

# A flexible policy mechanism to incentivize "CCS-ready" without delaying replacement of old coal-fired power plants

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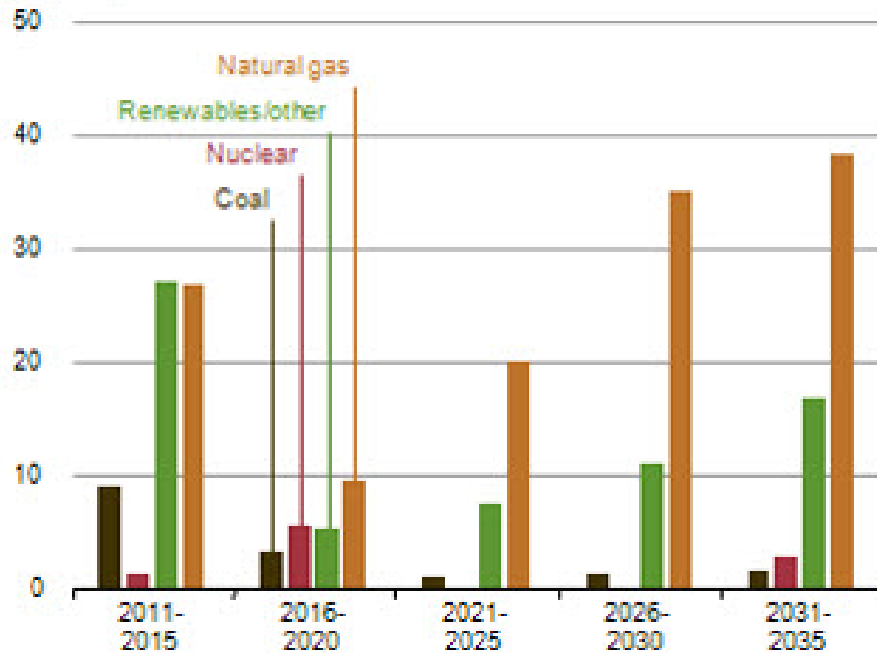
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Power Generation and the Environment: Choices and Economic Trade-offs  
Center for Energy Economics and Public Policy – School of Energy Resources  
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# Motivation

Figure 95. Electricity generation capacity additions by fuel type, including combined heat and power, 2011-2035 (gigawatts)



AEO 2012 – Reference case (with “GHG concerns”)

- AEO forecasts ~18GW of new coal capacity are expected to be installed before 2035
- Coal plants are long-lived assets!
- If new coal plants do not have CCS, it will be **hard to stabilize CO<sub>2</sub> emissions** from the electricity sector and harder to reduce them

# If we agree that CCS is needed...

What can Policy Makers do to **accelerate CCS deployment**?

What can they do to ensure that **any new fossil fired power plant has or is retrofitted with CCS**?



## Cap-and-trade / carbon price

- \*Most efficient way to meet an emissions target
- \*Firms have an incentive to exceed emission standards
- \*May not be stringent enough to incentivize CCS

## Technology standard

- \*EPA preferred way to exercise authority on GHG regulation
- \*Preferred by the U.S. public
- \*May be needed even in the presence of a carbon price!

# Disadvantages of Traditional Technology Standards

- Can extend the lives of existing (dirty) coal plants
  - Economics literature provides several examples of technology standards delaying investment (Gruenspecht 1982, Maloney and Brady 1988, Nelson et al. 1993, Bushnell and Wolfram 2006, Stavins 2007)

Investors response?

- CCS is not commercially mature!
  - Costs are high
  - Performance and long term O&M is uncertain
  - Physical infrastructure is undeveloped
  - Regulatory infrastructure is undeveloped



Hold off on investing  
in new coal facilities

# A better technology standard

## Advantage of having a Standard today:

All new plants will have CCS

## Disadvantage of having a Standard when CCS is not ready:

- Delay investment in coal-plants
- Delay learning in CCS
- Keep dirtier plants longer

Keep advantages and eliminate disadvantages ???

**Flexible standard**

Like EPA's proposed GHG rule?

# EPA's Innovative GHG Rule

- Deals with the problem of CCS immaturity
  - Weighted-average of emissions over 30 years must be below 1,000lb/MWh →  
Plant must be retrofitted with CCS but there are at least 10 years to start CCS operation

But

- Costs will not be felt until new investments are required
  - Policy reversal is plausible
- Investment in coal implies accepting uncertain -and unbounded- future capital and O&M costs of CCS

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# Flexible CO<sub>2</sub> Emissions Standard: ACP

- Owners pay an **Alternative Compliance Payment (ACP)** for new plants that fail to meet the maximum CO<sub>2</sub> emission rate standard
  - additional to any CO<sub>2</sub> price from Federal policy
- When plant is retrofitted ACP payment stops

## Is it feasible?

- ACP at the state level is not likely to face federal law obstacles
- ACP at the federal level would require legislative authorization but precedents exist under US CAA

# Refining the flexible standard

## Flexible standard with ACP:

Owner pays a  
surcharge for new  
plants that fail to meet  
standard

What to do  
with the ACP  
revenues?

## Flexible standard with ACP + escrow :

Accumulate ACP in an  
escrow to help pay for  
retrofits



# Flexible CO<sub>2</sub> Emissions Standard with ACP and **escrow**

- Owners pay ACP for new plants that fail to meet the maximum CO<sub>2</sub> emission rate standard
- ACP accumulates in an **escrow**:  
Investors can use escrow funds **to help finance**
  - CCS retrofits, or
  - plant replacements that meet the standard

## Advantages

- minimizes rate shocks,
- forces consumers in the present to help pay for future costs
- cost of not complying with the standard is bounded and known
- may accelerate investment

# Hypotheses

## Policy

**P1:** Inflexible  
standard

**P2:** Flexible:  
ACP

**P3:** Flexible:  
ACP + Escrow

Task:

Find the an ACP (\$/ton) that causes CCS investment the same year as under P1

# Approach

- I. Analytic framework
- II. Simulation – Stochastic optimization framework

For all policies

1. Simulate **investment and operating** decisions over 40+ years
2. Find emissions over 40+ years
3. Find NPV over 40+ years
4. Compare policies

