

## Problem #3

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# Can the Market Solve the Reliability Investment Problem?

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## Theory versus reality

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- This lecture discusses present reality.
- The present market has limitations that would take several years to remove.
- Removing them may not be worth the cost.
- For many consumers demand is not based on the competitive price.
- This violates an assumption of “perfect competition.”
- Standard economic theorems do not apply.

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## Two Types of Blackouts

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- Reliability = There is no “loss of load,” “load shedding,” or “blackouts.”
- **Type 1:** “Controlled rotating power outages,” ISO-CA term. Also called “rolling blackouts.”
- **Type 2:** “Uncontrolled or cascading power outages,” ISO-CA term. Also called “system collapse.”
- “Rolling (rotating) blackouts” = Load areas take turns being blacked out.
- Rolling is better than cascading.

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## Two Types of Reliability

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- Reliability = Security + Adequacy
- **Security** = No blackout if (1) a line breaks, or (2) a generator brakes.
- **Adequacy** = Having enough generators for the day with the greatest load.
- Adequacy must take account of the fact that there are always some broken generators (“outages”).

PSE, Ch. 2-3.2

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## Two Ways to Provide Reliability

- **For Security:** Keep extra generators running (spinning reserve). Have quick-start generators in reserve. Respect contingency limits for transmission.
- **For Adequacy:** Build enough (an adequate number of) generators.
- **For Security:** System operator must buy reserves and ancillary services. “The market” will not do this. Everyone agrees.
- **Q:** Will the market buy an adequate number of generators?

## Adequacy: The Biggest Controversy

- **The pure-market view:** The market will build enough generation if the system operator does not interfere. It’s just normal economics like in “The Complete Market Example.”
- **The public-good view:** Individual reliability cannot be purchased. So consumers do not tell “the market” how much reliability they want. Adequacy is an externality (outside the market) like security.

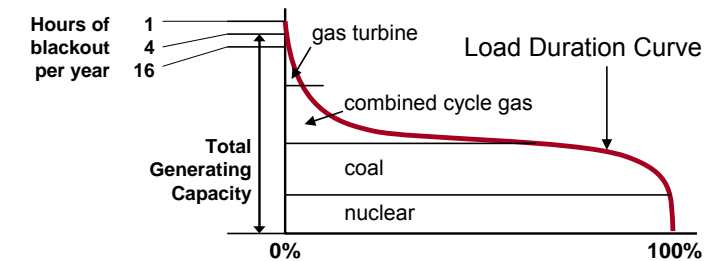
## Argument for the Pure-Market View

1. Economic theorem: competitive short-run prices induce optimal investment without regulation.
2. There is too much reliability because engineers and regulators are too cautious.
3. Optimal (less) reliability would save money, because fewer generators are needed.

Step 1 → A Pure-Market approach will work.

Step 2 & 3 → It is important.

## What Type of Generator to Buy?



Generators purchased for adequacy will make significant profits for less than 24 hours per year. The system should have the same number of coal and nuclear plants, for any adequacy level.

## For Adequacy: Minimize Fixed Cost

- For a generator that runs only 1-day per year, fuel cost (marginal cost) does not matter.
- Buy the cheapest generator to build.
- For all generators built by the market  
Less Fixed Cost  $\leftrightarrow$  More Marginal Cost
- The cheapest plant to build has  
**the highest marginal cost**  
( a cheap gas turbine, a **GT** )

## How Does a GT Make a Profit?

- A GT has the highest marginal cost,  $MC_{GT}$ .
- Short run profit  $> 0$  **only** when  $P > MC_{GT}$
- When  $P > MC_{GT}$  every other plant is running.
- Many GTs will run when  $P = MC_{GT}$ , but they will make very little profit.
- **An investor in a GT must cover fixed costs during a few super-peak hours when all generators are running at full capacity and  $P > MC$  of all generators.**

## Restatement of Controversy

- **The Pure-Market View:** The market
  - will send optimal signals (prices) for reliability
  - to investor in GTs
  - during the super-peak hours
  - when  $P >$  all MC, and
  - all generators are running.
- **The Public-Good View:** The market
  - Cannot find the competitive price in or near super-peak hours.
  - At these times, price is controlled by regulators and market power, not by competition

## The Argument that Pure-Markets Works

1. Economic theorem: competitive short-run prices induce optimal investment without regulation.

This is the only “proof” that a pure-market approach could work.

