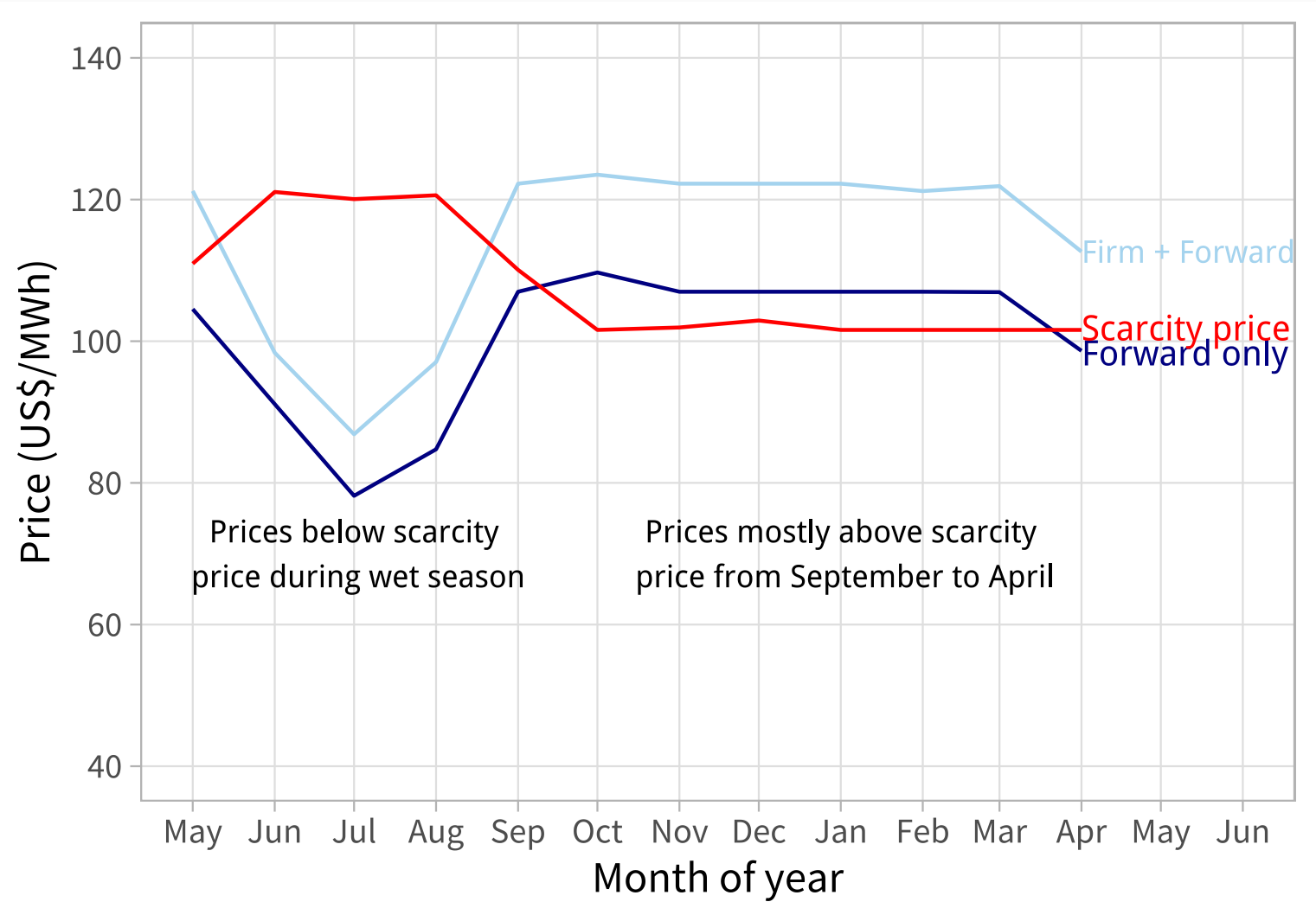


How does the firm energy mechanism affect market outcomes?

We simulate a counterfactual world without the firm energy mechanism to show why this matters

- Our analysis of the bidding and generation data show that the firms respond to the incentives created by the mechanism
- But we do not know what outcomes would look like in the absence of the firm energy mechanism
- We construct a simplified model of the Colombian market over a one-year period to compare two sets of outcomes:
  - Existing market structure with forward contracts and firm energy
  - Counterfactual market structure with only forward contracts
- Model is based on the three large firms choosing an optimal allocation of their scarce hydro resources (Bushnell, 2003)

Wholesale prices are lower for the counterfactual without firm energy, mostly due to removal of firm energy charge



Results shown for 2015–16 period, with 10% less water than actual inflows

Hydro and thermal generation resources used more efficiently in the counterfactual simulation without firm energy

	Firm + Forward	Forward only
Max price (US$/MWh)	127.10	120.85
Max hydro storage	76%	78%
Mean thermal cost (US$/MWh)	67.73	66.58

- Firm energy mechanism creates incentive for hydro operators to save less water during wet season
  - Lower storage raises the risk of a supply shortfall
  - More expensive thermal units are required to run during the dry season

What is an alternative to the firm energy mechanism?

Do forward contracts provide an alternative to meet the objectives of the firm energy mechanism?

- Three objectives of the firm energy mechanism (Fabra, 2018):
  1. Provide incentives to invest in generation
  2. Mitigate market power
  3. Provide incentives for plants to be available
- We saw that **forward contracts** already achieve (2) and (3)
  - Results suggest that combination of firm energy with forward contracts performs worse than forward contracts alone

Can forward contracting mechanism be adjusted to provide incentives for generation investment?

- Existing forward contracts are signed months to (at most) one or two years in advance
  - This does not give enough time to bring new generation resources on line
- Regulators could mandate that retailers purchase forward contracts **three to five years** in advance
- This would provide wholesale price certainty for consumers and a revenue stream for generators
- Sufficient time to build new generation units if required

Can forward contracting mechanism be adjusted to provide incentives for generation investment?

- We propose using standardized forward contracts cleared against the system load shape
- Retailers must hold these contracts to delivery and would face regulatory penalties for under-compliance
- Retailers and generators would be free to sign additional forward contracts if desired
- Forward contract prices could be used for setting regulated retail rates
- McRae and Wolak (2016) provides additional details about our proposed mechanism

Concluding remarks

Where to now for ensuring long-term resource adequacy in wholesale electricity markets?

- Firm energy mechanism is regarded as the best-practice design for capacity markets
- We show that firm energy interacts with forward contracts to **reduce** generation availability
- Generation firms in the longest-running firm energy market recognize and respond to these incentives
- Firm energy may have led to higher prices, higher generation costs, and lower reliability
- Modifications to the forward contracting mechanism could achieve the same objectives at a lower cost

Thank you