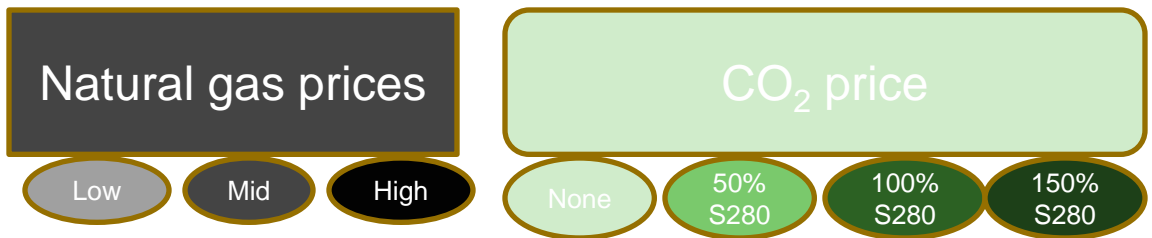
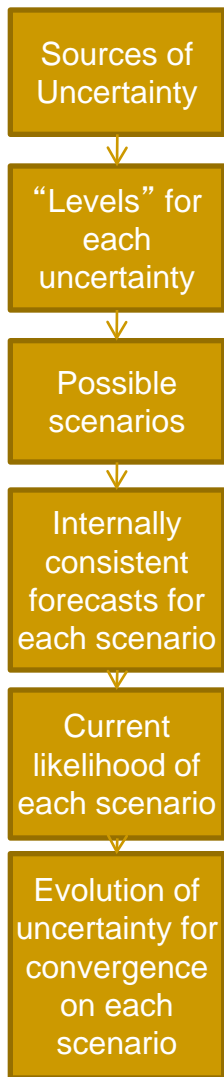
\*Policies:

1. Baseline = no technology standard
2. Inflexible standard
3. Flex with ACP \$1/ton – \$14/ton
4. Flex with escrow ACP \$1/ton - \$14/ton



30 different policies

# Uncertainty characterization



Assume all combinations are possible →  
12 scenarios

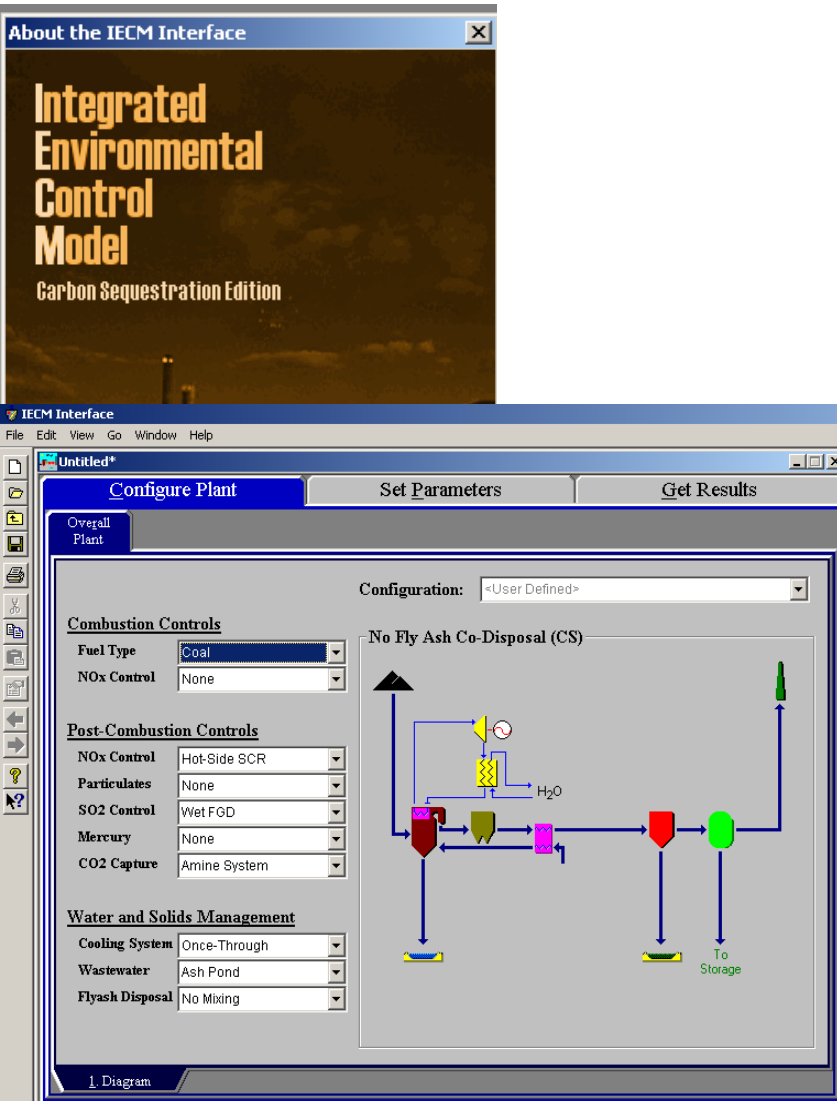
**Haiku:**  
Electricity prices, fuel prices, CO<sub>2</sub> prices,  
learning curves for CCS

Assumption → All 12 are equally likely

Example: Scenario probabilities when converging on Scenario 1

	2013	2014	2015	2016	2017	2018	2019	2020
<b>Scenario 1</b>	0.083	0.214	0.345	0.476	0.607	0.738	0.869	1
Scenario 2	0.083	0.065	0.055	0.044	0.033	0.022	0.011	0
....	0.083	0.065	0.055	0.044	0.033	0.022	0.011	0
Scenario 12	0.083	0.065	0.055	0.044	0.033	0.022	0.011	0