Let us take a closer look.

## The argument in more detail

1. The competitive locational (market) price is efficient and induces optimal generation investment, just like in “The Complete Market Example.”
2. Optimal generation investment must be “adequate” generation investment.
3. So the “The Complete Market Example” proves that market prices can solve the reliability/adequacy problem.
  - **This is wrong.**

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## Standard Economics Assumes Reliability

- In economics and in The Complete Market Example, 100% reliability is **assumed**, so
- there is no adequacy problem.
- In standard economics, “Optimal investment” **has nothing to do with adequacy.**
- Optimal investment means: enough investment to bring average price down to minimum long-run average cost.
- The concept of “adequate investment” is not in any economics textbook.

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## Does Economics Assume Reliability?

- It never mentions reliability ???
- It assumes the supply and demand curves always intersect. That means perfect reliability.
- If supply and demand intersect, then **everyone** who wants electricity at the market price will get it. Supply will equal demand. **There will never be a rolling blackout** (like we had in California).

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## Conclusion

- The argument for a pure-market approach to investment for reliability is based on a fundamental misunderstanding of economics.
- Standard economics does not support this claim.
  
- However, standard economics has been extended to cover the reliability/adequacy problem. What does this extension tell us?

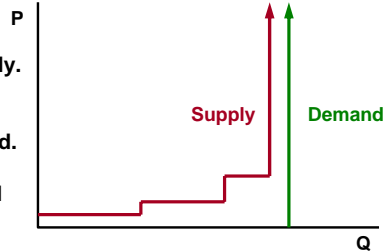
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## Putting Un-Reliability into Economics

Load is shed (lost) when demand is greater than supply.

There is no market-clearing price, where supply = demand.

There is no short-run optimal price, no CLPs.



The economics of reliability and adequate investment:

**When there is no competitive price (CLP), it is best to set  $P = \text{VOLL}$ , the value of lost load.**

## The Economics of VOLL

- $P = \text{VOLL}$  is the optimal short-run price.
- $P = \text{VOLL}$  is the optimal long-run price.
- Just like CLPs are short and long-run optimal.
  
- VOLL is the average value lost per MWh for customers who have their power cut off in a blackout. (Customers not identical.)
- We don't know what it is.
- Perhaps  $1,000 \text{ €} < \text{VOLL} < 100,000 \text{ €} / \text{MWh}$ .

## Is VOLL Real?

- Many think that because it cannot be measured with reasonable accuracy, that VOLL does not exist or is meaningless.
- Actually, VOLL could be measured with experiments and a market for blackouts.
- VOLL is a useful concept because it helps us understand what happens if we set  $P > \text{VOLL}$  or  $P < \text{VOLL}$ .
- Like "utility," VOLL would be useful even if it could not be measured.

## Why is $P = \text{VOLL}$ short-run optimal?

- A few customers can and do respond to price.
- They should reduce consumption if power is worth less to them than to those blacked out.
- They should not reduce consumption if power is worth more to them.
- $P = \text{VOLL} \rightarrow$  optimal consumption for price responsive consumers.
- Similarly, a few generators can supply more power, but at great cost.
- $P = \text{VOLL} \rightarrow$  optimal generation.

## Why is $P = \text{VoLL}$ Long-Run Optimal?

- It will induce optimal investment.
- Assume 20 hours / year of blackouts.
- 1 more MW of capacity will reduce lost load by 20 MWh. Value of 1 MW =  $20 \times \text{VoLL}$ .
- Payment to 1 MW =  $20 \times \text{VoLL}$ .
- If capacity costs less than  $20 \times \text{VoLL}$  it will be built. If it costs more it will not be built.
  - ➔ The optimal amount of capacity for blackouts costing  $\text{VoLL} / \text{MWh}$  will be built.

