# 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

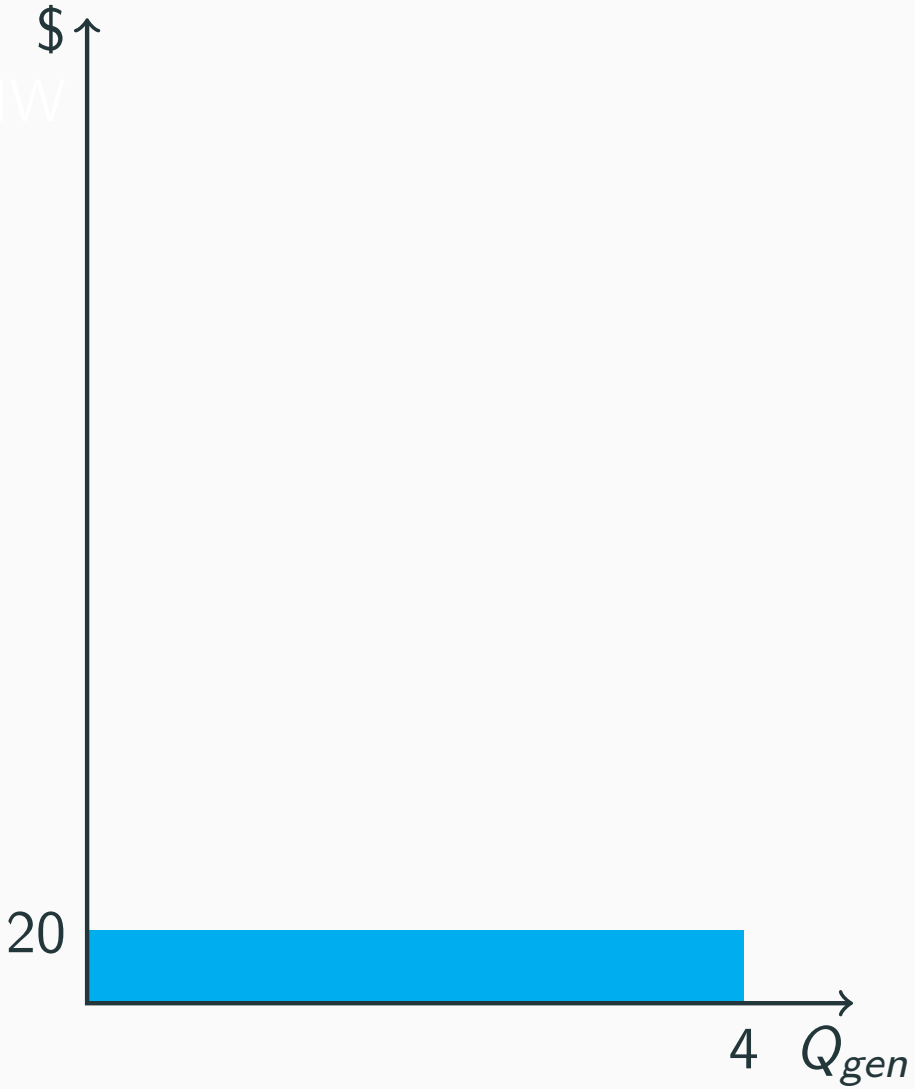
- Administrative formula sets a **scarcity price**
- Scarcity periods occur when the market price exceeds the scarcity price
- During scarcity periods:
  - The price that load pays for electricity is capped at the scarcity price
  - Generators have an obligation to make or pay the difference between 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

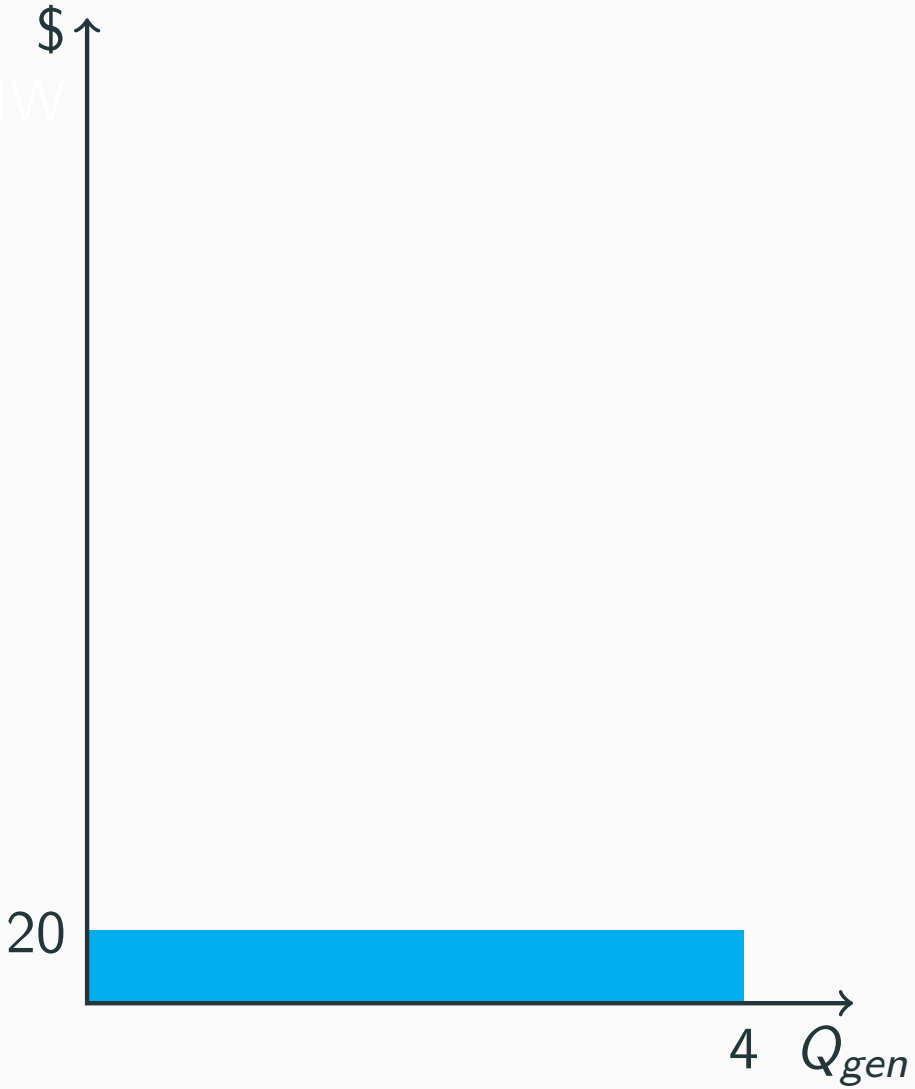
# What are forward contracts?