# Investment alternatives



1. Subcritical
2. Supercritical
3. Ultra supercritical
4. IGCC
5. NGCC

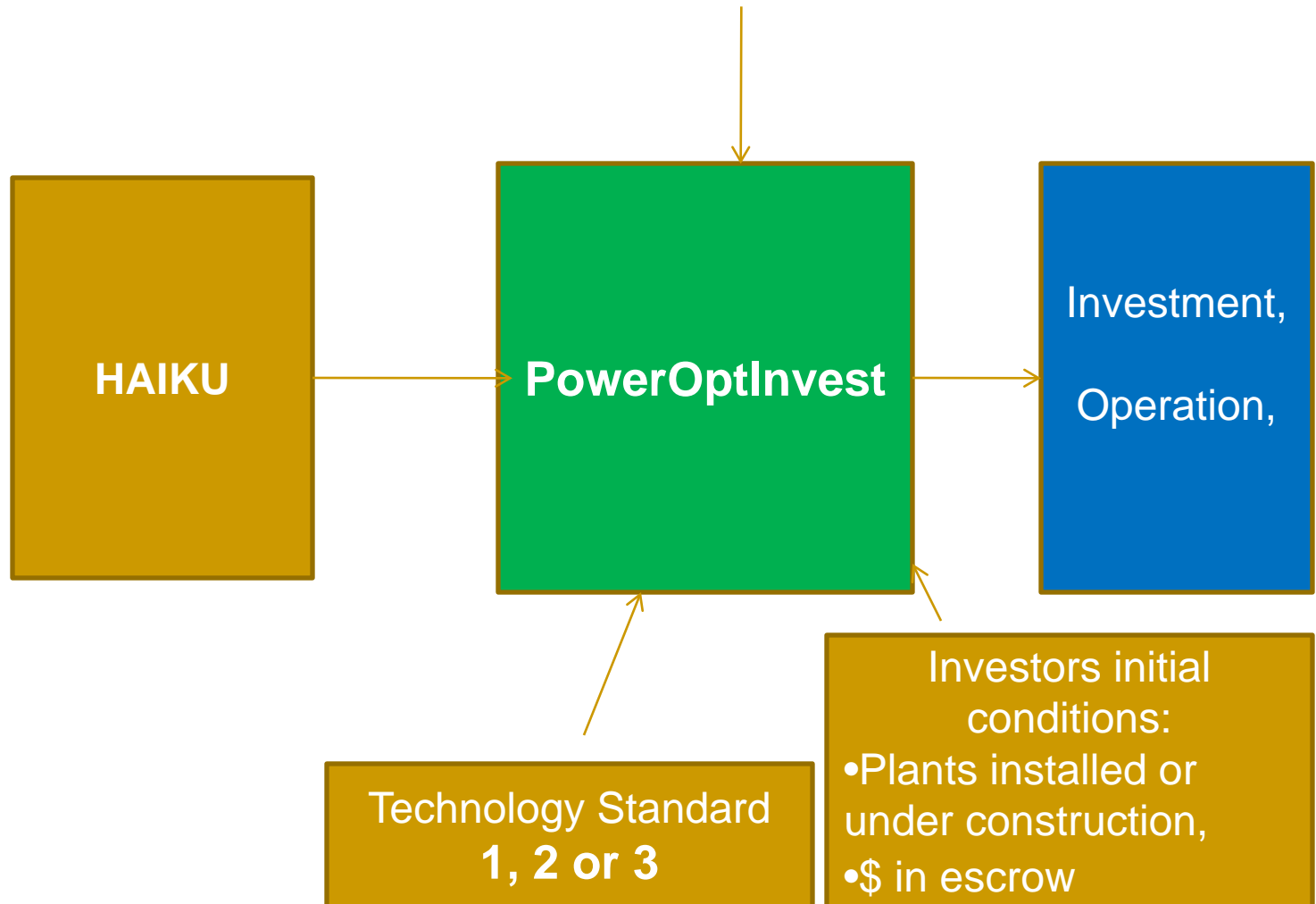
- Can be installed with or without CCS
- Retrofits cost 30% more than new installations
- CCS cost are 2x IECM costs initially, and decline linearly to year 2020

Every year solve an optimization problem

1 knowing the scenario for the next 30 years

or

2. Knowing probabilities of each scenario



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# PowerOptInvest: almost **Perfect foresight**

- Investor has perfect foresight for 30 years
- Each year can see next 30 years
  - When making decision in year 1, is able to see info for years 2 to 31
  - When making decision in year 2, is able to see info for years 3 to 32 etc..
- We look at 43 years of investment and associated costs and emissions
  - When making decision in year 13, is able to see info for years 14 to 43 etc..