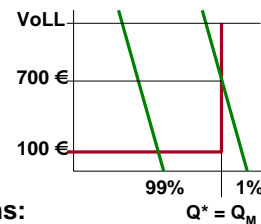
## The economic theory of adequacy

- What can cause an adequacy problem?
  - Market flaws
    - Most load does not respond to price in real time
    - Load that has not purchased power cannot be cut off
    - Load that has purchased power with a bilateral contract cannot be protected from a blackout.
  - Regulatory flaws
    - Price caps that are too low
    - Capacity targets that are wrong (likely too high)

## Case 1: No real adequacy problem

With enough demand elasticity, there is no real adequacy problem.

Example.  $\text{FC} = 6 \text{ €} / \text{MWh}$ , high demand 1% of the time.



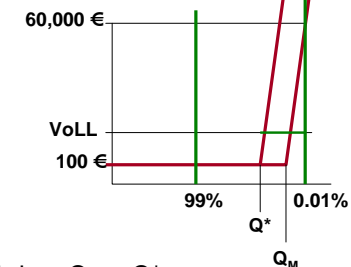
### Two possible regulatory problems:

1.  $P_{\text{CAP}} < P_{\text{MAX}} < \text{VoLL}$ . ➔  $Q_M < Q^*$   
The regulator can set the price cap too low and cause too little market investment. May or may not hurt reliability.
2.  $Q_T > Q^*$ . ➔  $Q_R > Q^*$   
The regulator can set the capacity target too high.

## Case 2: Market price > VoLL

Supply and demand can intersect at a market-clearing price > VoLL. (60,000)

This can happen with a competitive or monopolistic supply curve.



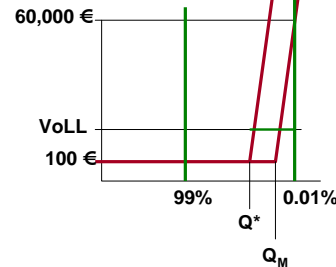
The market will have an equilibrium  $Q_M > Q^*$ .

The level of reliability is too high because consumers are paying more than the value of the power. They would prefer a blackout to paying so much.

## Case 2: Market price > VoLL

For the optimal  $Q^*$  a peaker earns FC (6 €/MWh) from a price that is capped at VoLL.

$Q^* < Q_M$  because  $Q_M$  relies on prices > VoLL.



Regulatory improvement:  $P_{CAP} = VoLL \rightarrow Q_M = Q^*$

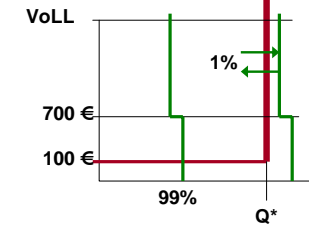
### Two possible regulatory problems:

1.  $P_{CAP} < VoLL \rightarrow Q_M < Q^*$
2.  $Q_T > Q^* \rightarrow Q_R > Q^*$

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## Case 3: No market equilibrium

The demand curve moves up to its maximum as shown on 1% of the days, but it spends only 0.1% of the time intersecting the supply curve at  $Q^*$ . This is the only time when  $P > 100$  € and  $P$  is defined.



Consequently, the market price cannot support the optimal level of  $Q, Q^*$ .

If the regulator defines a price when  $S \neq D$ , then there will be an equilibrium, but the market does not have an equilibrium of its own.

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## Interaction of regulation and market

$(Q_M, Q_R)$	Regulatory Rules			
	1	2	3	4
Compares Market & Regulated Q with $Q^*$	$P_{CAP} < V$	$P_{CAP} < V$	$P_{CAP} = V$	No $P_{CAP}$
	$Q_T > Q^*$	$Q_T = Q^*$	No $Q_T$	No $Q_T$
No market flaw	1 less, more	less, =	=, =	=, =
P sometimes > V	2 less, more	less, =	=, =	more, more
No equilibrium	3 less, more	less, =	=, =	?, ?

$V = VoLL$ . Assumes no market power or excess risk.

$Q_R$  = Total capacity including regulatory purchases.

$Q^*$  = optimal (adequate) capacity.

$Q_T$  = regulator's target capacity.