# 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

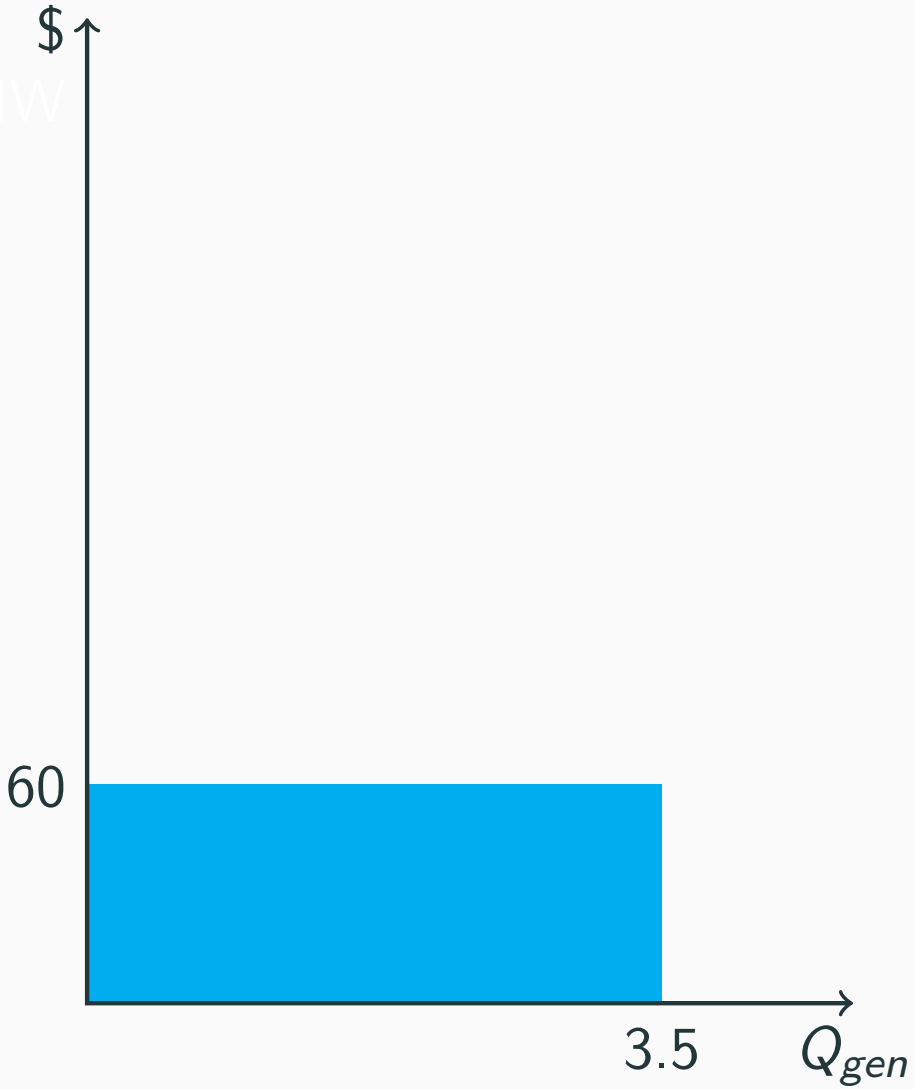
+80

Forward obligation

NET REVENUE

80

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




Generation sales

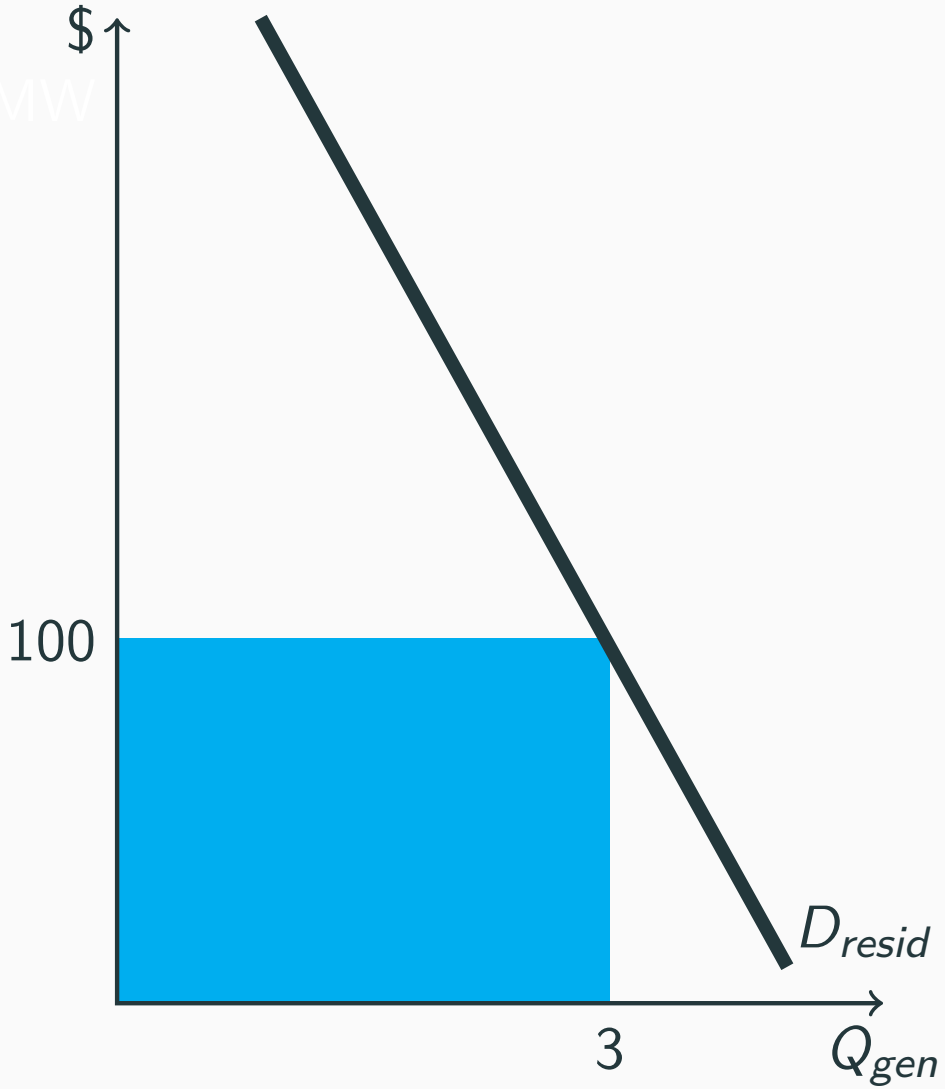
+210

Forward obligation

NET REVENUE

210

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




Generation sales

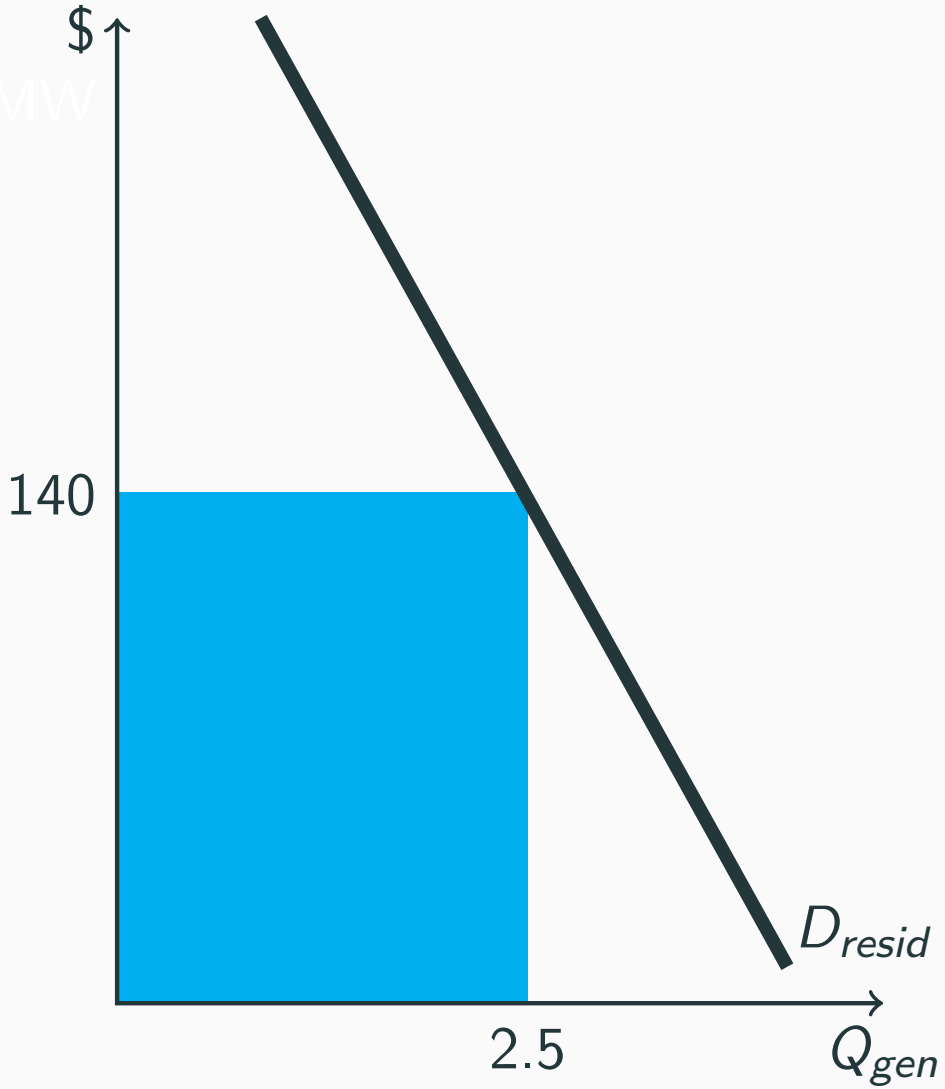
+300

Forward obligation

NET REVENUE

300

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




Generation sales

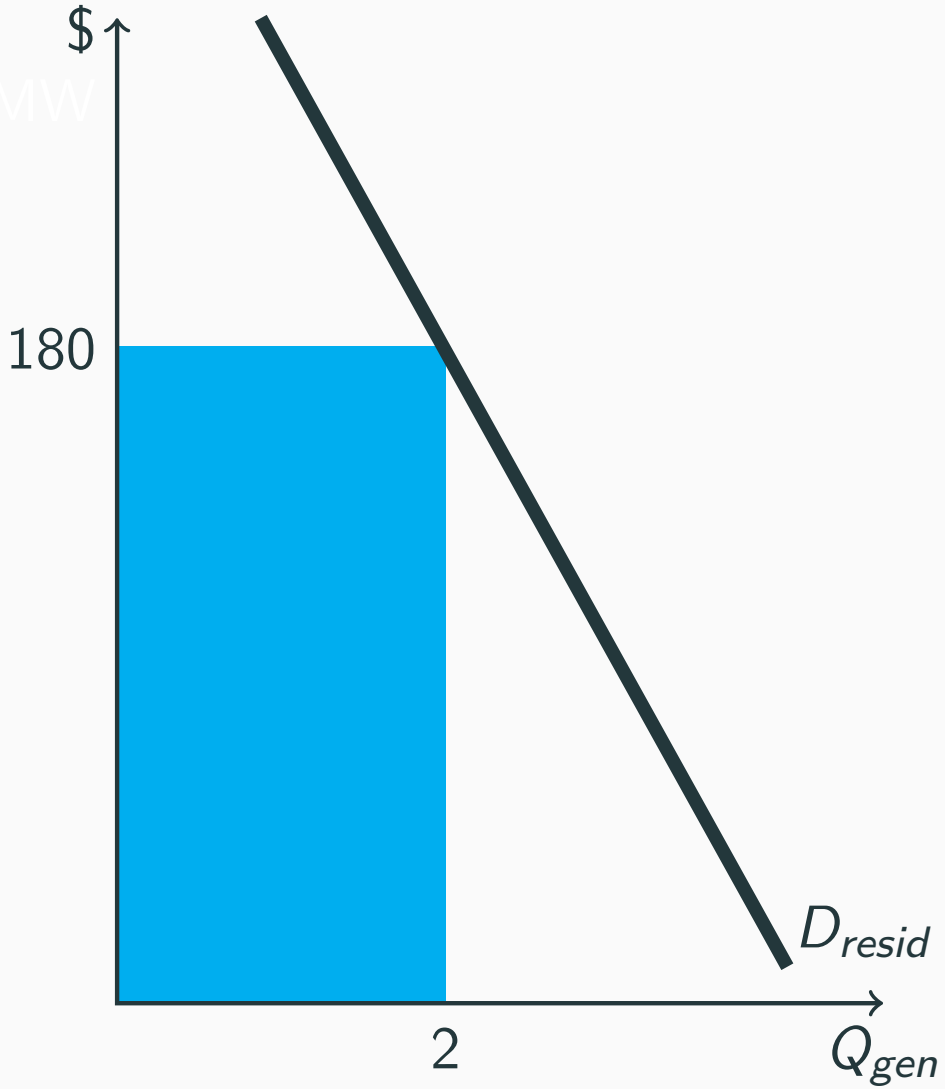
+350

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