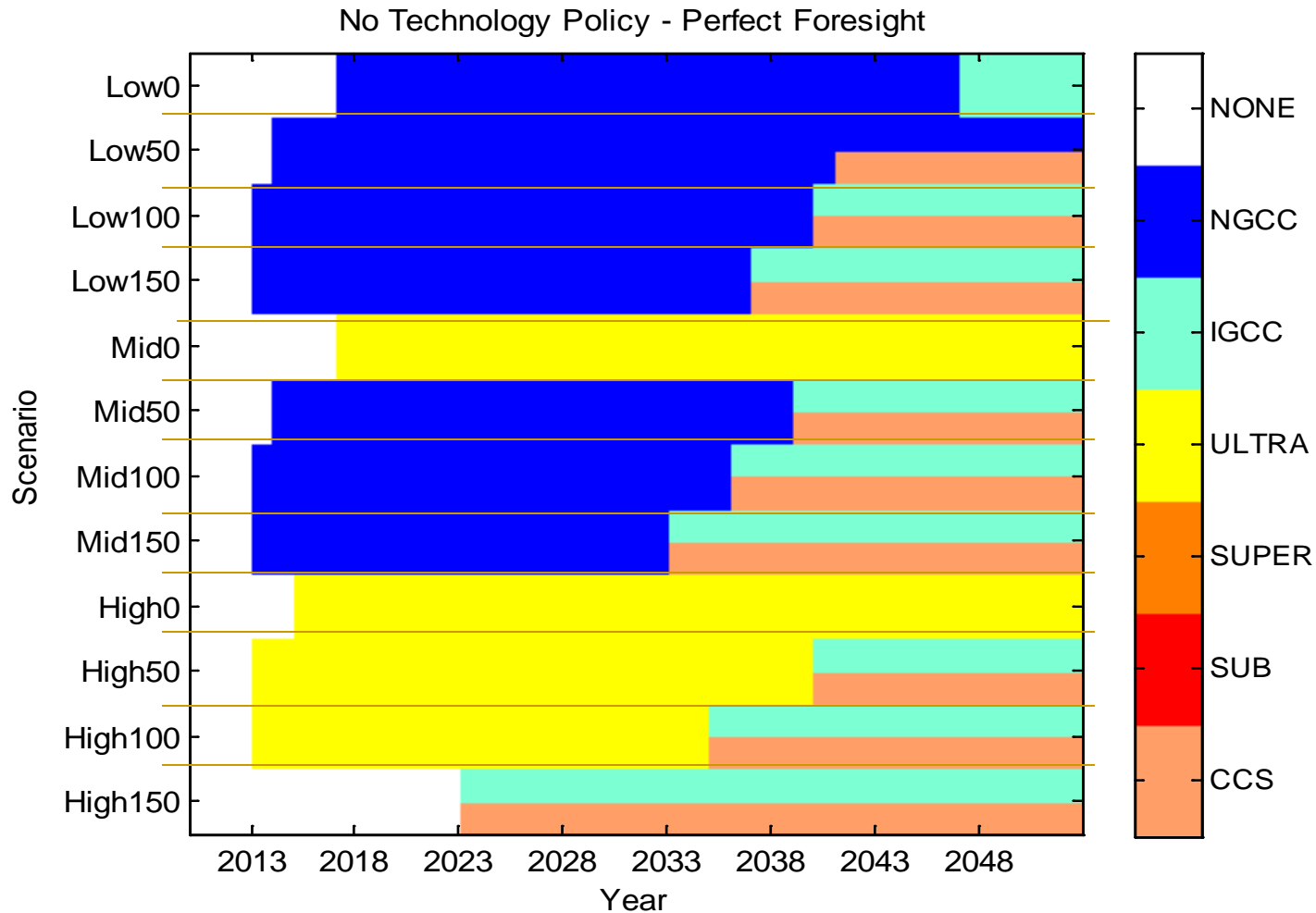
# Results

- ~Perfect Foresight
- Under uncertainty

- Investment
- CO<sub>2</sub> emissions
- Investor profits



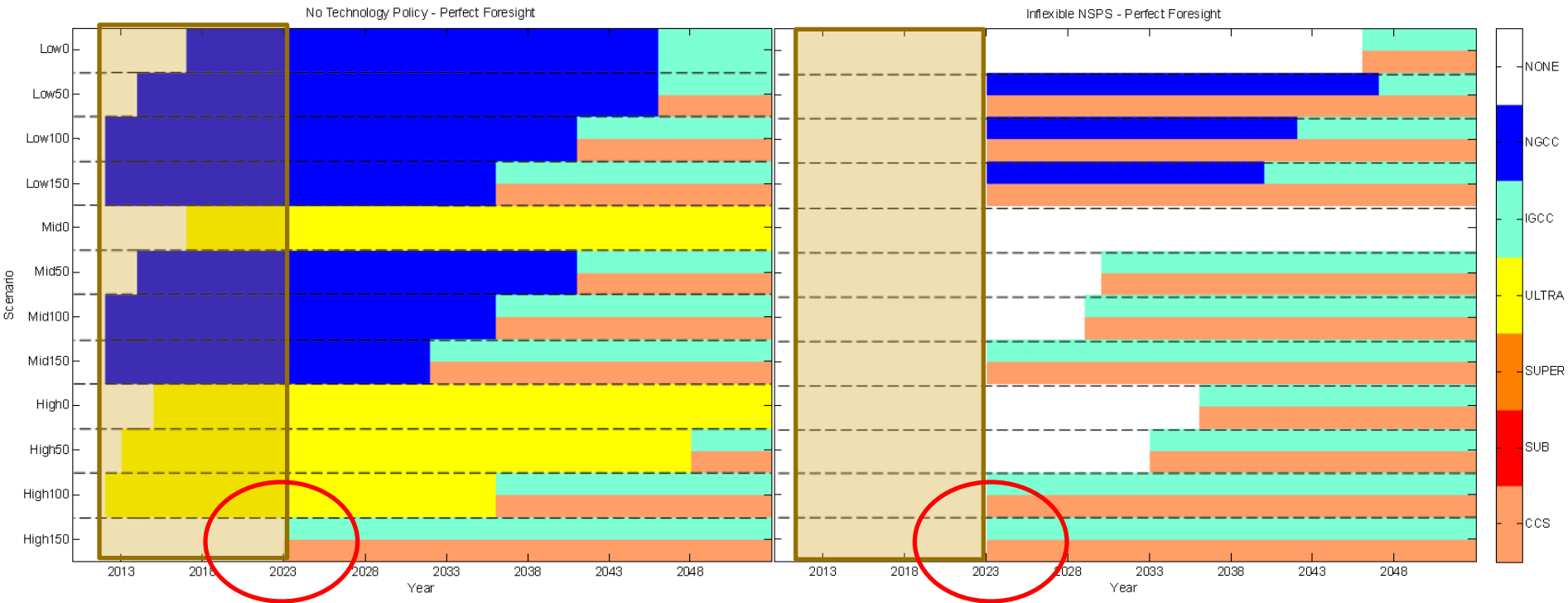
# No technology policy: ~perfect foresight



# Investments with Perfect Foresight

Baseline: No Technology Policy

Inflexible standard



- Investments are delayed in *almost* every case
- Only exception is High150.

# Defining beta star for flexible stnds

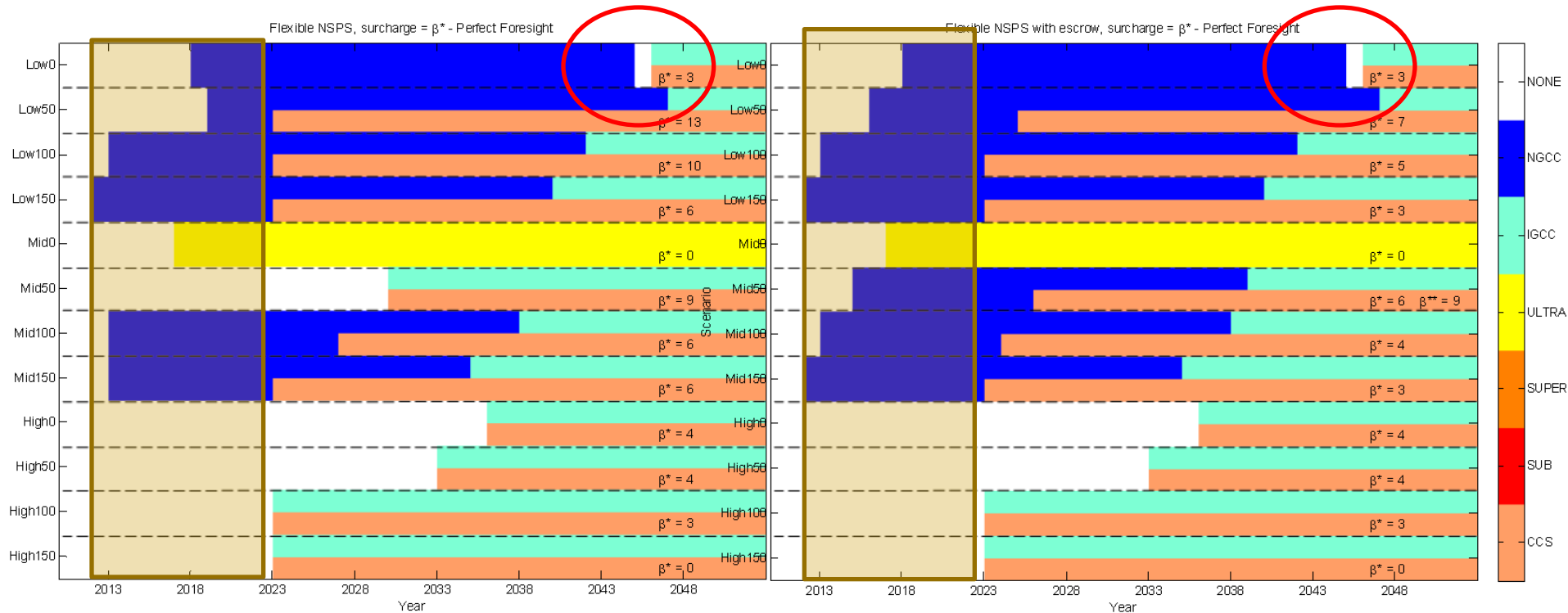
$\beta^*$  : Minimum ACP (\$/ton CO<sub>2</sub>) that causes installation of CCS **the same year or before** than under the inflexible NSPS

