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

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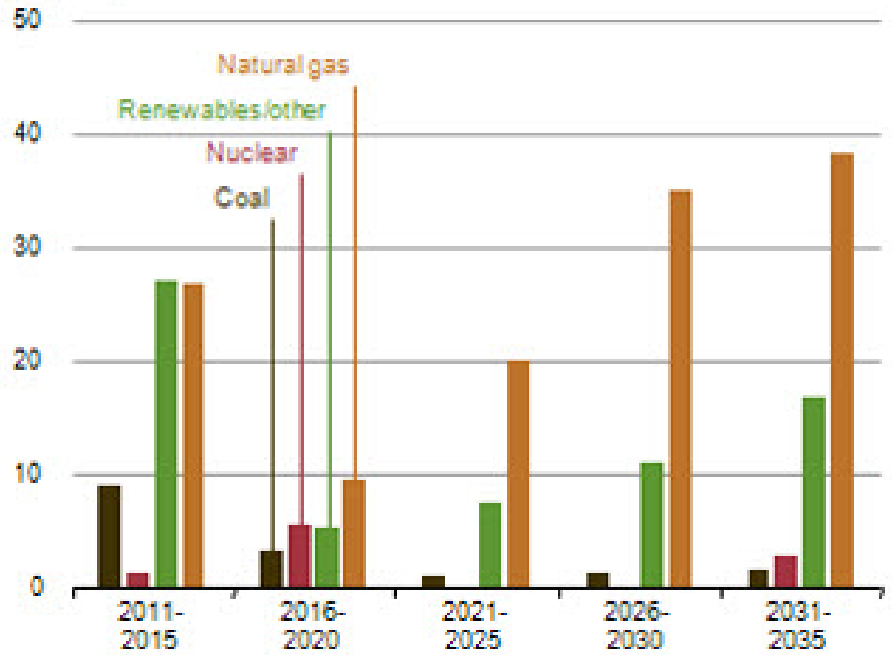
Power Generation and the Environment: Choices and Economic Trade-offs

Center for Energy Economics and Public Policy – School of Energy Resources

University of Wyoming, October 1-2, Teton Village - Wyoming

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_2 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

Flexible CO_2 Emissions Standard: ACP

- Owners pay an **Alternative Compliance Payment (ACP)** for new plants that fail to meet the maximum CO_2 emission rate standard
  - additional to any CO_2 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_2 Emissions Standard with ACP and **escrow**

- Owners pay ACP for new plants that fail to meet the maximum CO_2 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

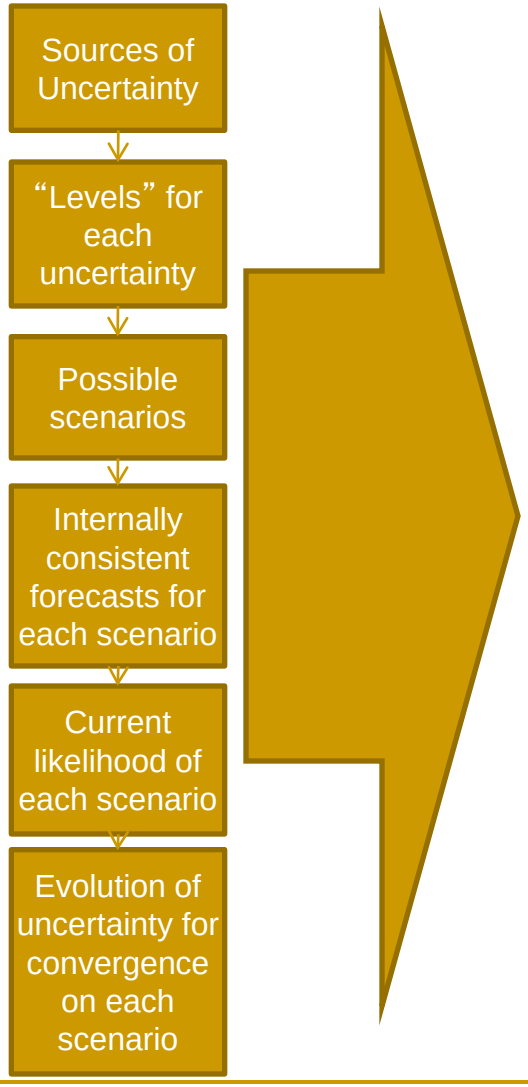
1. Simulate **investment and operating** decisions over 40+ years
2. Find emissions over 40+ years
3. Find NPV over 40+ years
4. Compare policies