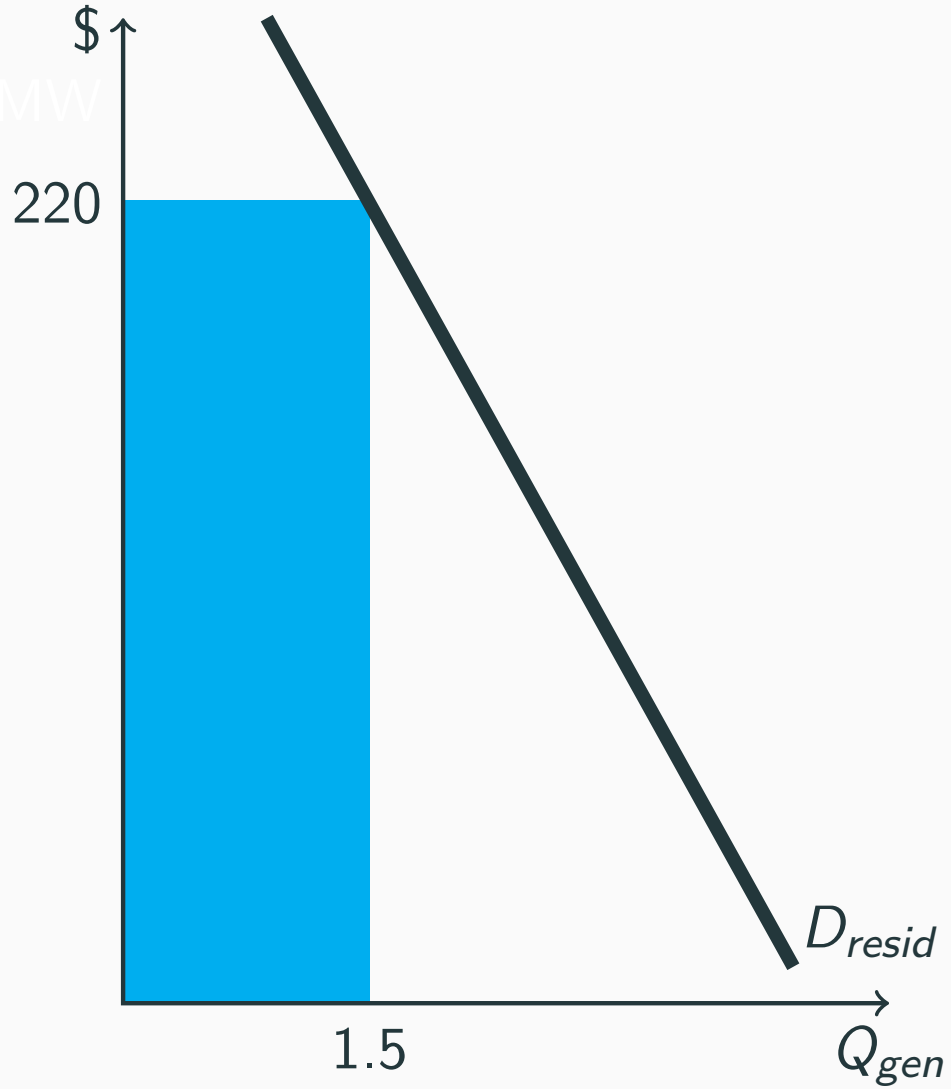



Generation sales
+360

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

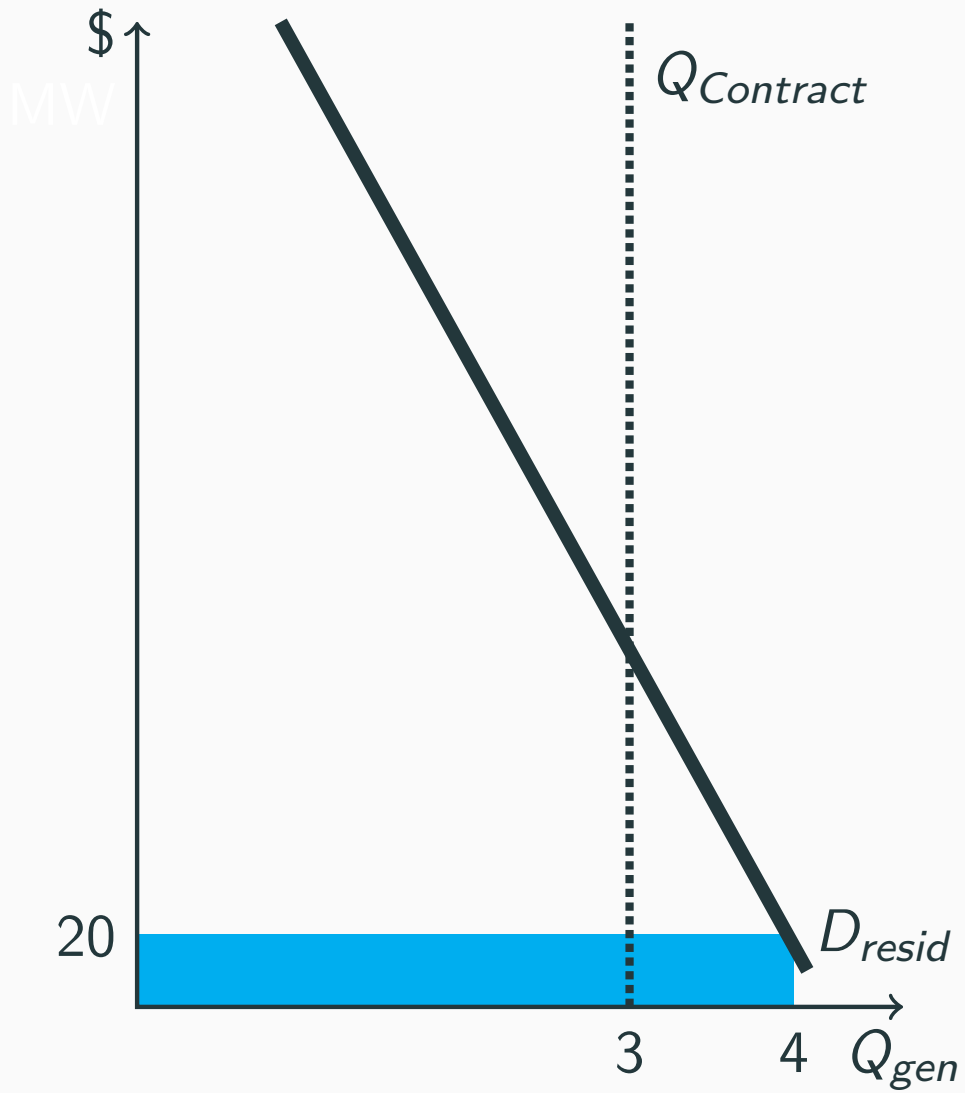
NET REVENUE

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



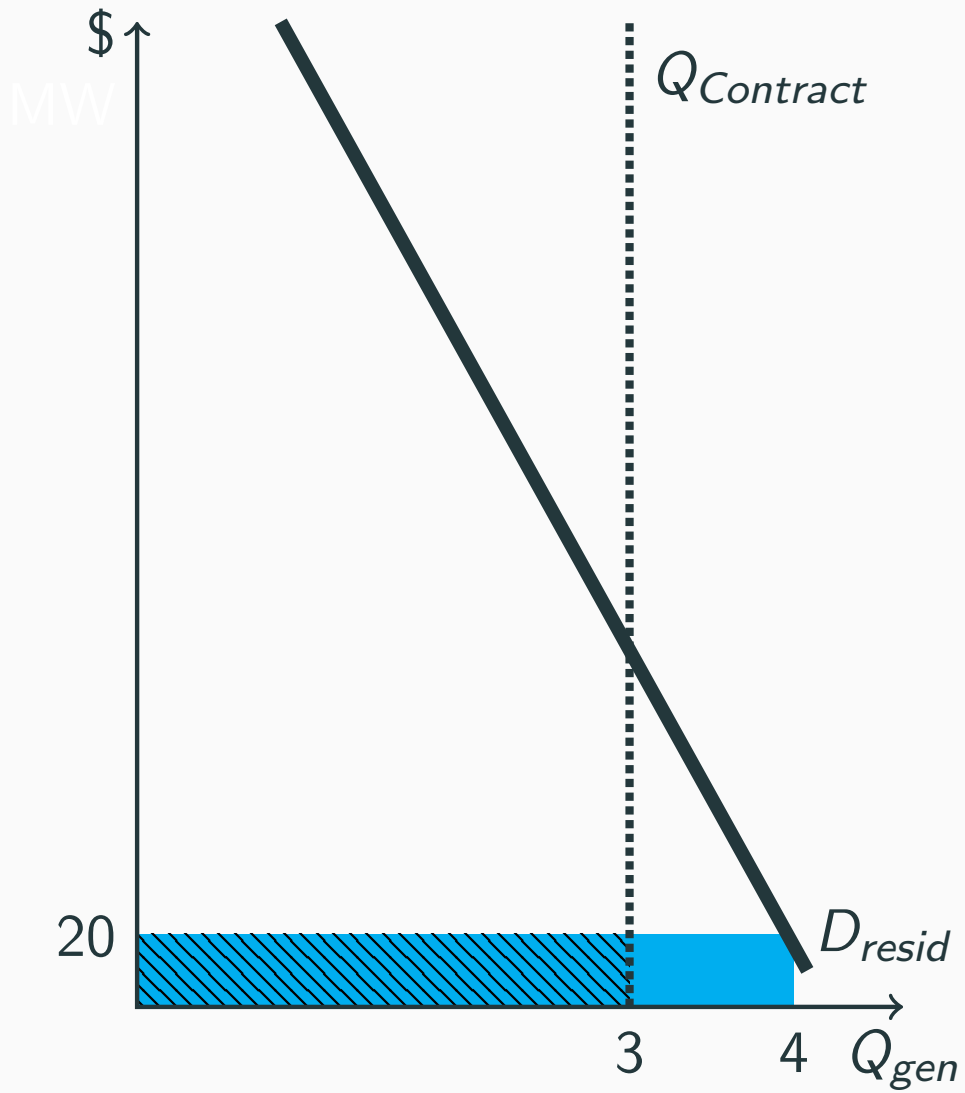

Contract sales
+180

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

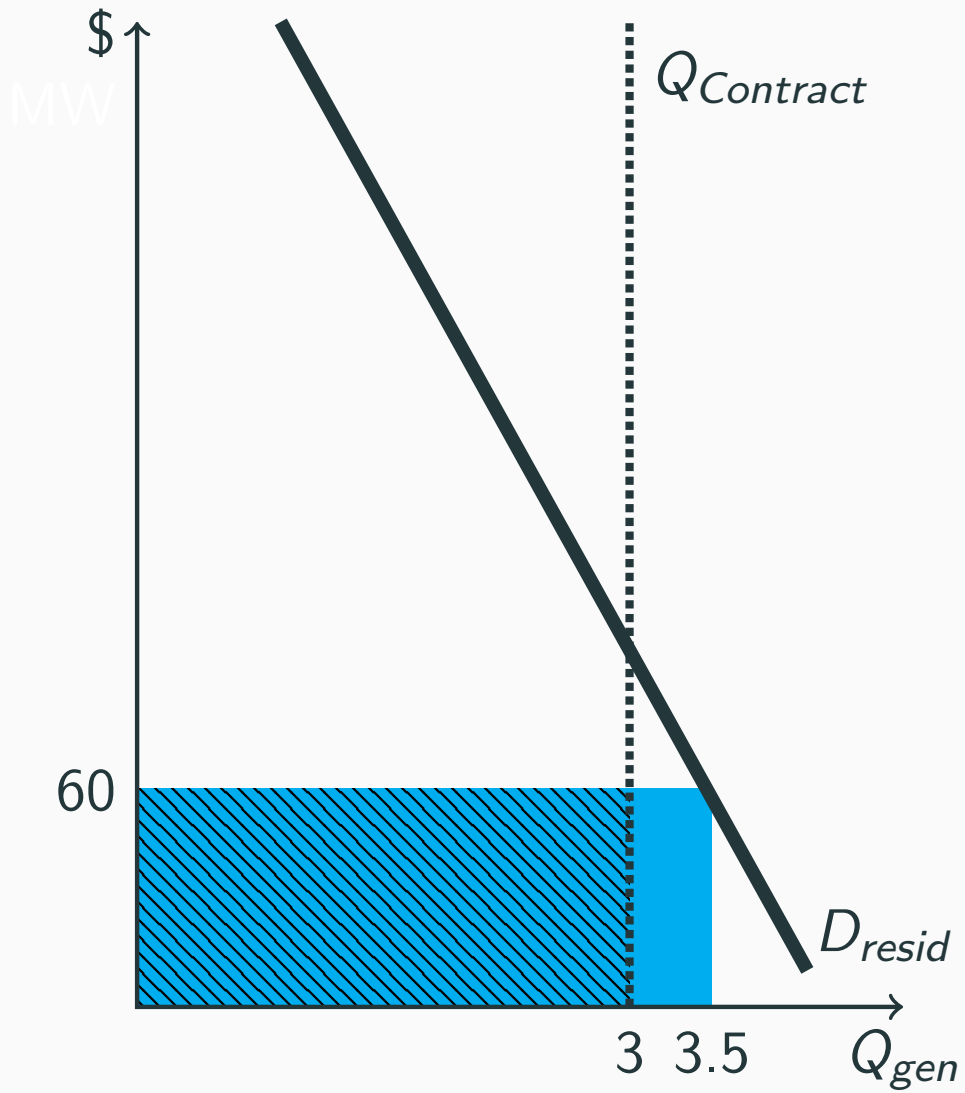
Forward obligation

−60

NET REVENUE

200

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



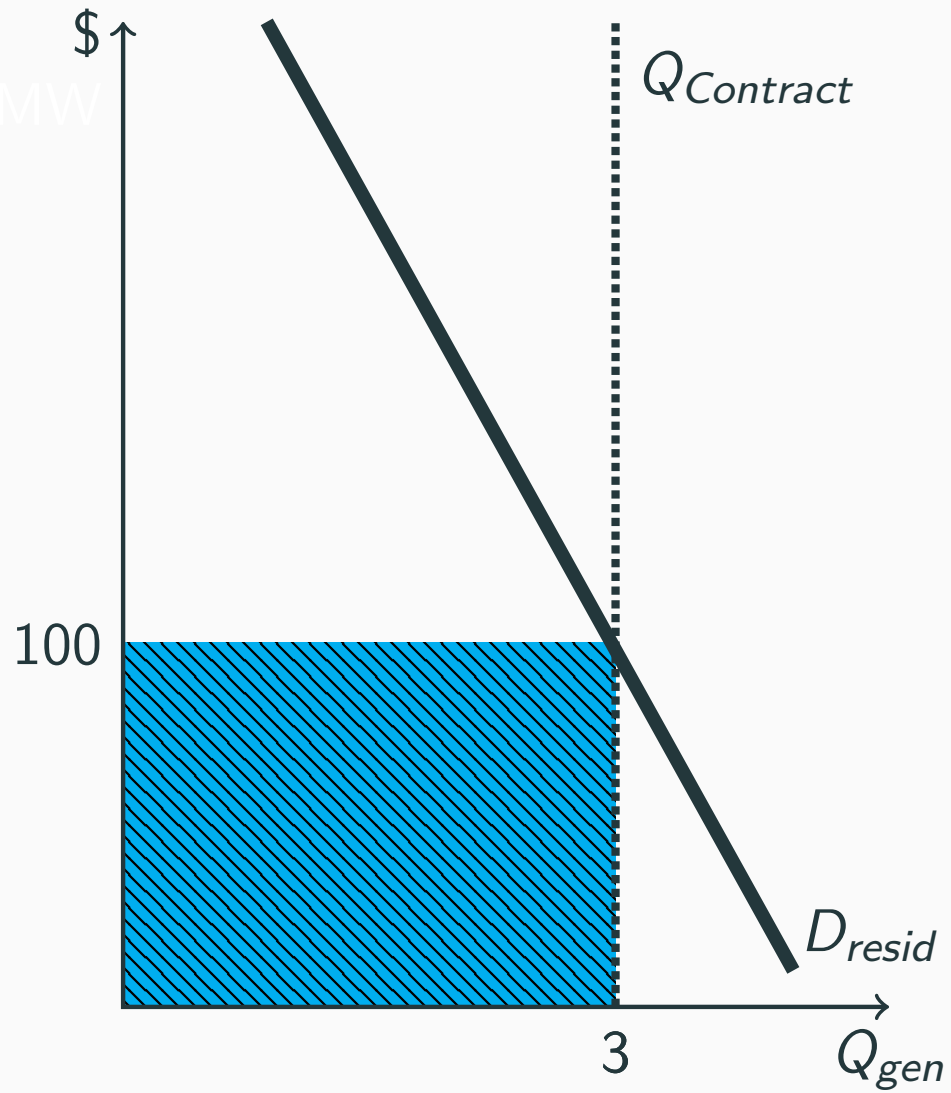

Contract sales
+180

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