- $\beta^* = 0$  means
  - Baseline policy causes the same investment than inflex NSPS (like scenario 12)
  - There is no investment under inflex, so no need for a beta to beat this
- For a few scenarios  $\beta^* < \$14/\text{ton}$  does not exist

# Investments with Perfect Foresight

## Flexible Standard

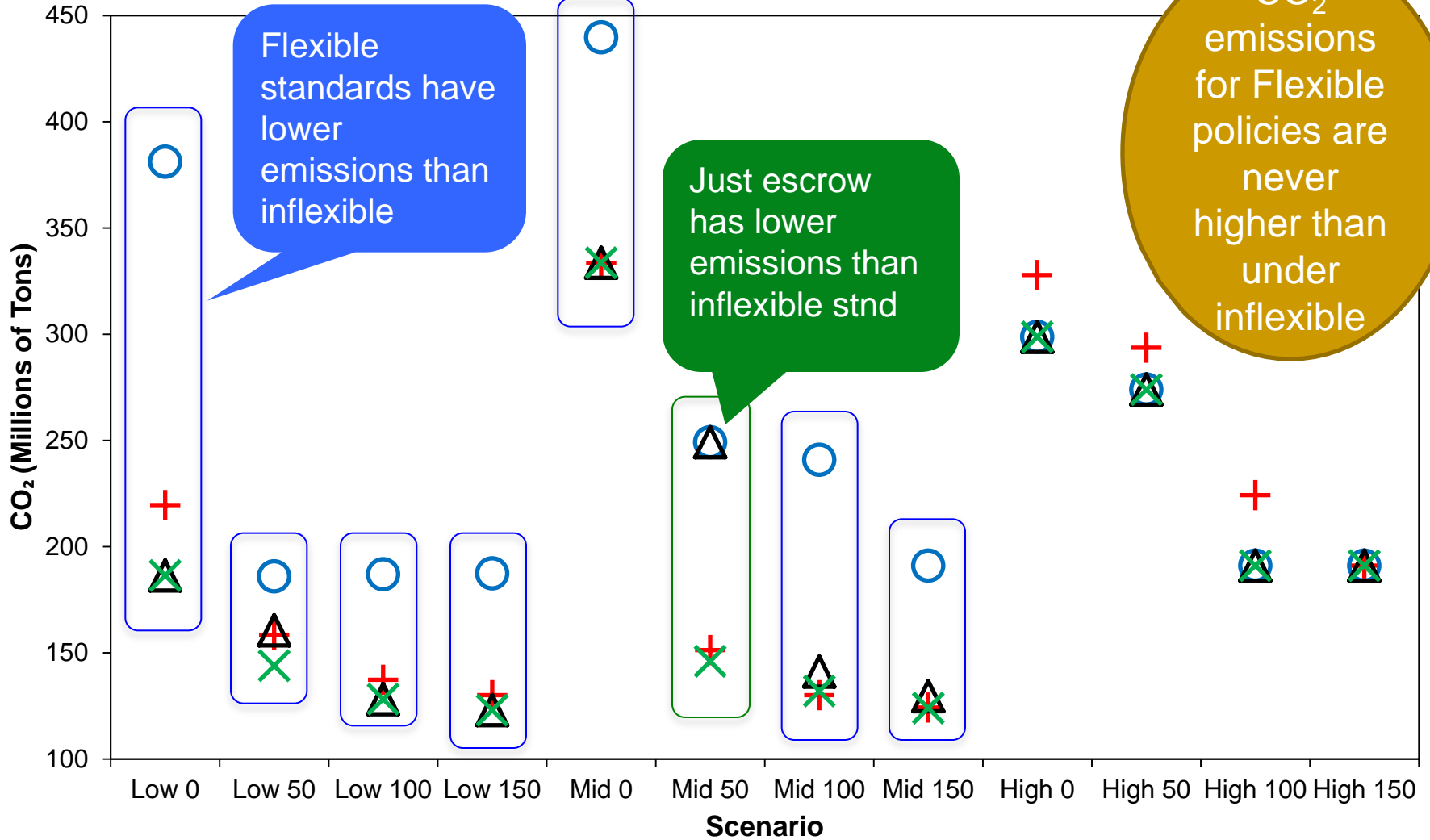
## Flexible Standard with Escrow



- Both policies accelerate investment compared to inflexible standard.
- Escrow leads to slightly earlier investment in generation and CCS
- Escrow requires lower ACP for some scenarios
- Low0 – investor reverts to wholesale power market in 2045 before installing IGCC w/CCS