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## Interpretation of table

- Column 4 is the pure-market approach because the market cannot set  $P = VoLL$ .
- The pure-market approach assumes cell (1, 1), and proposes to move to cell (1, 4).
- With market power, columns 3 & 4 could indicate (more, more) in all positions.
- In Columns 1 & 2,  $P_{CAP}$  must be less than the maximum market price in order to distort investment. Even in this case it may not cause an adequacy problem.

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## Could the market set $P = VOLL$ ?

- No.
- It would have to read our minds.
- Two problems:
  - Markets cannot read minds.
  - Our minds are blank.
- Do you know your VOLL?
- Have you ever told “the market” what it is?
  
- (But a market for individual blackouts could set the price of blackouts to VOLL.)

## Pure-market theorem 1:

- A pure-market approach can solve the adequacy problem only if there is no market flaw causing an adequacy problem.
- If the pure-market approach solves the adequacy problem, it will make the market 100% reliable.
- If the market is currently too reliable, then the pure market approach cannot solve the adequacy problem.

## Theorem Interpretation

- The pure market approach removes the price cap and capacity target. If these were the only market problems, then this will solve all of the problems.
- If the demand curve is severely distorted and this causes an adequacy problem, the market cannot solve this problem.
- If optimal capacity is determined by VoLL, the load duration curve, and the cost of peakers, then optimal capacity will not produce 100% reliability and the pure market approach cannot solve the problem.

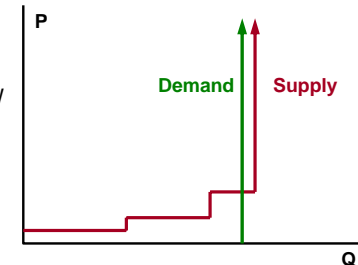
## Super-peak market power

Before the super-peak, how much market power is there?

Say Supply > Demand by 290 MW

Any supplier that owns 500 MW can turn off 300 MW and raise the price from 150 € to 10,000 €.

Problem: How profitable is this?



Near the super-peak, GTs will make a profit only from market power. During the supper peak, they will make a profit according to the arbitrary 10,000 € price set by the system administrator.

Their profit will never come from a competitive market price.

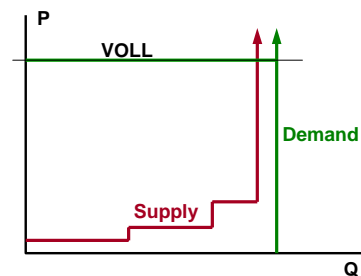
## Super-peak risk

Assume the SO sets  $P = \text{VOLL}$  when demand > supply.

Assume no market power.

US reliability  $\rightarrow$   $\text{VOLL} = 180,000 \text{ €}$ .

GT investors make their profits when  $P = \text{VOLL}$ . They need 60,000 € per year.



Investors cover their fixed costs with 20 minutes of short-term profits.

But those 20 minutes do not happen every year. Sometimes there may be 4 hours of rolling blackouts, and then none for 11 more years. It averages out to 20 minutes per year. Investors think this is risky business. Risk is expensive.

Convergence

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## “Pure-market” summary

- SO sets arbitrary high cap on monopoly power.
- SO sets price high when Demand > Supply.
- SO sets a medium high price when short of reserves.
- Investment is determined by SO and market power.
- Investment is not related to optimal reliability or to minimizing long-run costs.
- Investor risk is high because price spikes are rare.
  
- Actual “Pure-Market” proposals are not at all pure. They will induce adequate capacity only if the regulator does a good job. The market will not help out.

Convergence

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## “Pure-market” summary

- The “pure market” approach can work only if there is no market flaw. In this case the market will make the equilibrium capacity adequate by controlling demand to prevent all blackouts.
- Advocates do not believe this will happen.
  - They say reliability is too high.
  - They propose price caps in case of market power.
  - These caps set the price during a blackout.
  - They suggest the regulator raise prices when operating reserves are short.

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## The ICAP market approach

- While the market still has an adequacy problem,
  - Engineers should
    - determine the adequate level of investment.
  - The regulator should:
    - (1) use an installed capacity (ICAP) market.
    - (2) use high prices for performance incentives.
    - (3) use a hedge to reduce risk and market power.