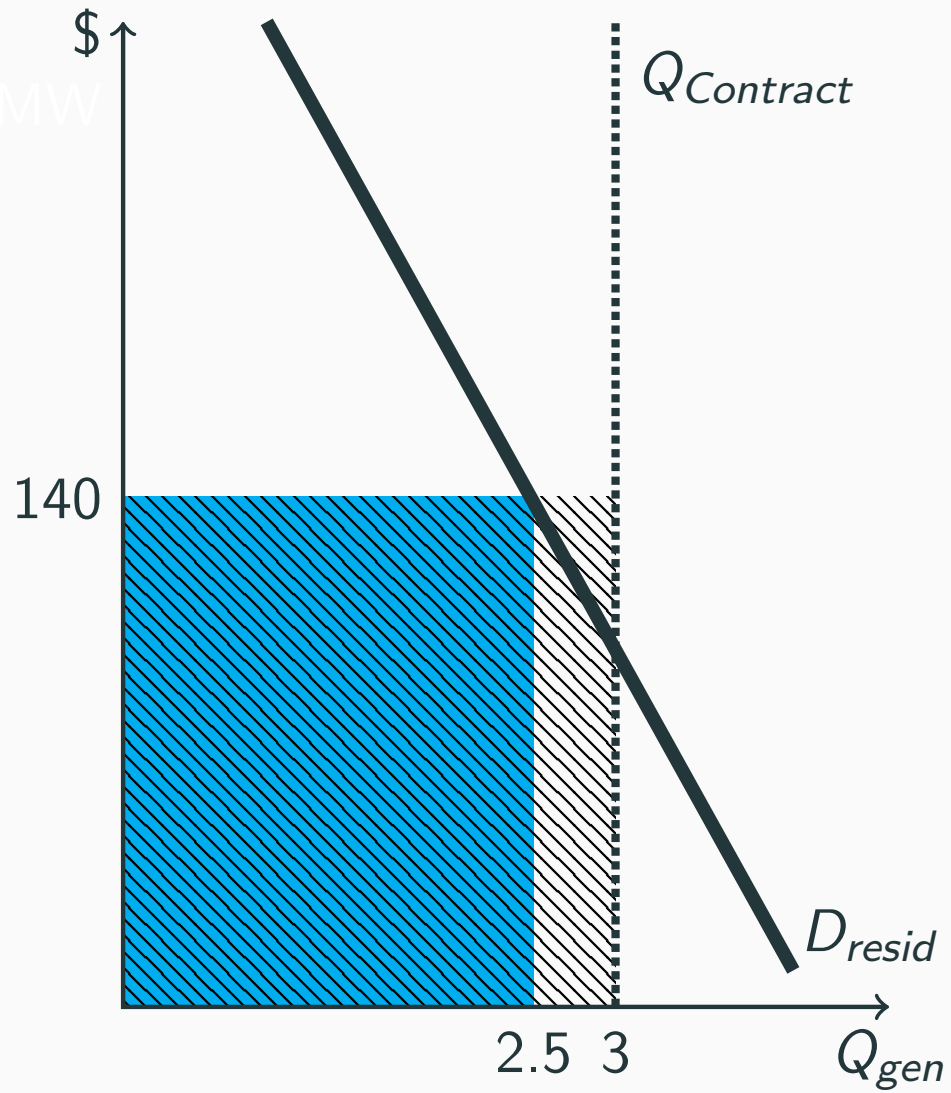

Contract sales
+180

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



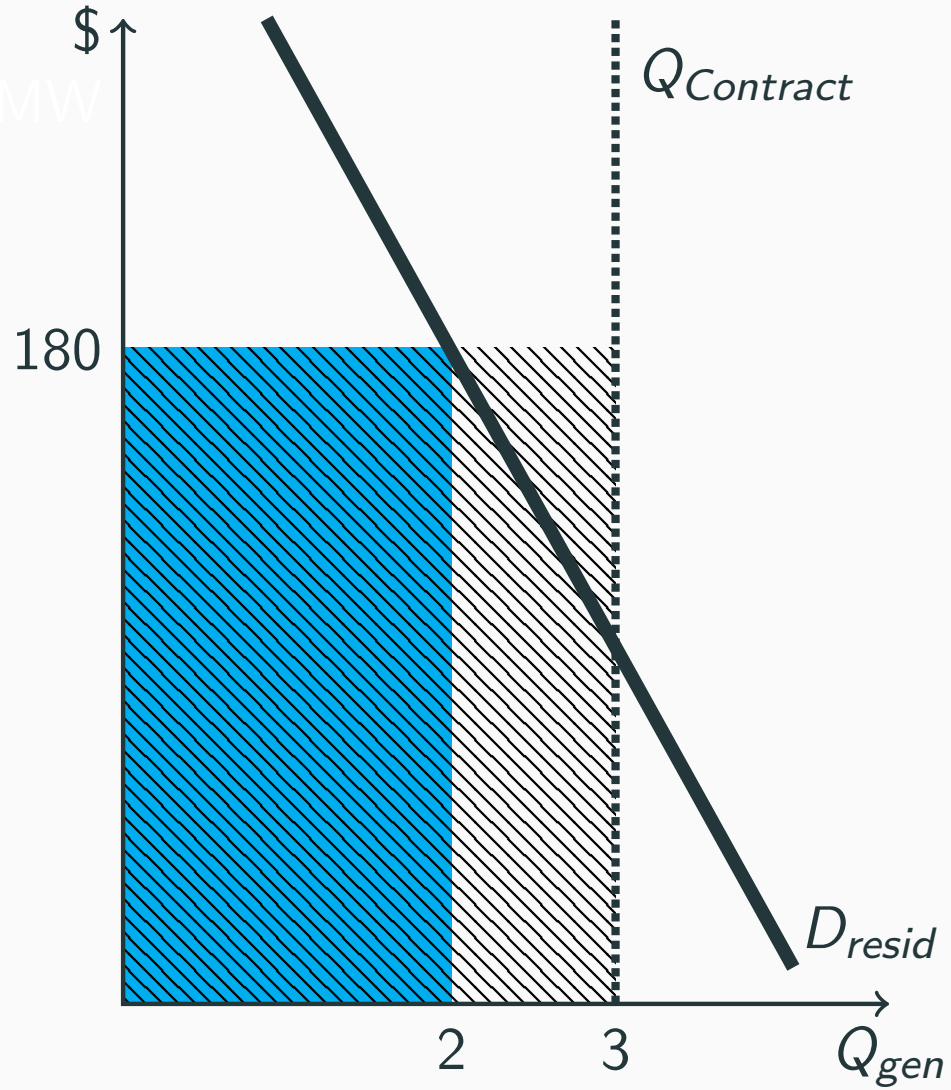

Contract sales
+180

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

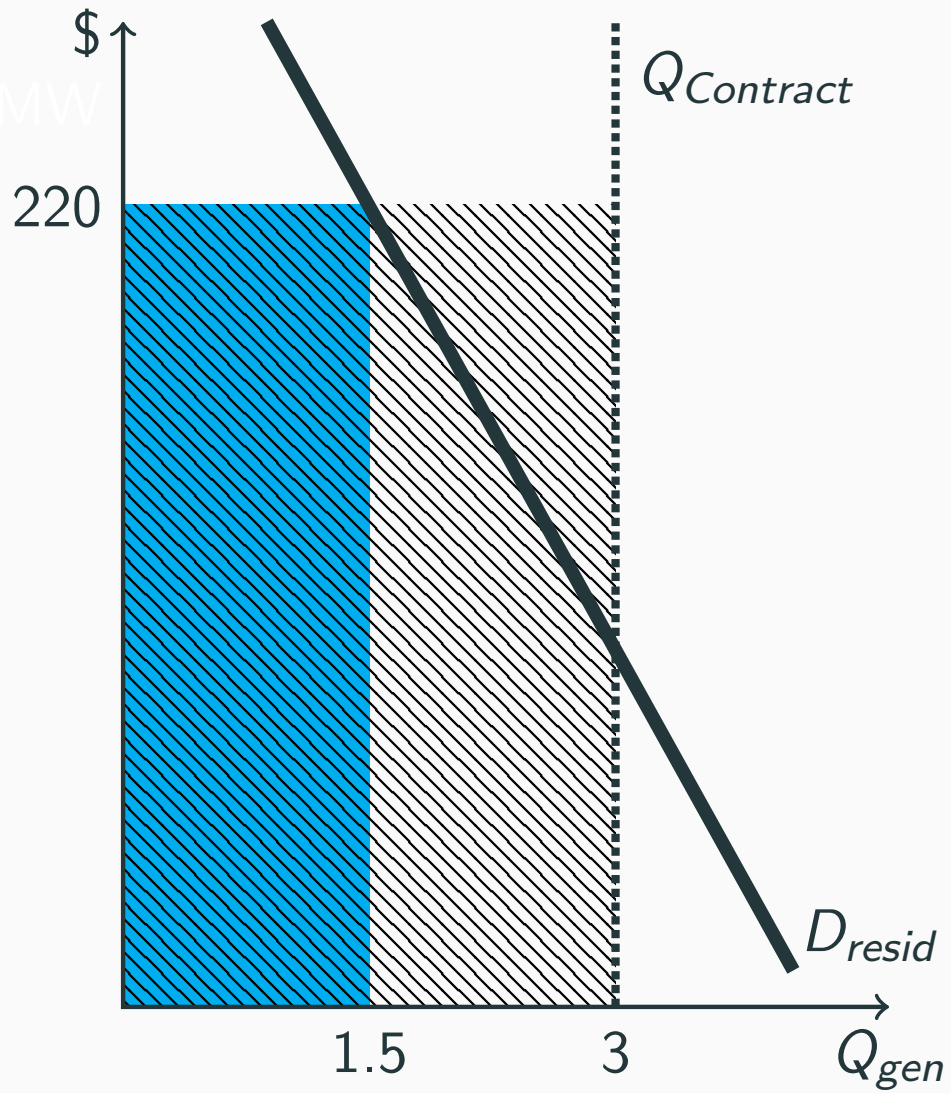
Forward obligation

−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

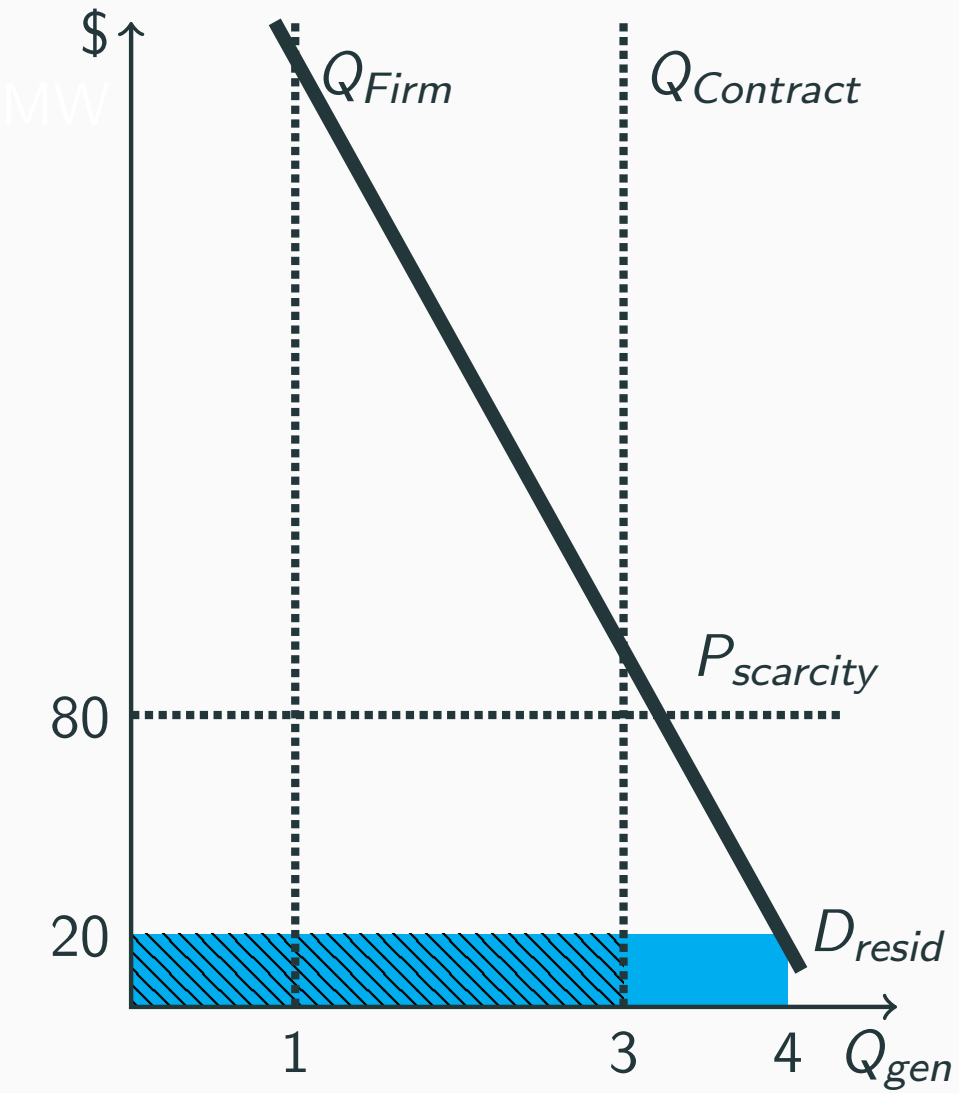
- In this example, net revenue is highest when the firm generates a quantity of 3.5 GW
- No longer profitable to withhold generation and increase the market price—because this will also increase the size of the forward contract obligation