# Perfect foresight:

CO<sub>2</sub> Emissions Under Perfect Foresight



+ No Technology Policy

○ Inflexible NSPS

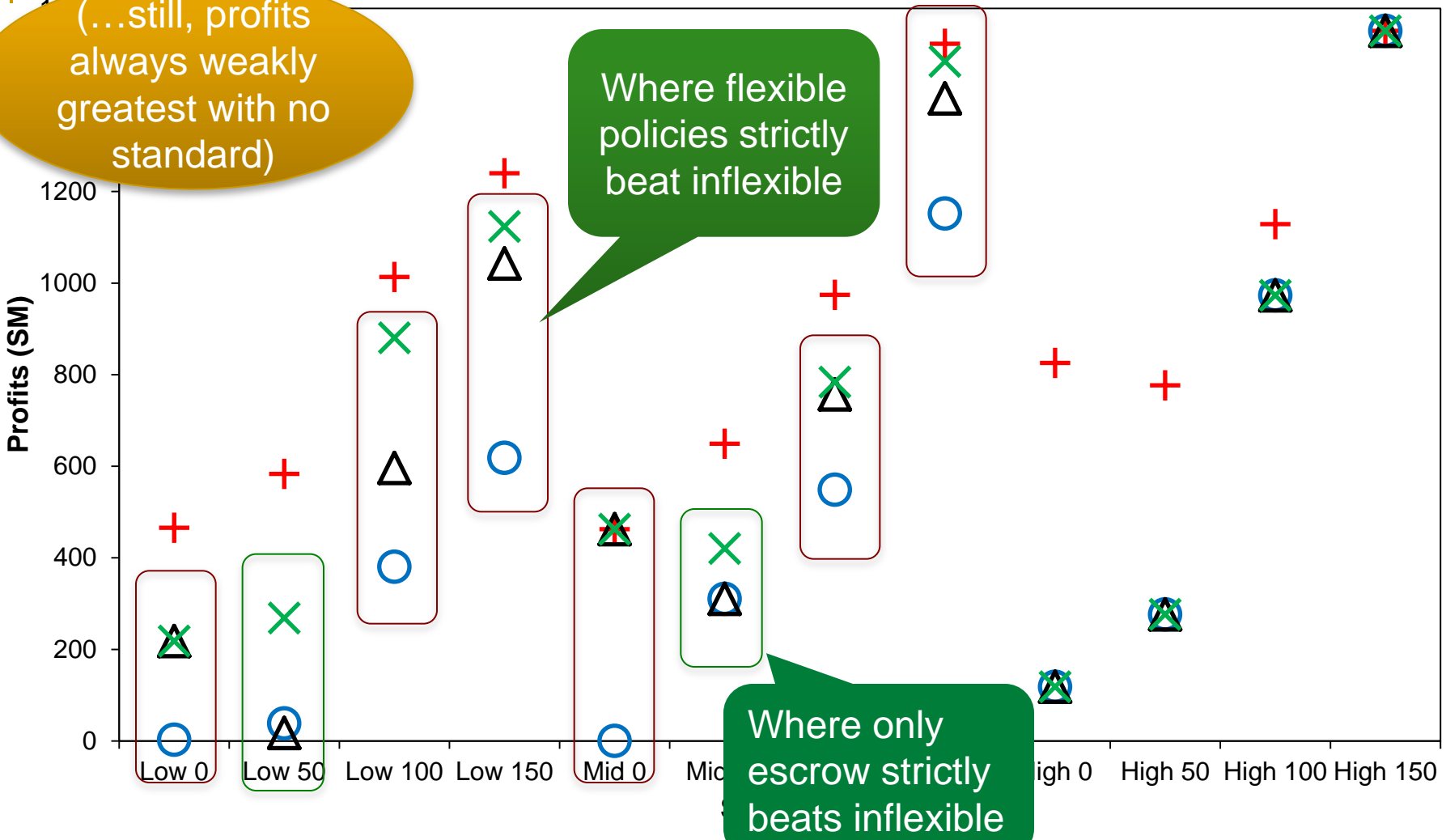
△ Flexible NSPS, surcharge =  $\beta^*$

× Flexible NSPS with escrow, surcharge =  $\beta^*$

# Perfect foresight:

Investor Profits Under Perfect Foresight

(...still, profits always weakly greatest with no standard)



Where flexible policies strictly beat inflexible

Where only escrow strictly beats inflexible

- + No Technology Policy
- Δ Flexible NSPS, surcharge =  $\beta^*$
- Inflexible NSPS
- X Flexible NSPS with escrow, surcharge =  $\beta^*$

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# Optimization model - Uncertainty

- Multi-stage, Stochastic, Mixed integer program (MIP)

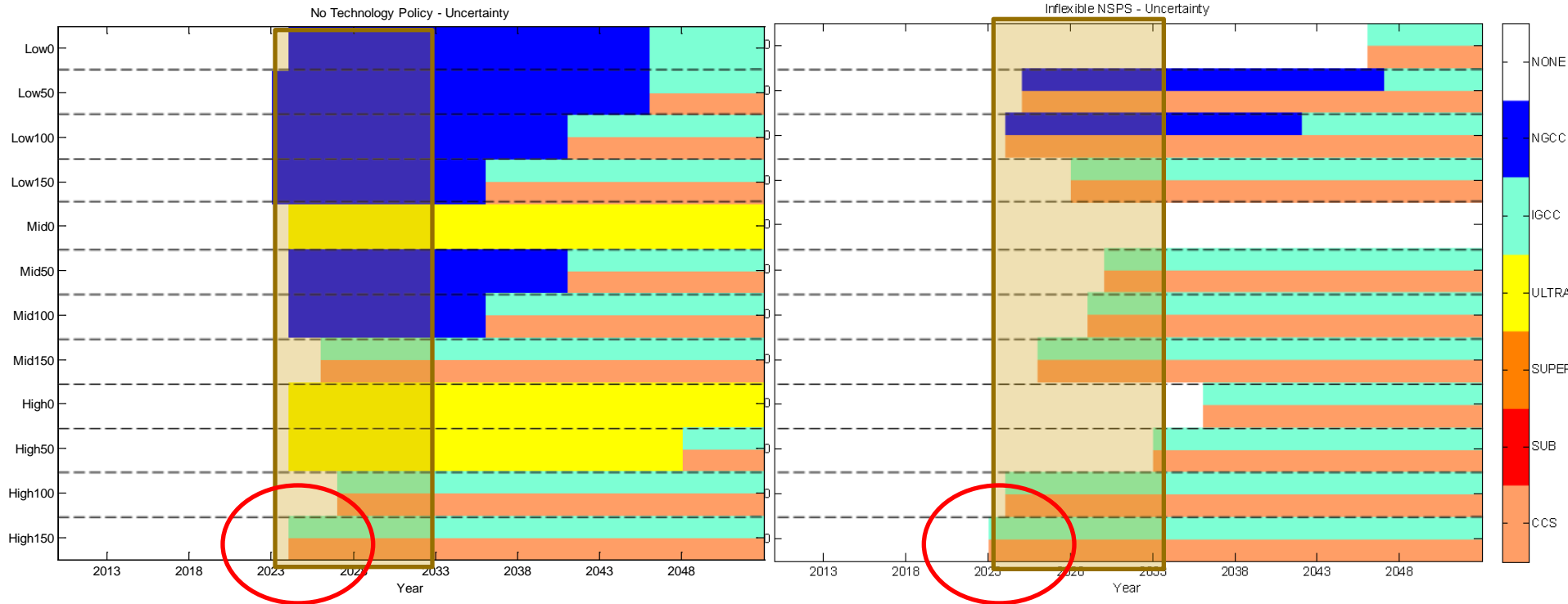
For example, for year  $t=1$ :

- First stage decision:  
Investment & operation in year 1
- Multi-stage decision:  
Investment & operation in years 2,3,..30 under scenarios 1, 2, 3,...12