Convergence

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## **Two old approaches**

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The “pure” approach:

- high prices for
  - Determining installed capacity
  - Good performance incentives
- A hedge to reduce market power

The old capacity-market approach

- Low prices to reduce market power
- A capacity market to determine installed capacity

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## **The new convergence**

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- high prices for good performance incentives
- A hedge to reduce market power and risk
- A capacity market to determine installed capacity.
  
- The trick is to use the hedge to prevent the high prices from controlling capacity and to keep the capacity market from hurting incentives.

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## **What works and what doesn't**

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- Competitive locational prices are excellent for:
  - Dispatch
  - Consumption
  - Inducing investment of the right quality and type of generation.
- But they have problems:
  - They are risky and risk is expensive.
  - They invite market power.
  - They are a poor signal for total investment

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## **What works and what doesn't**

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- Hedges (call options)
  - Greatly reduces risk
  - Greatly reduces market power
  - Do not block the good incentives of CLPs
- A market-determined capacity payment
  - Is an excellent signal for total investment
  - Sends no performance signal

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### How the ICAP market works (without a hedge)

- Engineers estimate needed capacity in 2011.
  - 52 GW is needed
  - 50 GW exists (or is being built).
- Old and new capacity bid  $B \text{ € / MW capacity}$ .
- The SO accepts cheapest bids, up to  $B^*$ .
- All the winners are paid  $B^*$  in 2011.
- New suppliers lock in  $B^*$  for 5 or 10 years.
- Short-run profit = Annual  $\sum (P - MC) + B^*$
- Competition limits short-run profits to just enough to induce investment.

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### Adding a Hedge (call option)

- Payment to generators works like this:
- $P^*$  = strike price = about 250 € / MWh.
- $\sum (P - P^*)$  is hedge payment to load
- Generators are paid  $B^* - \sum (P - P^*)$  for ICAP. (when  $P > P^*$ )
- This eliminates most price-spike risk,
- And eliminates most on-peak market power.
- Keeps performance incentives.

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### Total short-run profit (net revenue)

$$= \text{Annual } \sum (P - MC) + B^* - (P - P^*)$$

$$= \text{Scarcity rent} + \text{ICAP payment} - \text{Hedge payment}$$

$$= \text{Hedge payment only when } P > P^*.$$

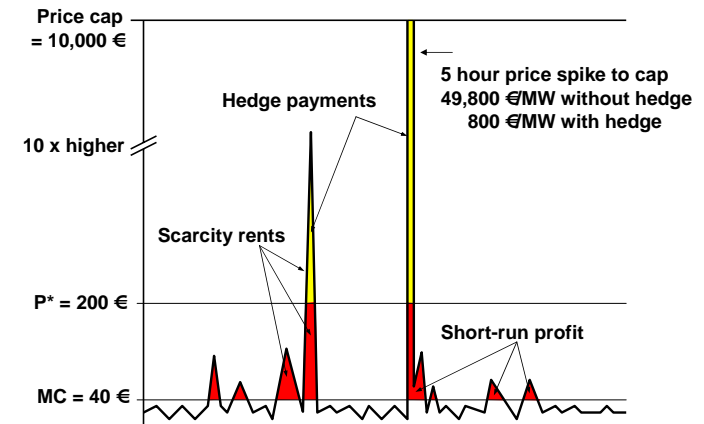
Let  $P_H = \text{minimum}(P, P^*)$

$$= \text{Annual } (P_H - MC) + B^*$$

$$= (\text{Scarcity rent as if } P^* = \text{price cap}) + \text{ICAP payment}$$

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### How the hedge reduces risk



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## The hedge does not hurt generators

- The generators lose the tops of the price spikes.
- Suppose these are worth 40,000 € / MW-year on average.
- They bid 40,000 € / MW-year higher in the ICAP auction and the clearing price,  $B^*$ , is 40,000 € higher.
- A very random 40,000 € is replaced with a very steady 40,000 €.
- The same is true for consumers.