# 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

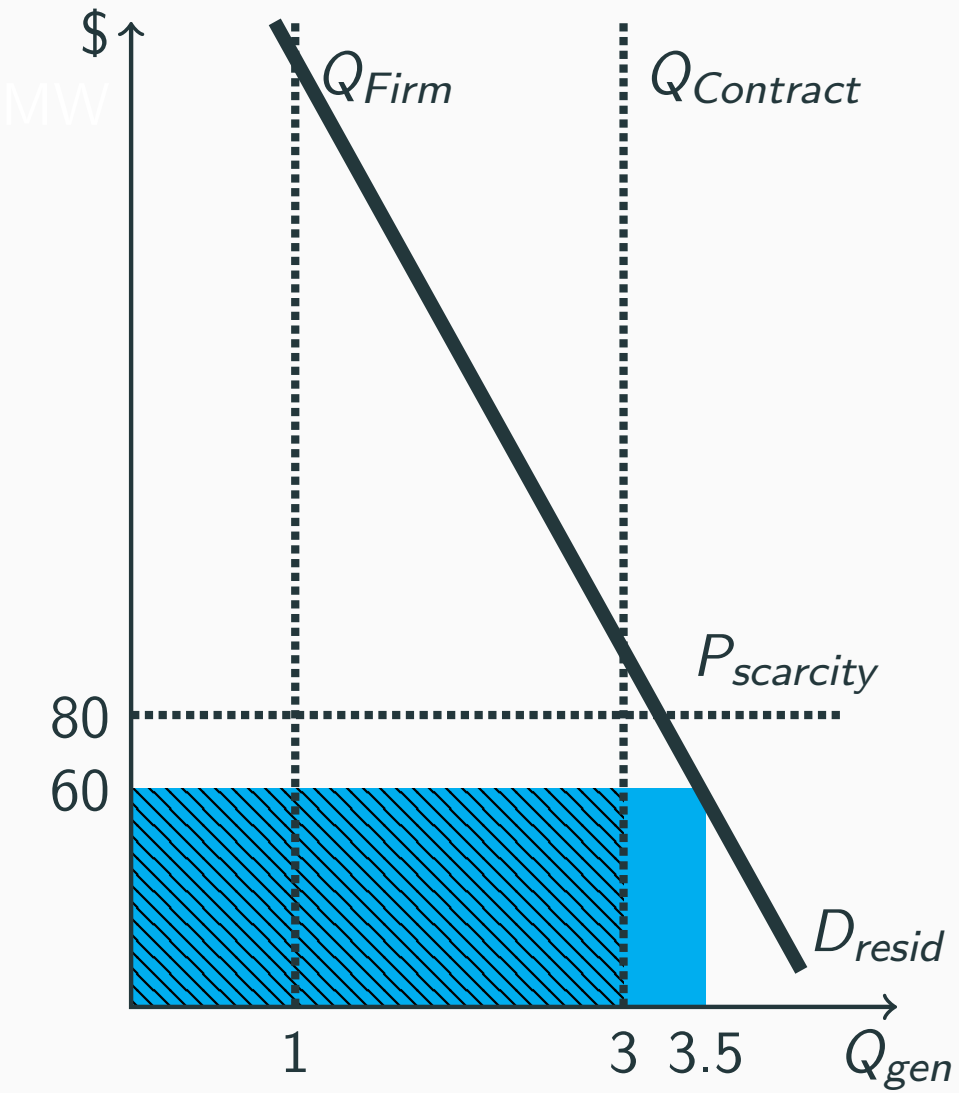
Forward obligation

−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

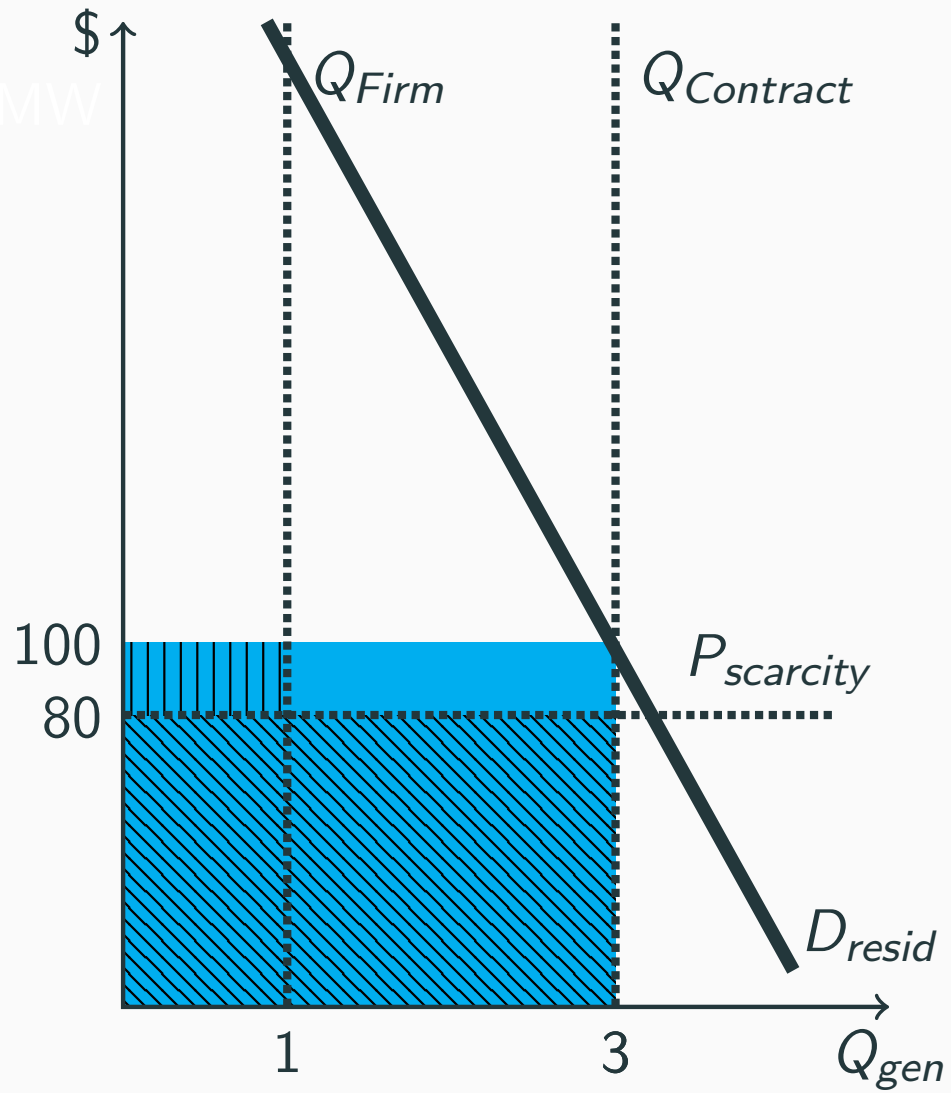
Forward obligation

−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

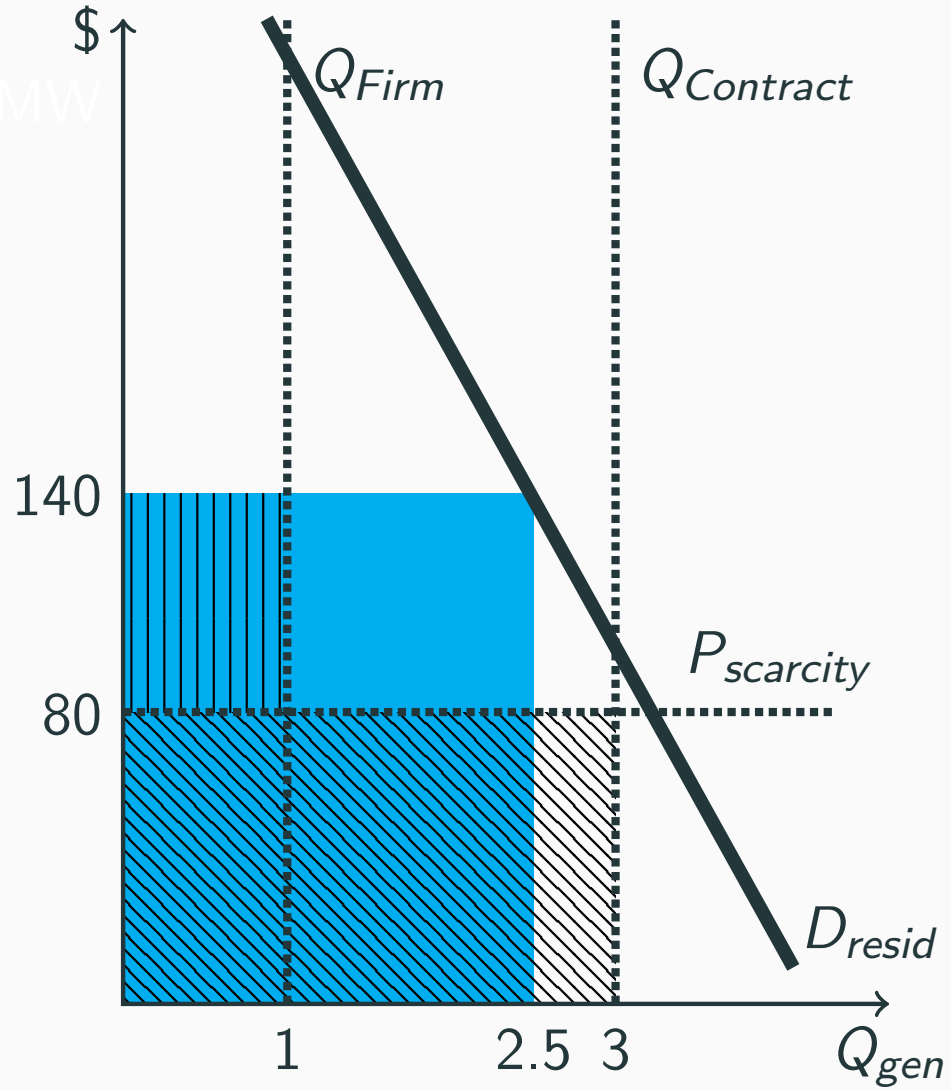
Generation sales
+300

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

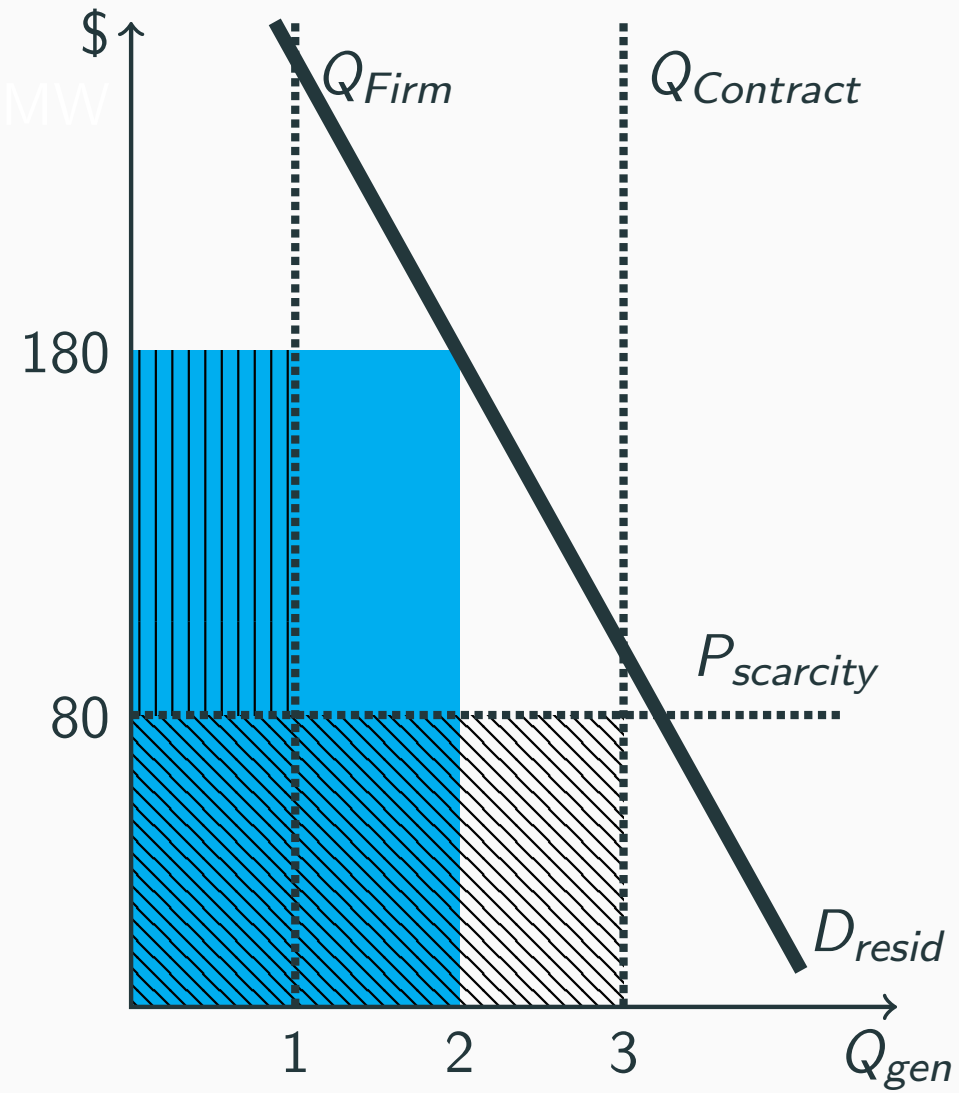
Generation sales
+350

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

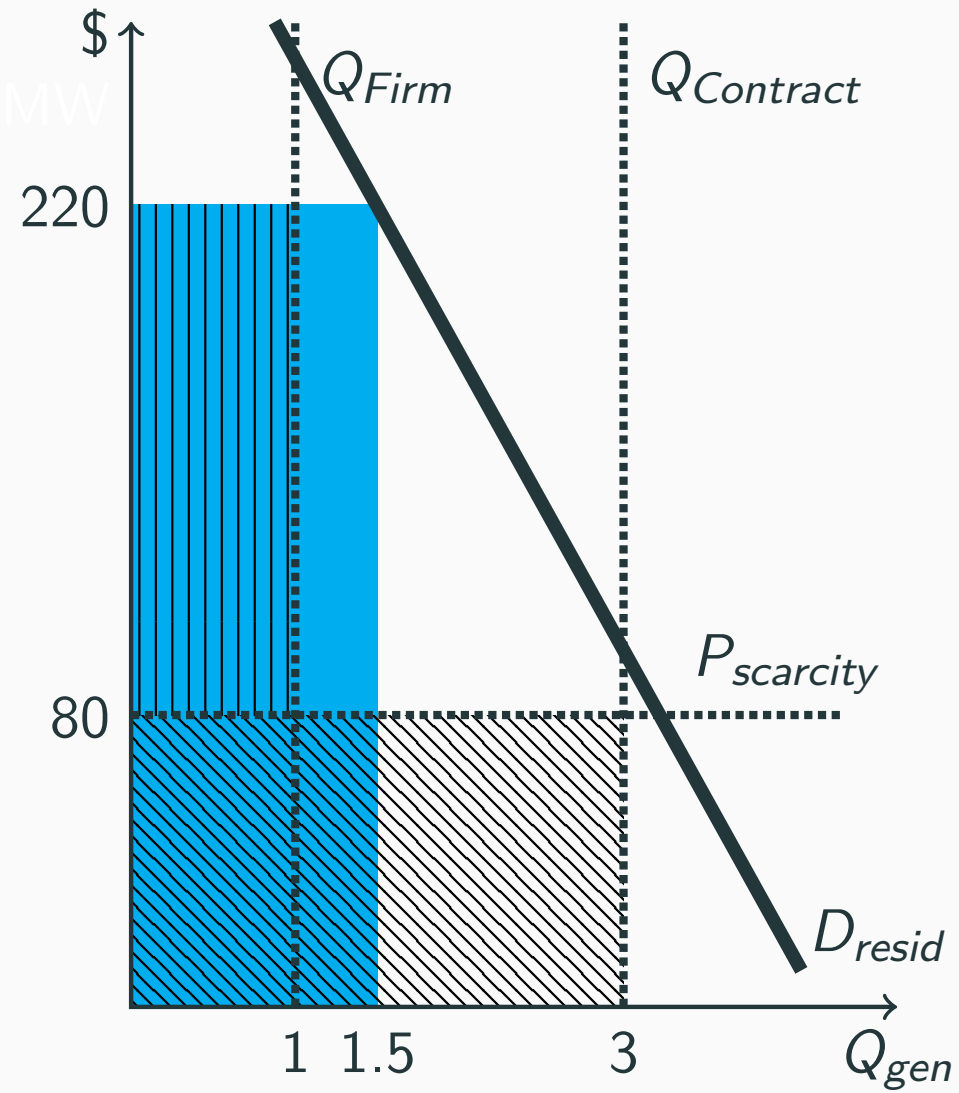