*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



Natural gas prices

Low | Mid | High

CO_2 price

None | 50% S280 | 100% S280 | 150% S280

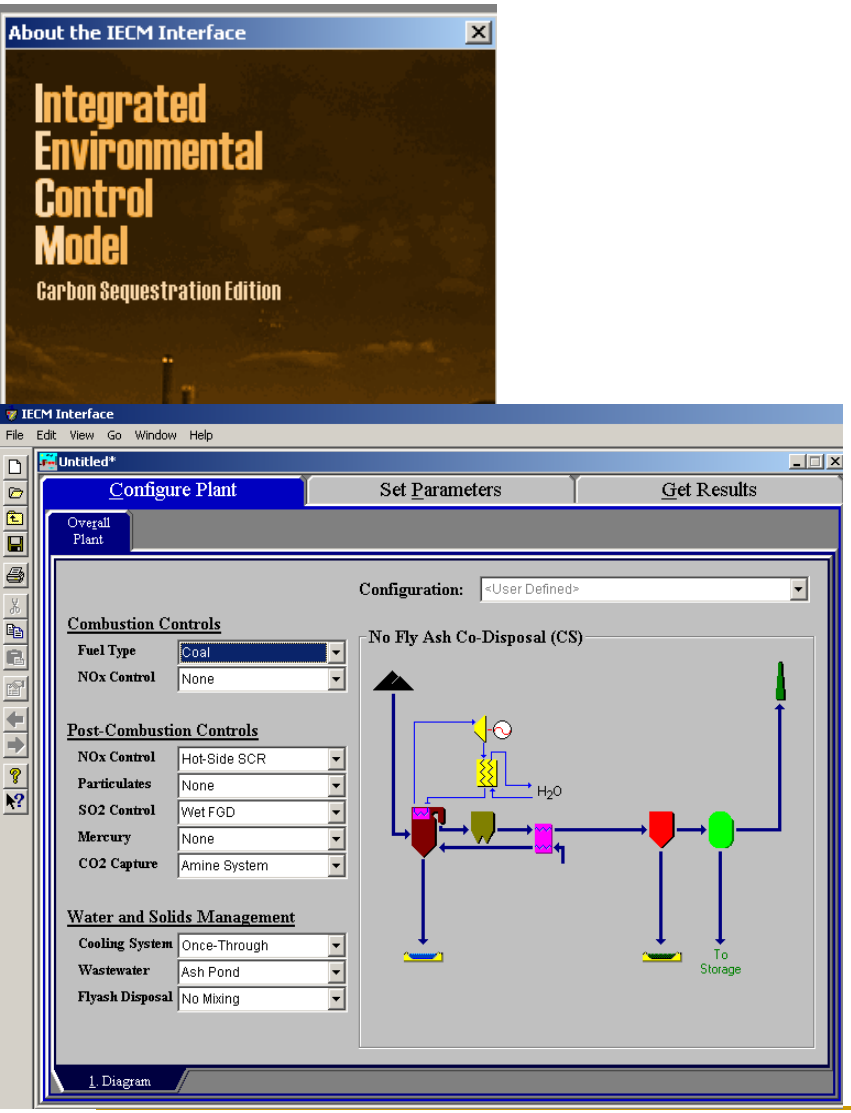
Assume all combinations are possible → 12 scenarios

Haiku:
Electricity prices, fuel prices, CO_2 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**
Scenario 1	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