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## The hedge eliminates most market power

- Suppose a generator exercises market power and turns a 100 € price spike into a 10,000 € price spike.
- Without a hedge, profit = 9,900 € / MWh.
- With the hedge, profit = 160 € / MWh.
  
- But this is only half the story.
- Next consider the incentive to produce.

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## Hedge does not affect incentives

- Is it stupid to pay a 10,000 € price and then take back 9,800 € in hedge payments?
- Why not just have a 200 € price cap?
- Because of the incentive.
- If there is a 10,000 € price spike for 1 hour, and the generator does not produce,
  - The generator does not make 10,000 € / MW.
  - The generator must still pay its 10,000 € / MW hedge payment.
- The incentive is the same as with a 10,000 price.

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## 2<sup>nd</sup> Half of market-power story

- In order to raise the price from 100 € to 10,000 €, the supplier must withhold some MW.
- These MW will earn no revenue but must pay a 10,000 hedge payment.
- The call option (hedge) makes it expensive to withhold and exercise market power.

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## Incentives for consumers

- With a hedge and a high price cap, industrial consumers who pay the real-time price will have a strong incentive not to consume.
- In a near emergency, when the price goes to the cap, it is good to have strong incentives for both producers and consumers.

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## Summary of a good ICAP Market

- The engineers decide:
  - Reliability level, VOLL, level of installed capacity
  - These are all equivalent (1 decision)
- This is because the market cannot do this.
- But the market can and should decide
  - Which types of generators
  - Which suppliers are cheapest
  - The level of performance
- The market can and should avoid
  - Price risk (but not performance risk)
  - Market power

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## Is this market failure surprising?

- “Adequate generation” solves the problem of “demand > supply.”
- This is both a reliability problem and a severe market failure—there is no competitive price and not even a market-clearing price.
- It would be strange if a market could solve a problem that happens only when the market fails.
- Of course if the market does not fail (if there is perfect reliability) then we expect the market to work, and it does.

Convergence

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## What about excess-reliability cost?

- The advocates of the pure-market approach, claim that regulators buy too much reliability and this is costly.
- If so, then there is more time when Demand > Supply.
- There should be more market failure.

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## What about excess-reliability cost?

- There will be market power during super peak hours, unless no supplier is larger than about ~2% of the market.
- So prices will be higher than competitive prices.
- The investment signal will be too strong,
- There will be more than optimal capacity and more than optimal reliability—possibly 100% reliability.

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## Pure-market Theorem 2

- If a pure market approach works efficiently it will provide 100% reliability (theorem 1).
- If a pure market approach provides 100% reliability that does not imply it is working efficiently (it may only indicate excess capacity caused by market power).

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## What about excess-reliability cost?

- Suppose pure-marketers are right, that engineers buy too much reliability.
- Typical: capacity > peak load by 18%
- Maybe 10% extra is enough (all engineers would disagree). That's 8% savings.
- But there is no fuel cost savings: 8% → 4%
- Peaker capacity is very cheap: 4% → 1.5%
- That's wholesale savings.
- Retail savings is about 0.7%

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## What about the cost of risk?

- Risk premium for peaker equity might drop by 4% because of the mandatory hedge.
- 50% equity financing → 340/2 €/kW at risk.
- $170 \text{ €} \times 4\% / (60\% \times 8760) = 1.3 \text{ €/MWh}$   
60% is the average capacity factor of **all capacity**.
- Typical wholesale cost = 35 € → 3.7% increase.
- Large because **all capacity** earns the same revenue from price spikes and has the same risk.

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## The “theory” of too-little risk

- The energy-only approach (pure market) argues that we should create more risk so that generators can make more money selling insurance (hedges) to consumers.
- Fire insurance is good, but people may not buy enough. If not, then we should burn down some house so there is more risk. They will buy more insurance.
- Risk is costly. Increasing cost, so that people will try harder to reduce cost is not economics.

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## Which problems are most important?

- Buying too much capacity is cheap, and there is currently no way to have a competitive market determine capacity. Optimizing reliability is one of the least important problems.
- Creating too much risk with super-high price spikes (energy-only approach) is more costly.
- High price spikes cause political problems that can destroy the market.
- High prices exacerbate market power.

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