Generation sales
+360

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?

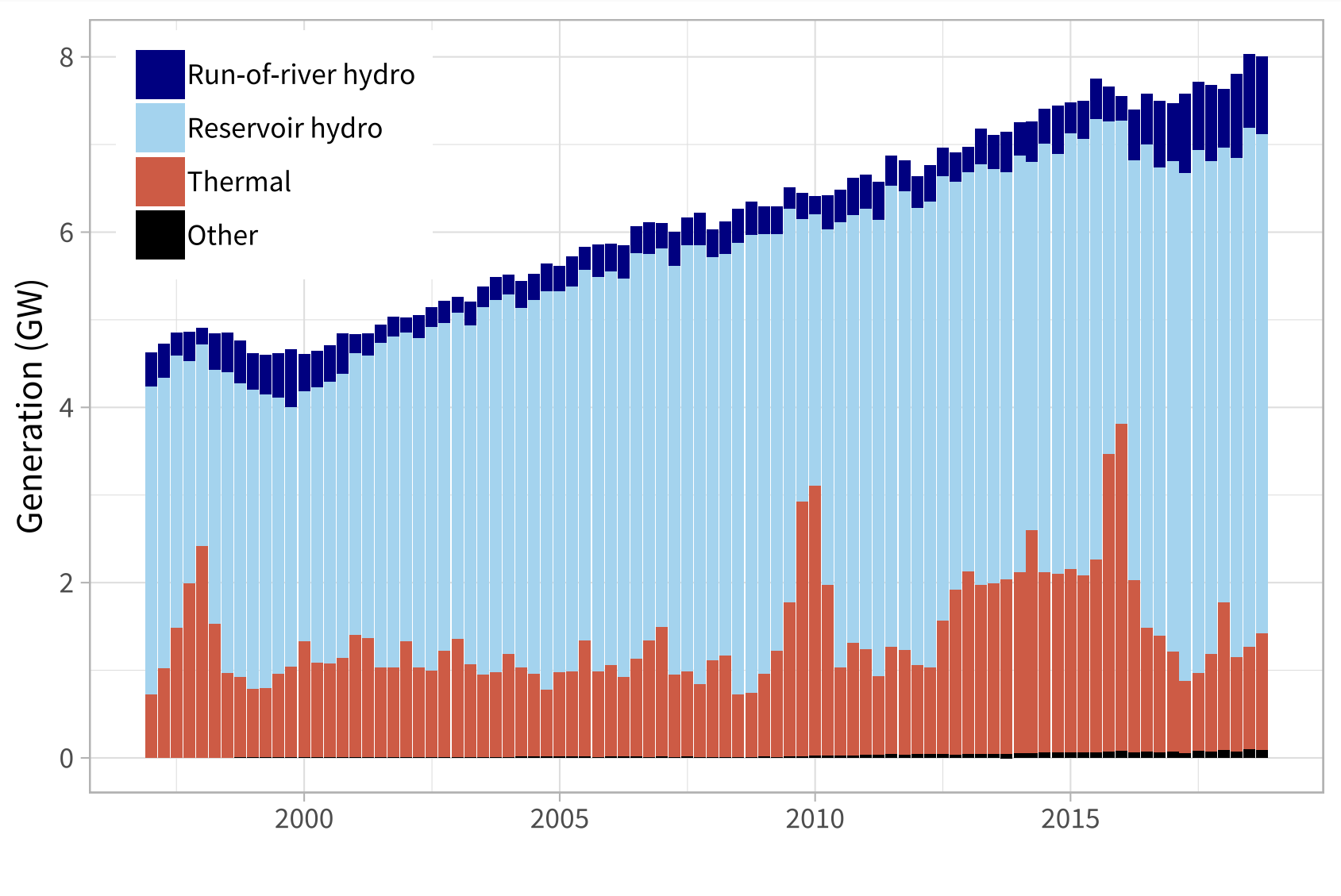
- Math relies on firm energy quantity being lower than forward contract quantity
- With intermittent renewable generation, this will usually be the case
- System operator assumes a "worst case" scenario for calculating firm energy

# 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



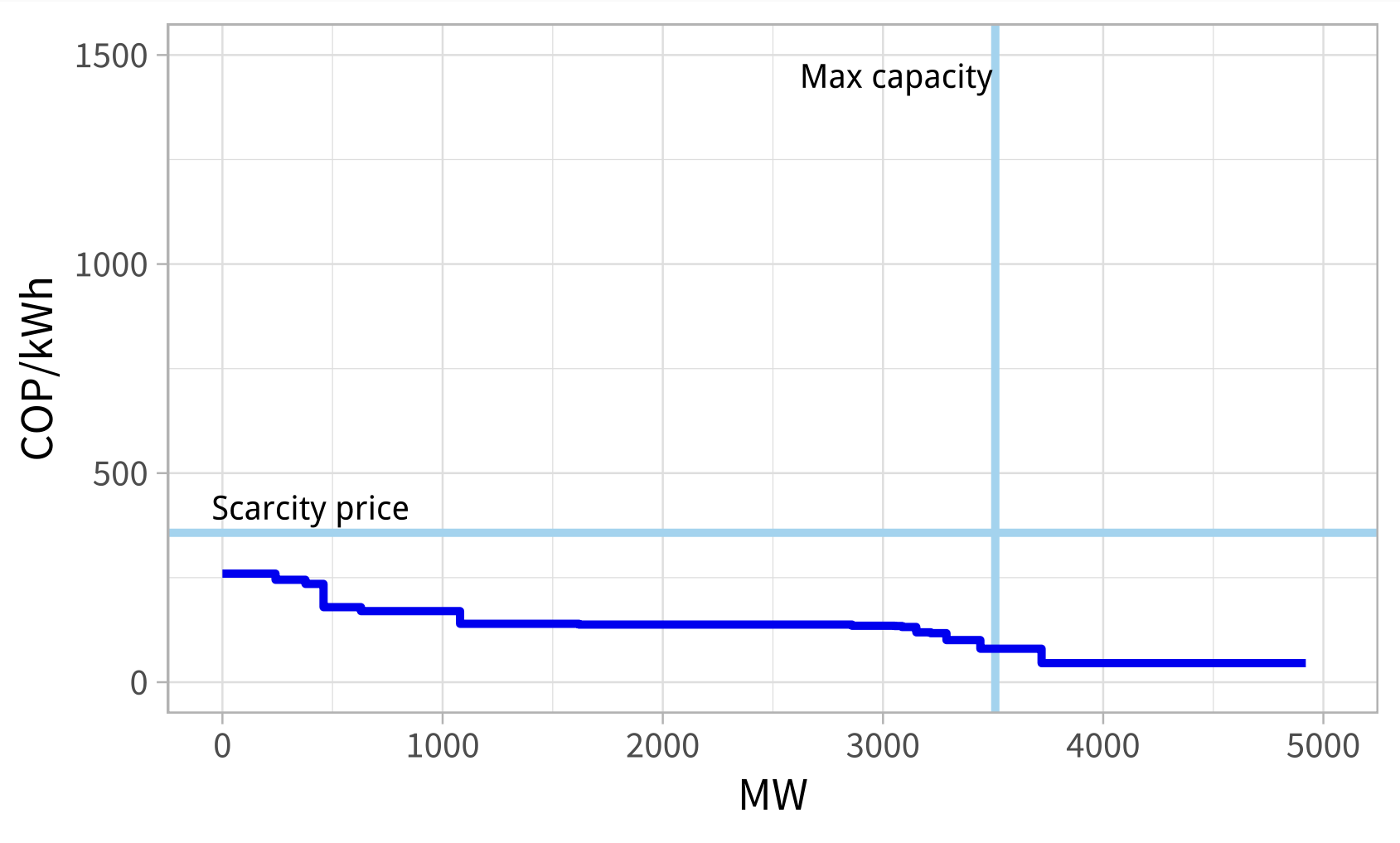
# We use hourly data from the Colombian system operator XM to study the performance of the firm energy mechanism