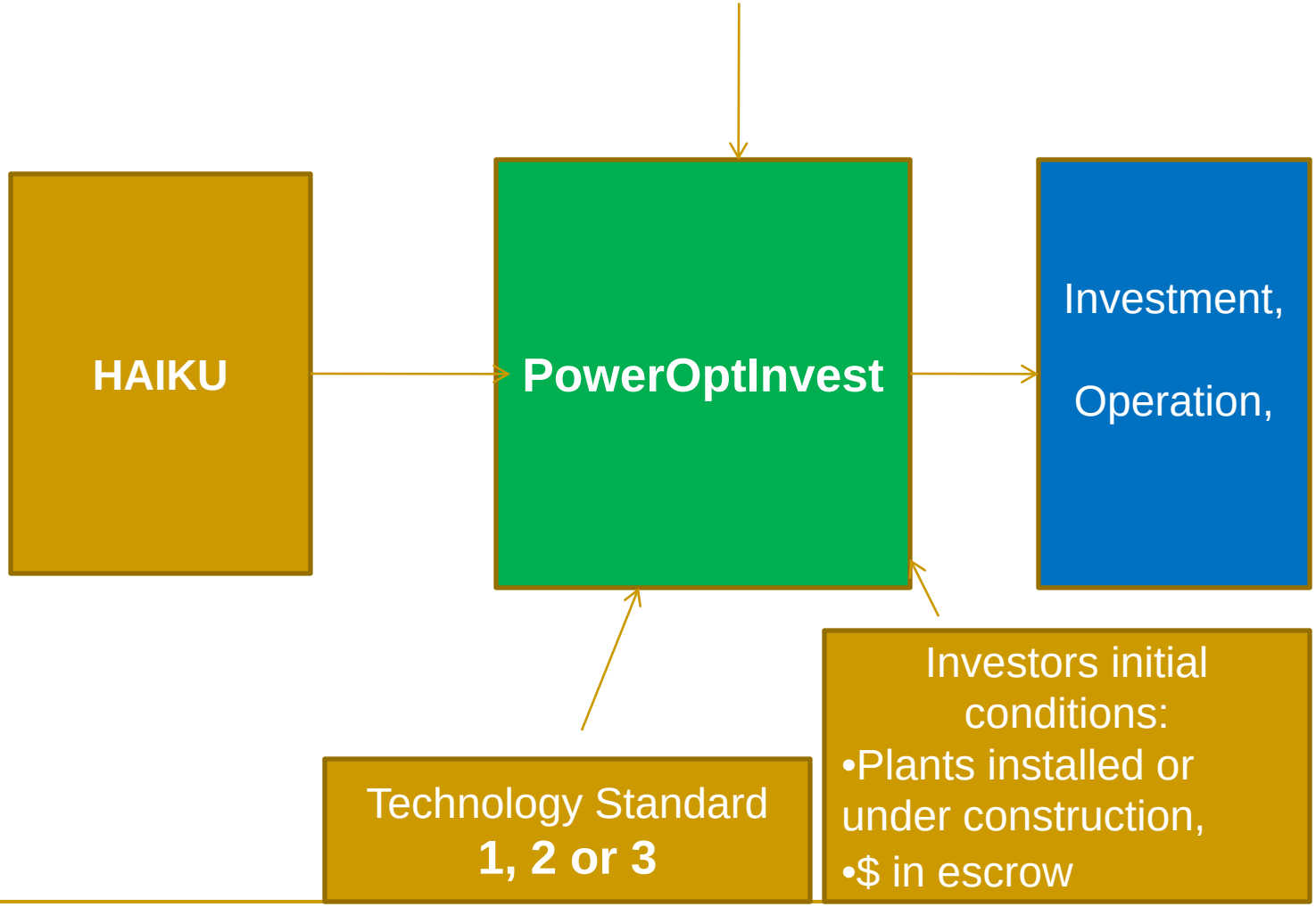
- Can be installed with or without CCS
- Retrofits cost 30% more than new installations
- CCS cost are 2x IECM costs initially, and decline linearly to year 2020