# Investments with Uncertainty

Baseline: No Technology Policy

Inflexible NSPS



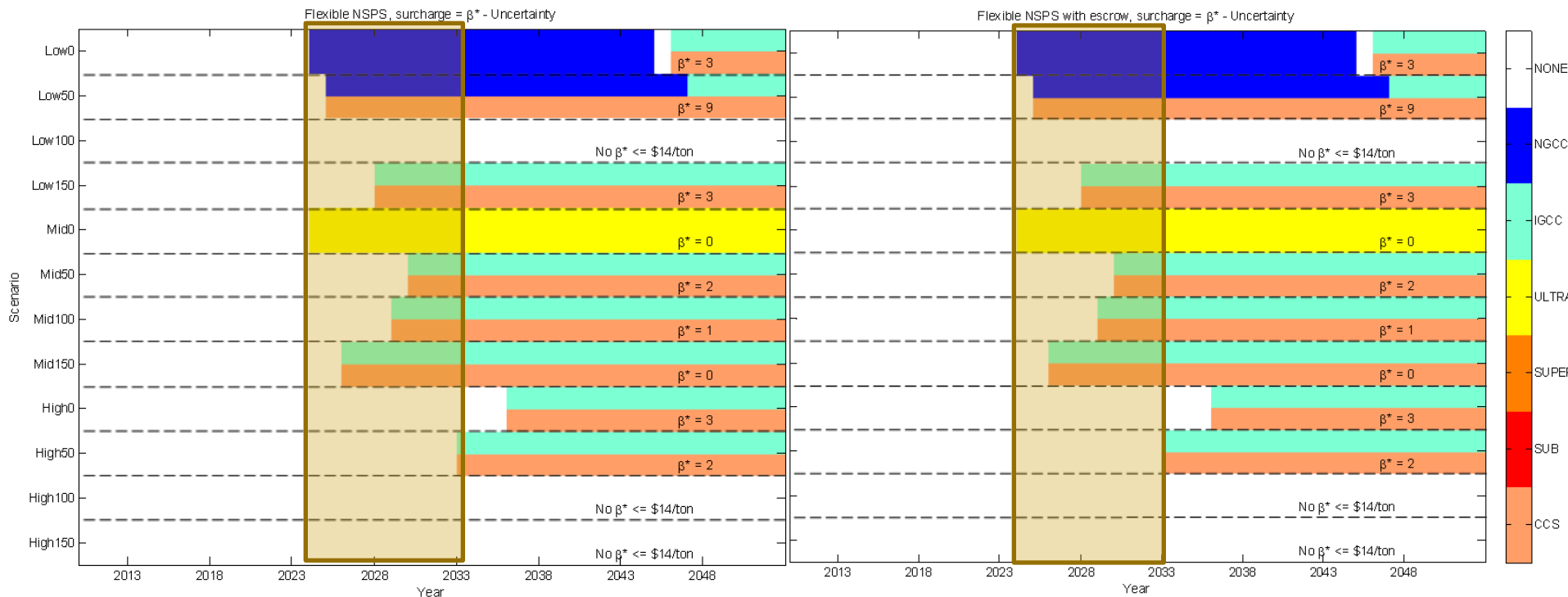
- Note uncertainty delays investment: *value of waiting*
- Again, inflexible NSPS delays investments in almost every case, but effect is not as great as under perfect foresight
- One exception: High 150, where policy removes value of waiting!



# Investments with Uncertainty

## Flexible Policy

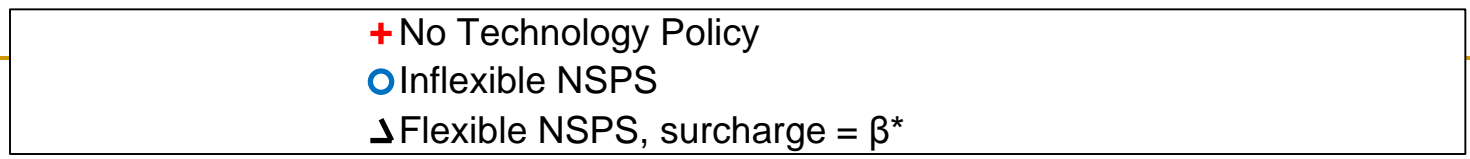
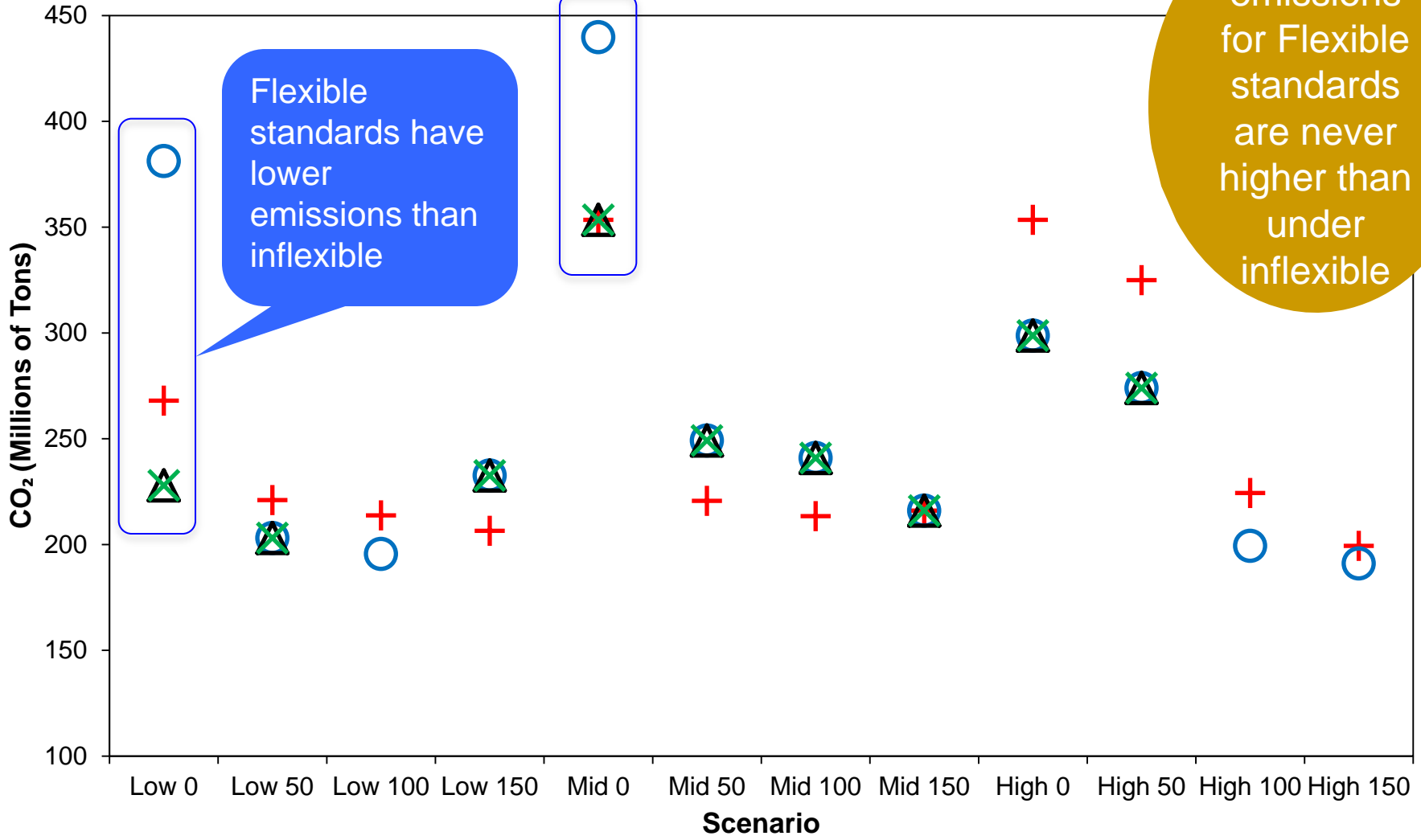
## Flexible Policy with Escrow