- 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

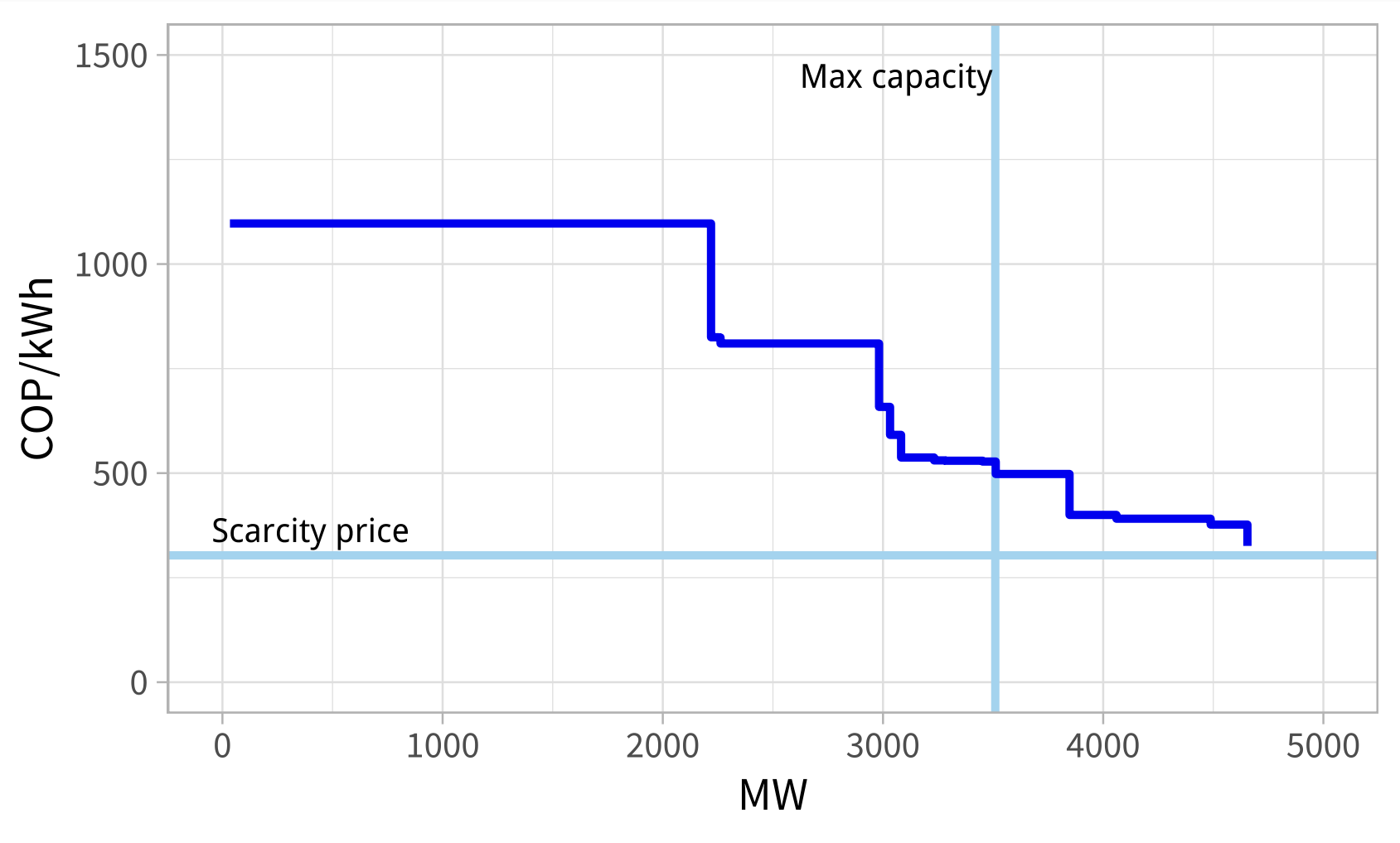
- For each firm and hour, we calculate the residual demand that it faces
  - This is the market demand, less the bids of all of the other firms
- Generation firm can choose combination of price and quantity along its residual demand curve

# 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

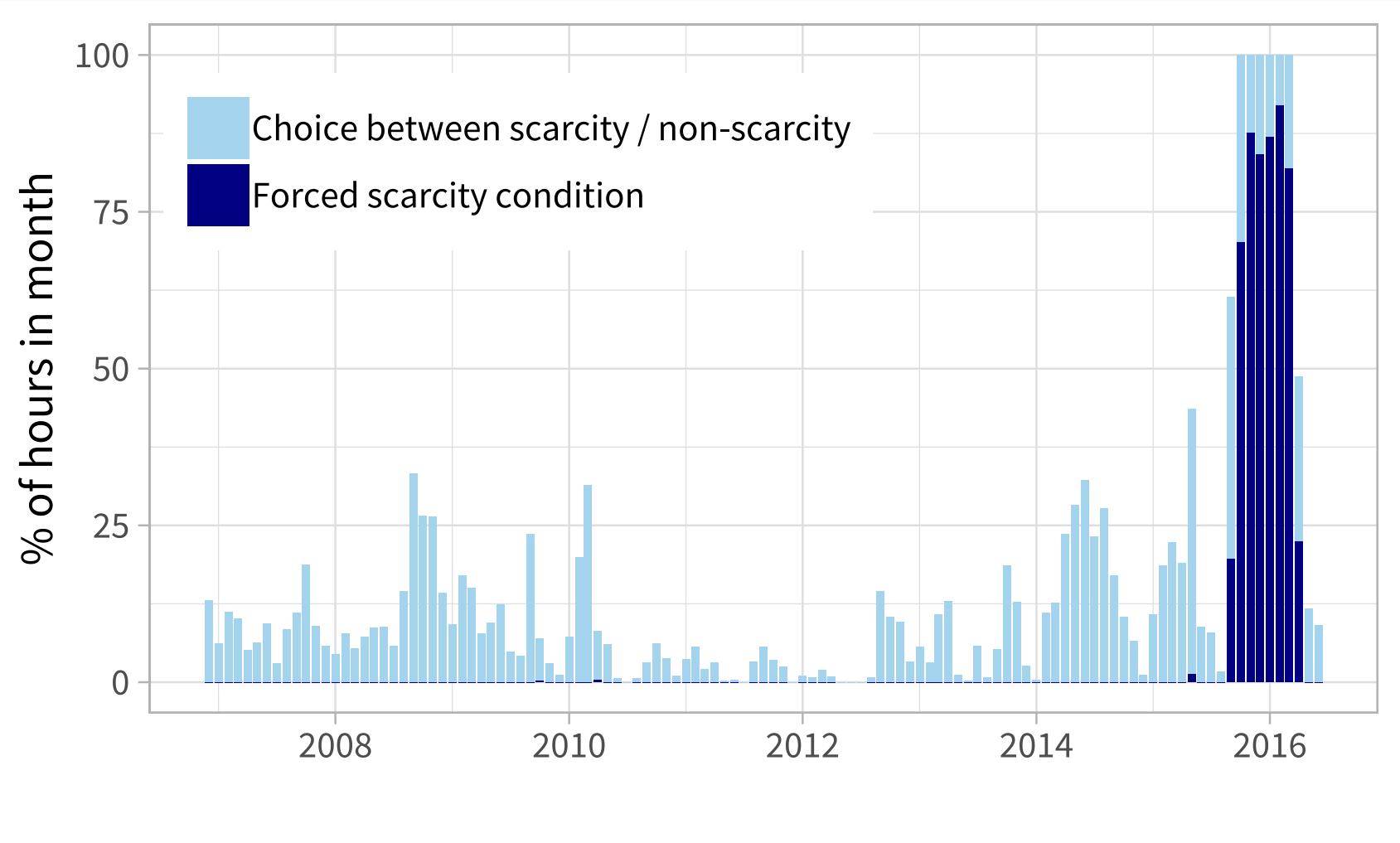



Residual demand for EPM on 25 November 2015, at 6:00 PM.

# 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.

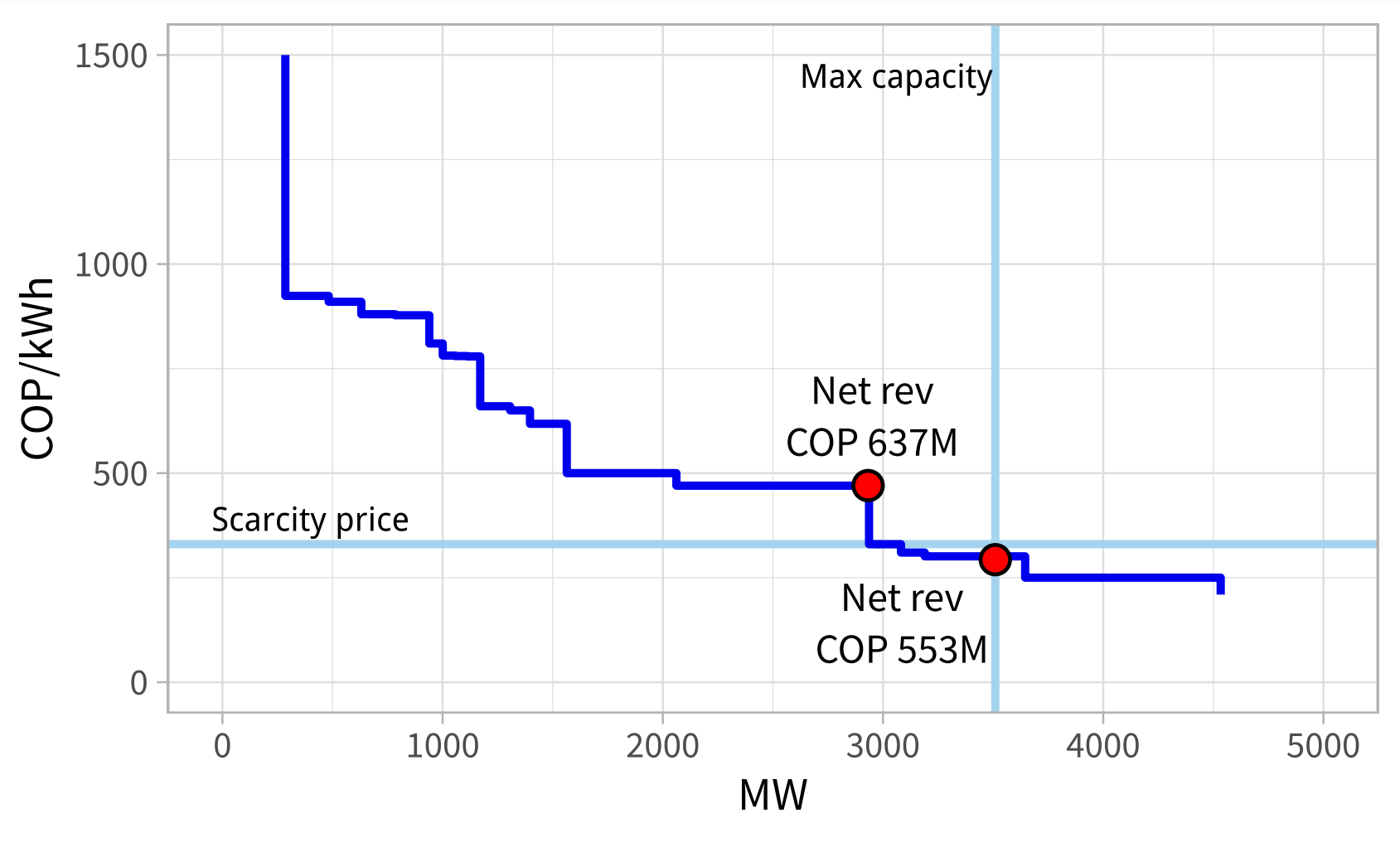
# For EPM, in 10% of hours in the sample (18% during 2015) it had the ability to choose between scarcity and non-scarcity



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

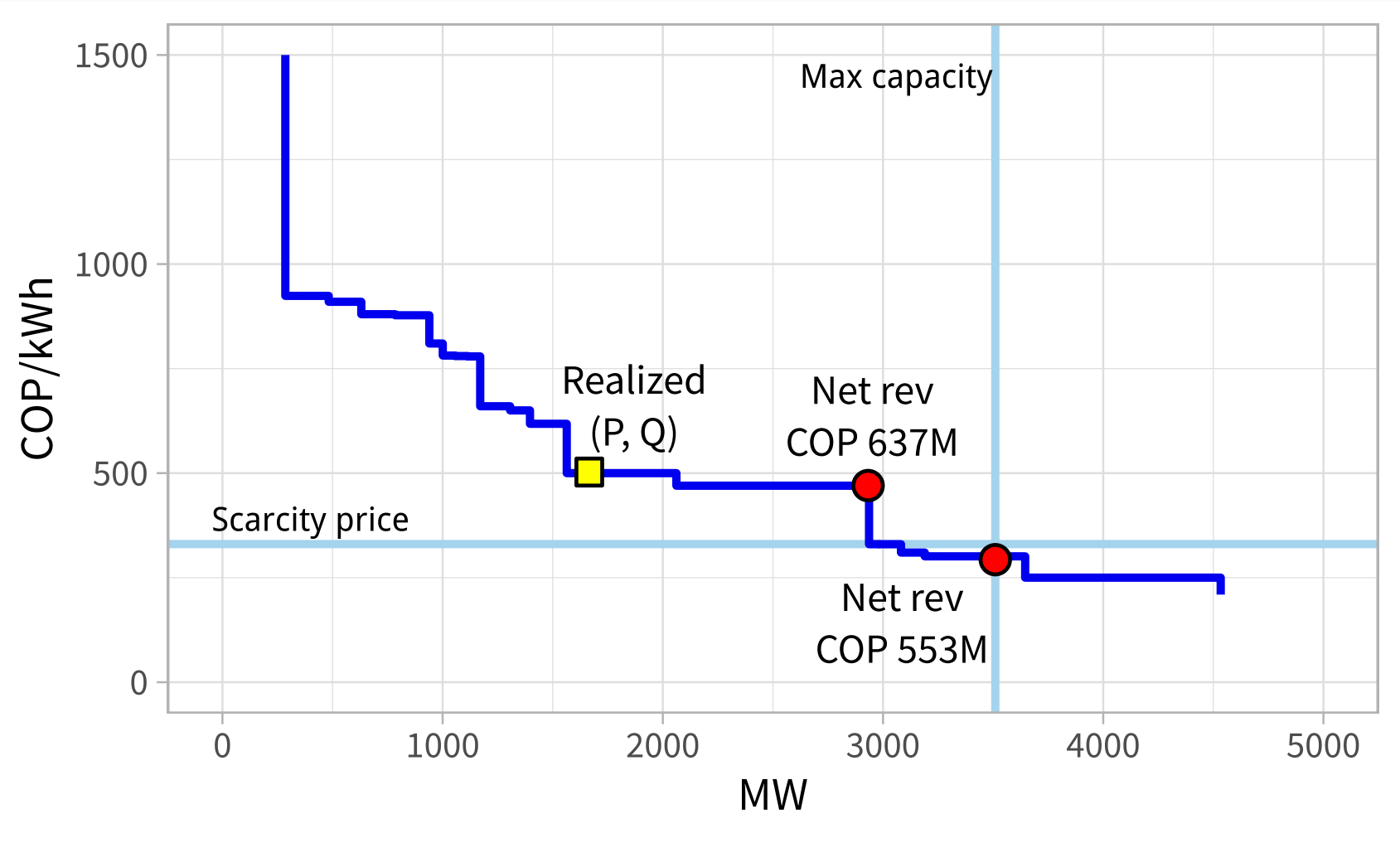
- Search along non-scarcity section of residual demand curve to find the optimal price and quantity
- Search along scarcity section of residual demand curve to find the optimal price and quantity
- Which of the two options would lead to higher net revenues?