Every year solve an optimization problem

1. knowing the scenario for the next 30 years

or

2. Knowing probabilities of each scenario



PowerOptInvest: almost **Perfect foresight**

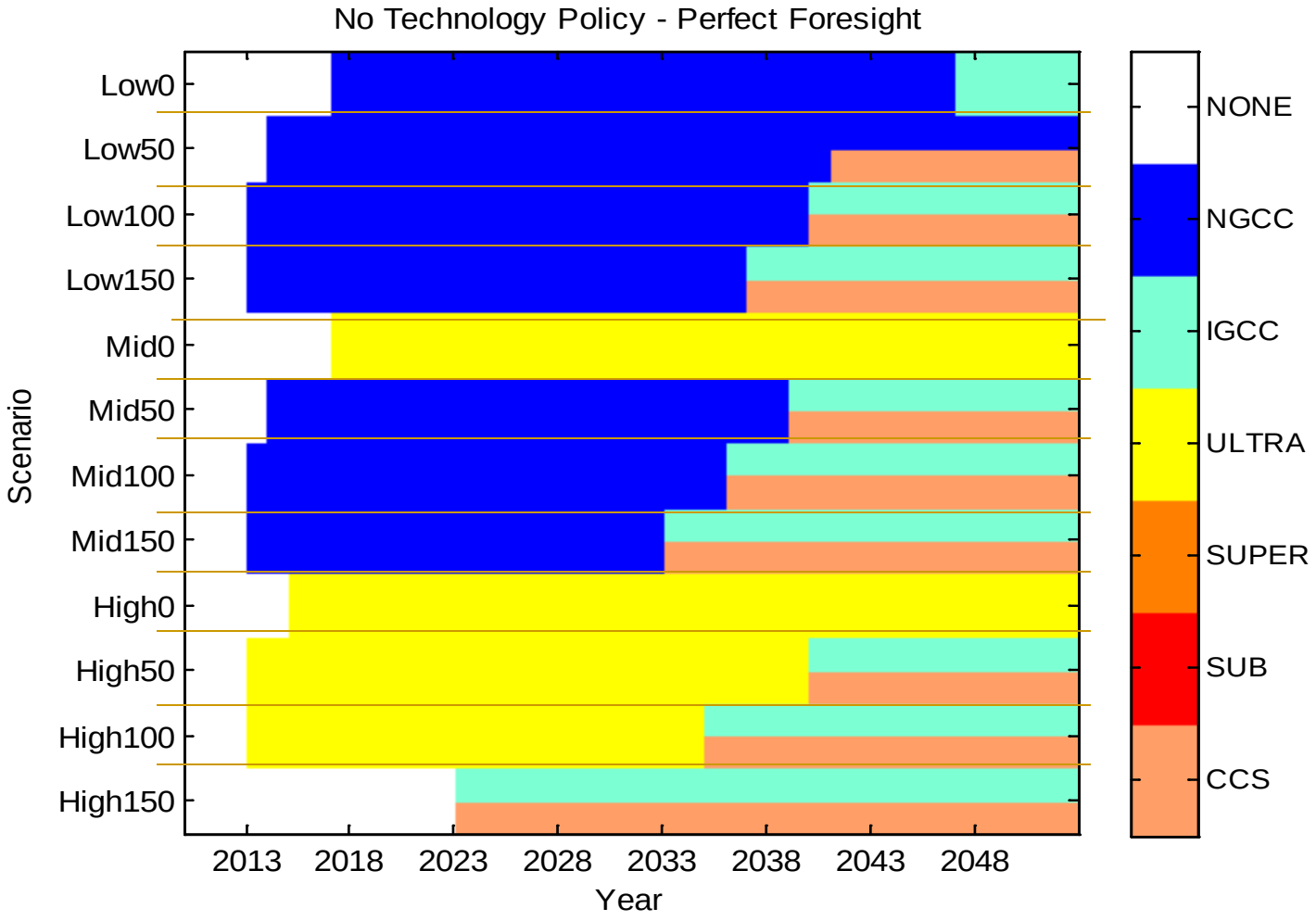
- Investor has perfect foresight for 30 years
- Each year can see next 30 years
  - When making decision in year 1, is able to see info for years 2 to 31
  - When making decision in year 2, is able to see info for years 3 to 32 etc..
- We look at 43 years of investment and associated costs and emissions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

Results

- ~Perfect Foresight
- Under uncertainty

- Investment
- CO_2 emissions
- Investor profits

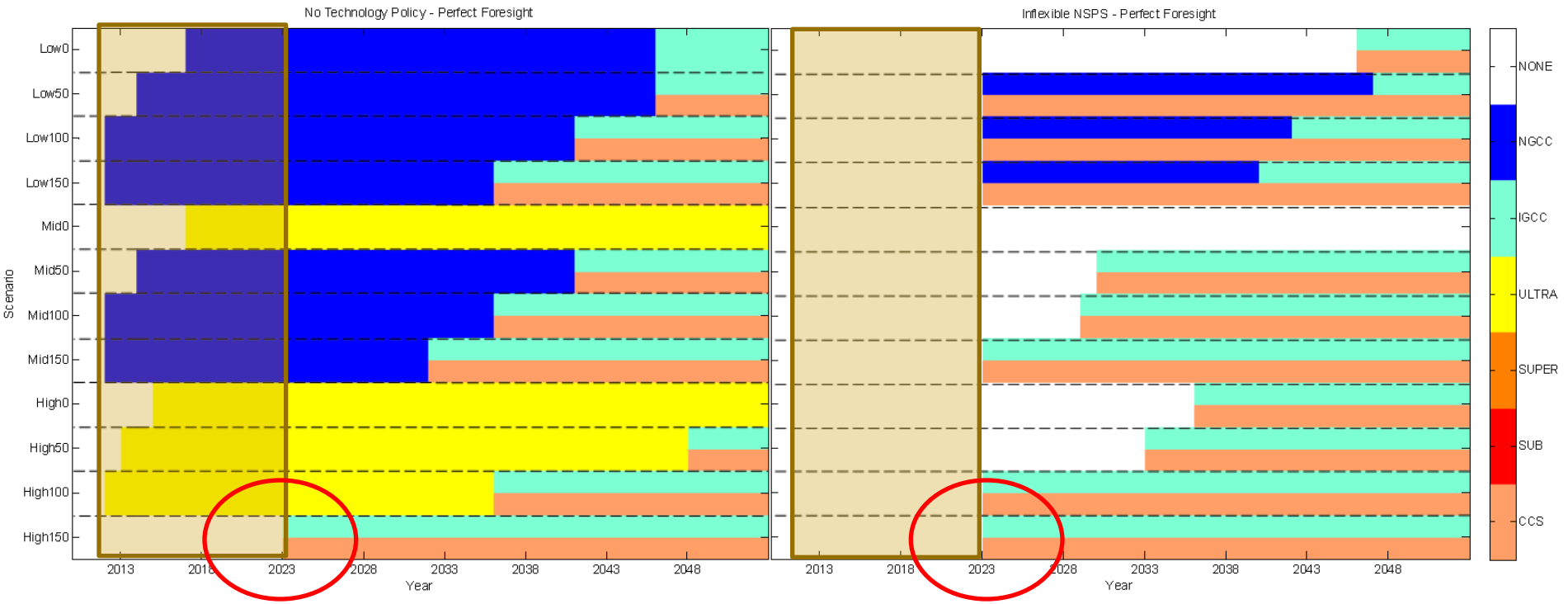
No technology policy: ~perfect foresight