- Flexible policy – all investments except Low0 have CCS
- (Almost) no escrow funds accumulate - no difference with uncertainty

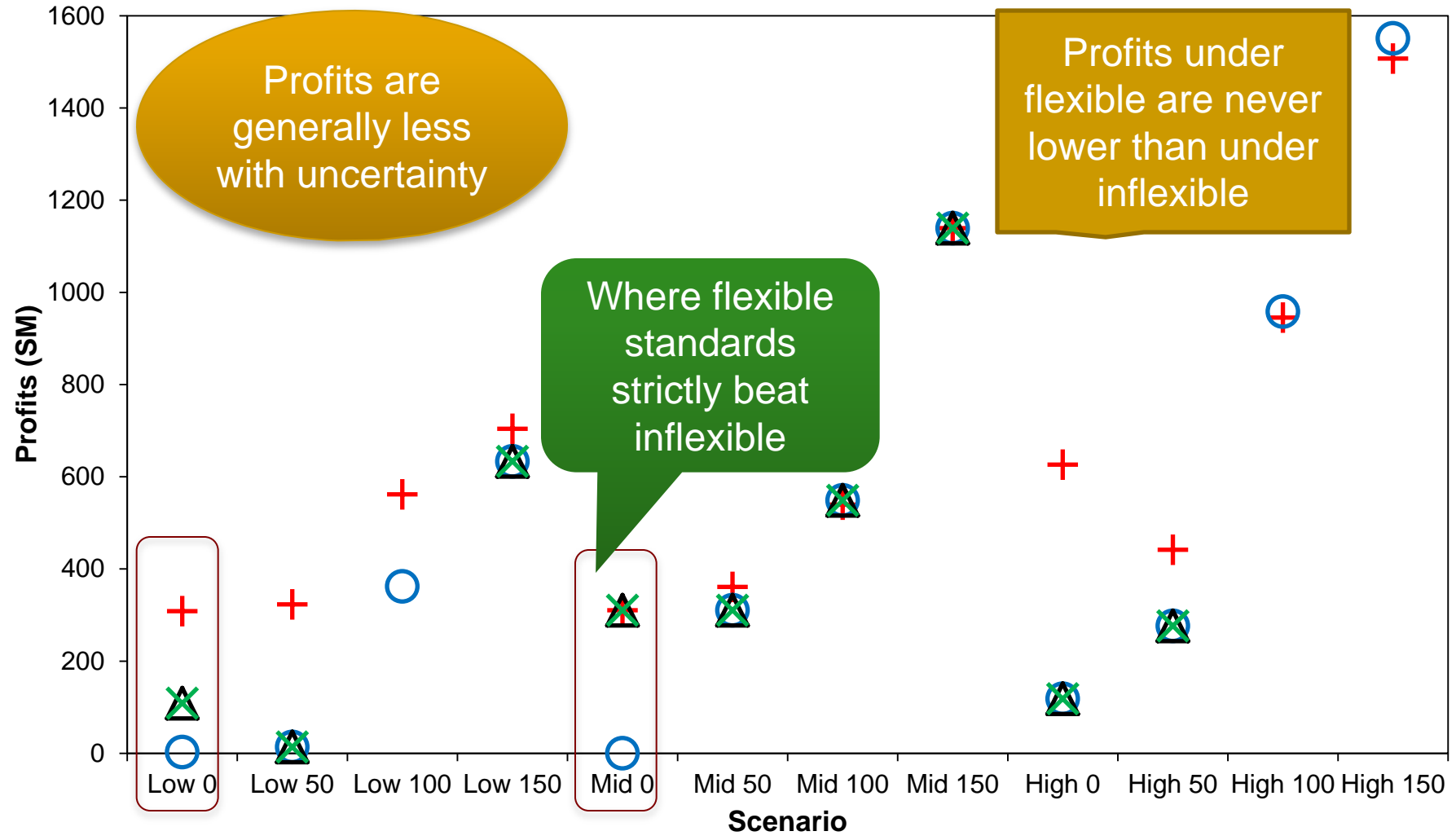
# Uncertainty:

## CO<sub>2</sub> Emissions Under Uncertainty



# Uncertainty: flexibility

Investor Profits Under Uncertainty



- + No Technology Policy
- o Inflexible NSPS
- $\Delta$  Flexible NSPS, surcharge =  $\beta^*$
- x Flexible NSPS with escrow, surcharge =  $\beta^*$

# Conclusions:

- Analytical and simulation approaches confirm that **inflexible standards delay investment**
- Incorporating **flexibility** into a technology standard **does not delay** and instead could **advance the timing of investment** in new more efficient generation technology (coal or gas)...
- Flexibility (with right ACP) **does not delay CCS investment and sometimes accelerates it**
- The existence of an **escrow fund can accelerate the date of installation of CCS**. (Effect depends on the ACP level, the return on the fund, the rules, and the expectations on technological advance on CCS)

## What happens under uncertainty?

- Uncertainty delays investment
  - Magnitude of delay is comparable to the one caused by the inflexible policy
- Inflexible standards tend to delay investment but less than under perfect foresight
  - Inflexible standards may accelerate investment compared to the no-policy scenario (it eliminates investment alternatives and reduces the value of waiting to invest)
- A Flexible standard leads to earlier investment and adoption of CCS
  - With our choice of escrow rules, scenarios, and uncertainty characterization there is no difference between flexible and flexible + escrow
- Optimal ACP is different for every scenario → How to find the best ACP?

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# Thank you!

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