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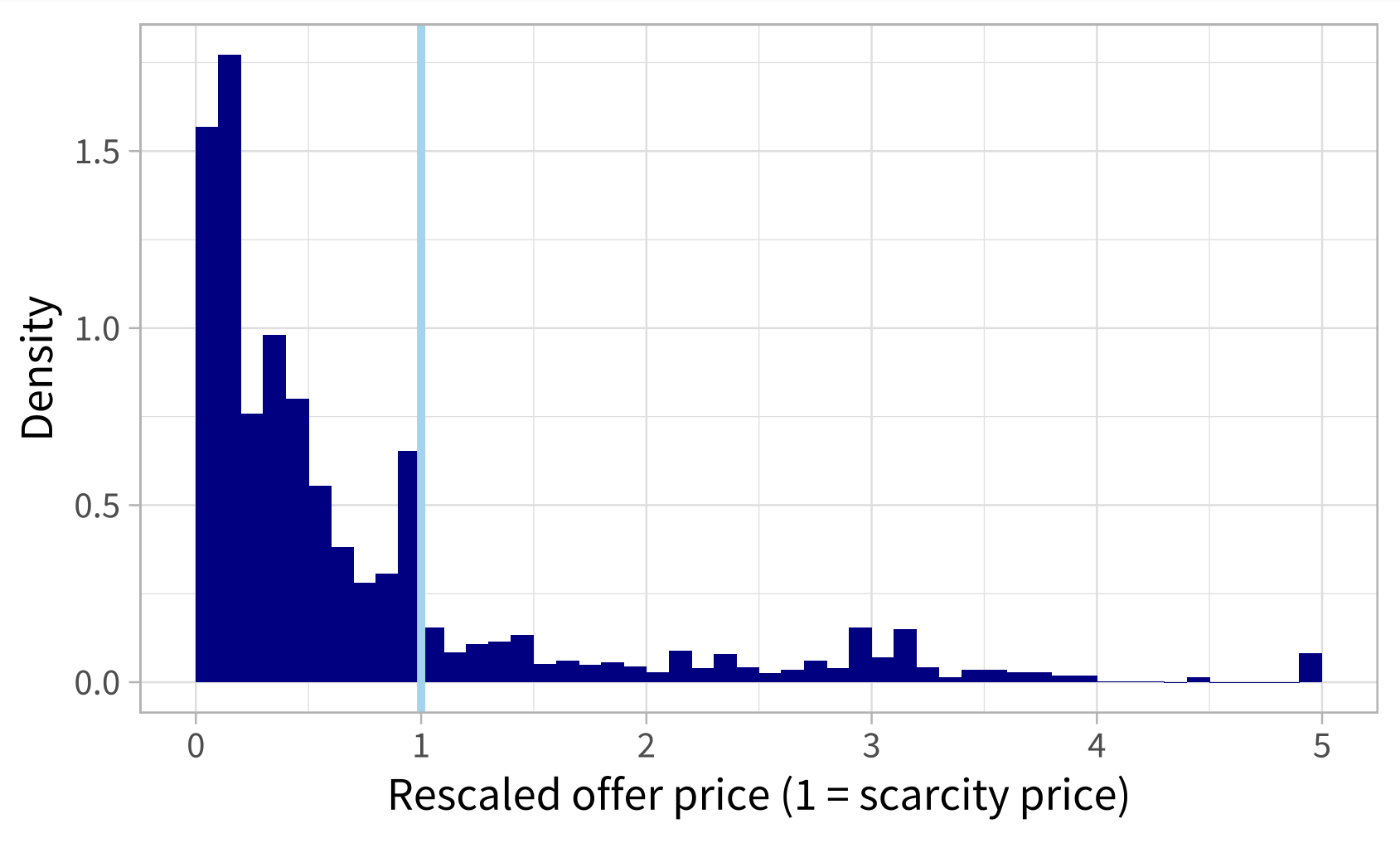
# Optimal choice for the firm between scarcity and non-scarcity periods predicts the observed market outcomes

- 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

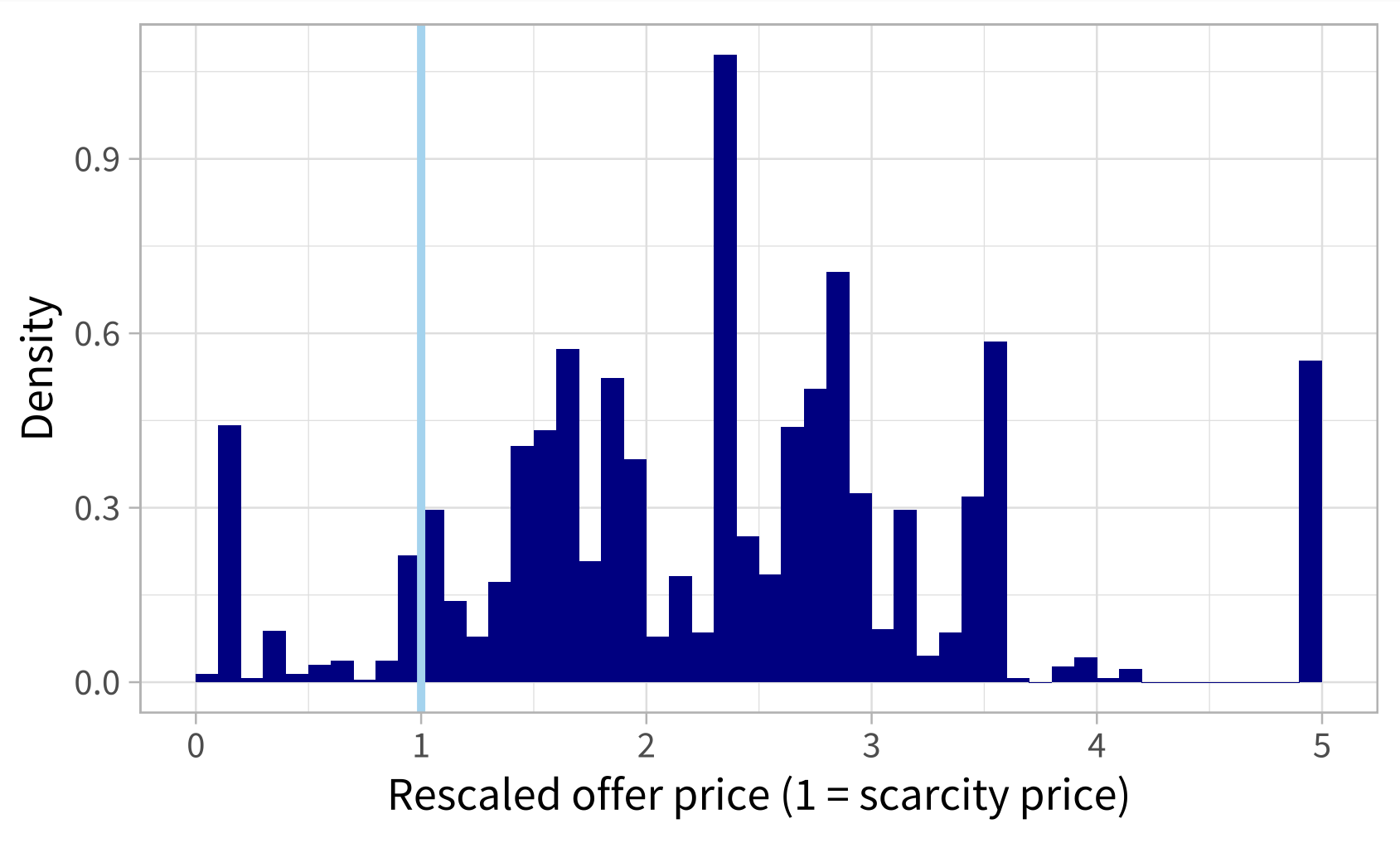
## Are these differences in the optimality of the scarcity condition reflected in the bidding behavior of the firm?

- 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

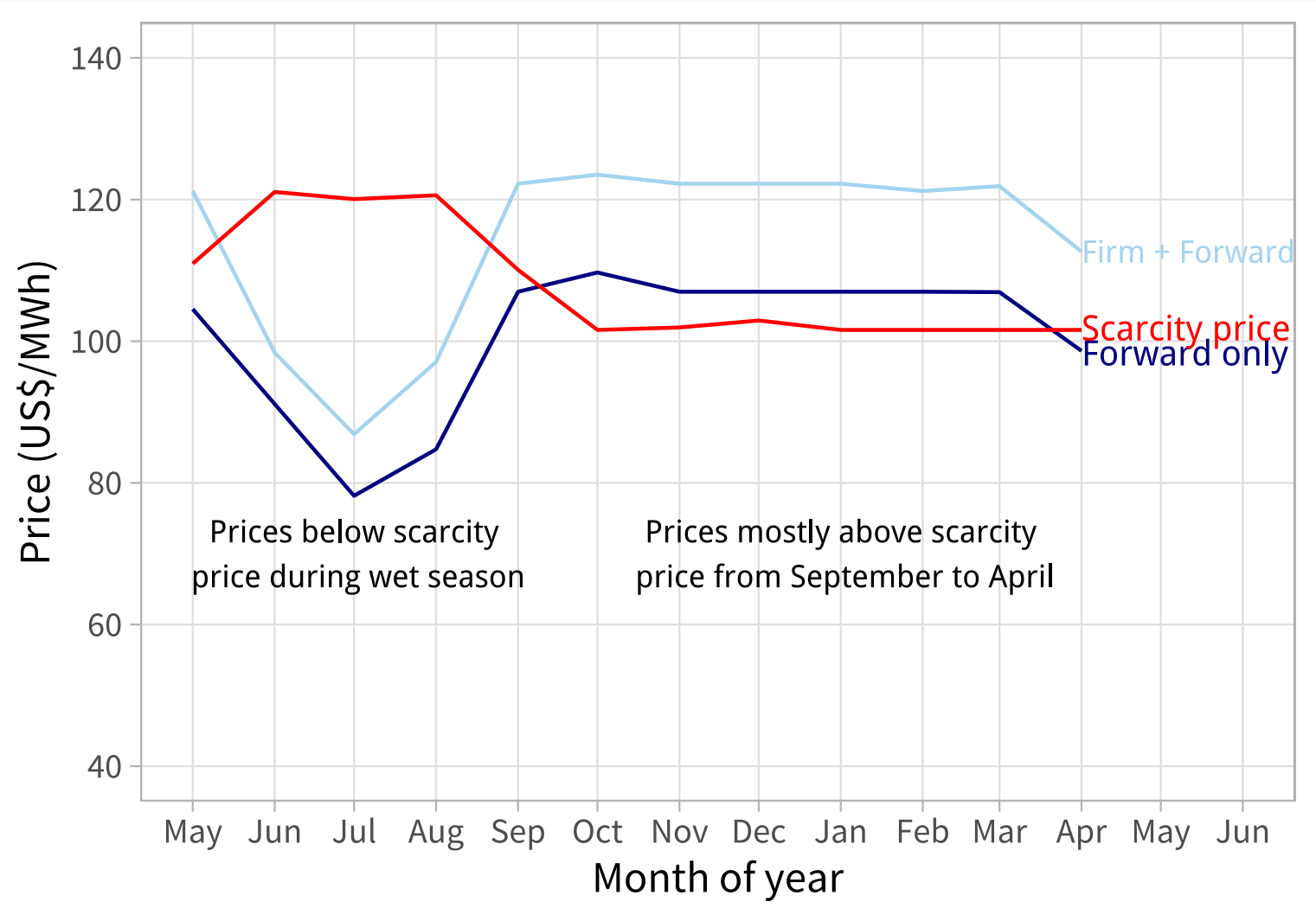


How does the firm energy mechanism affect market outcomes?

# 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