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

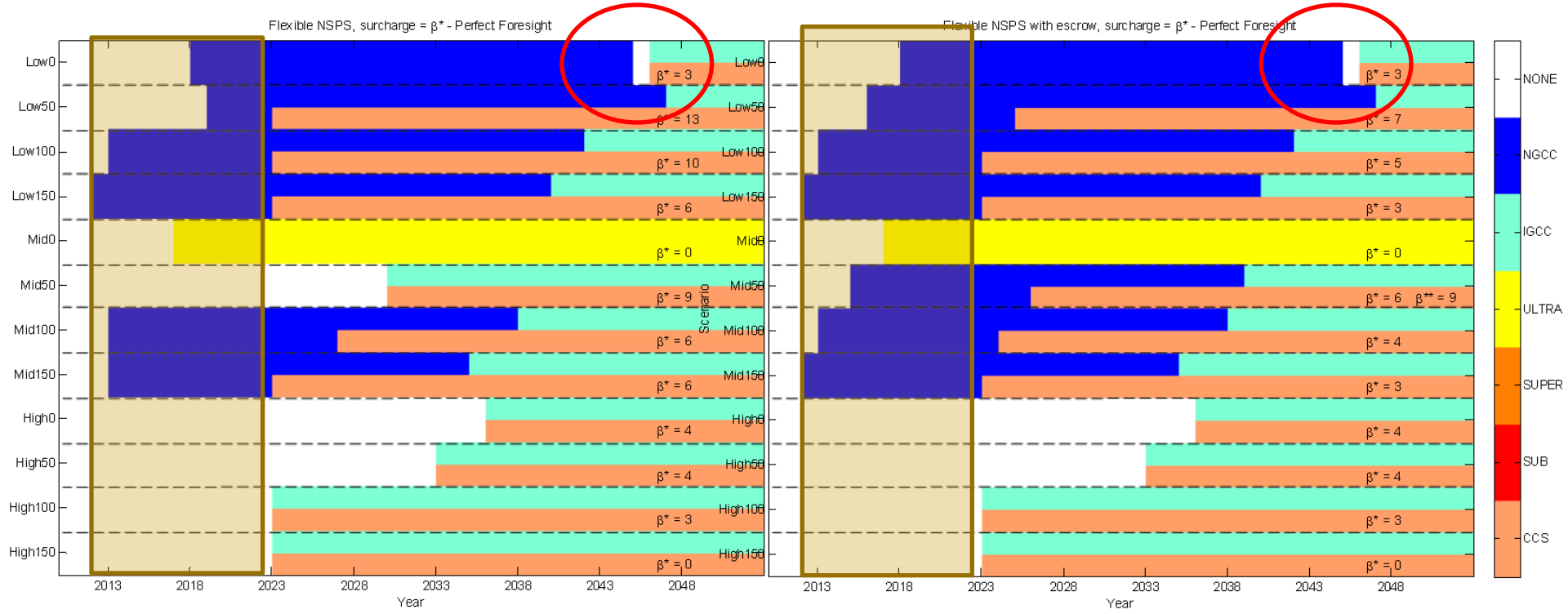
β* : Minimum ACP ($/ton CO_2) that causes installation of CCS the same year or before than under the inflexible NSPS

- β* = 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 β* < $14/ton does not exist

Investments with Perfect Foresight

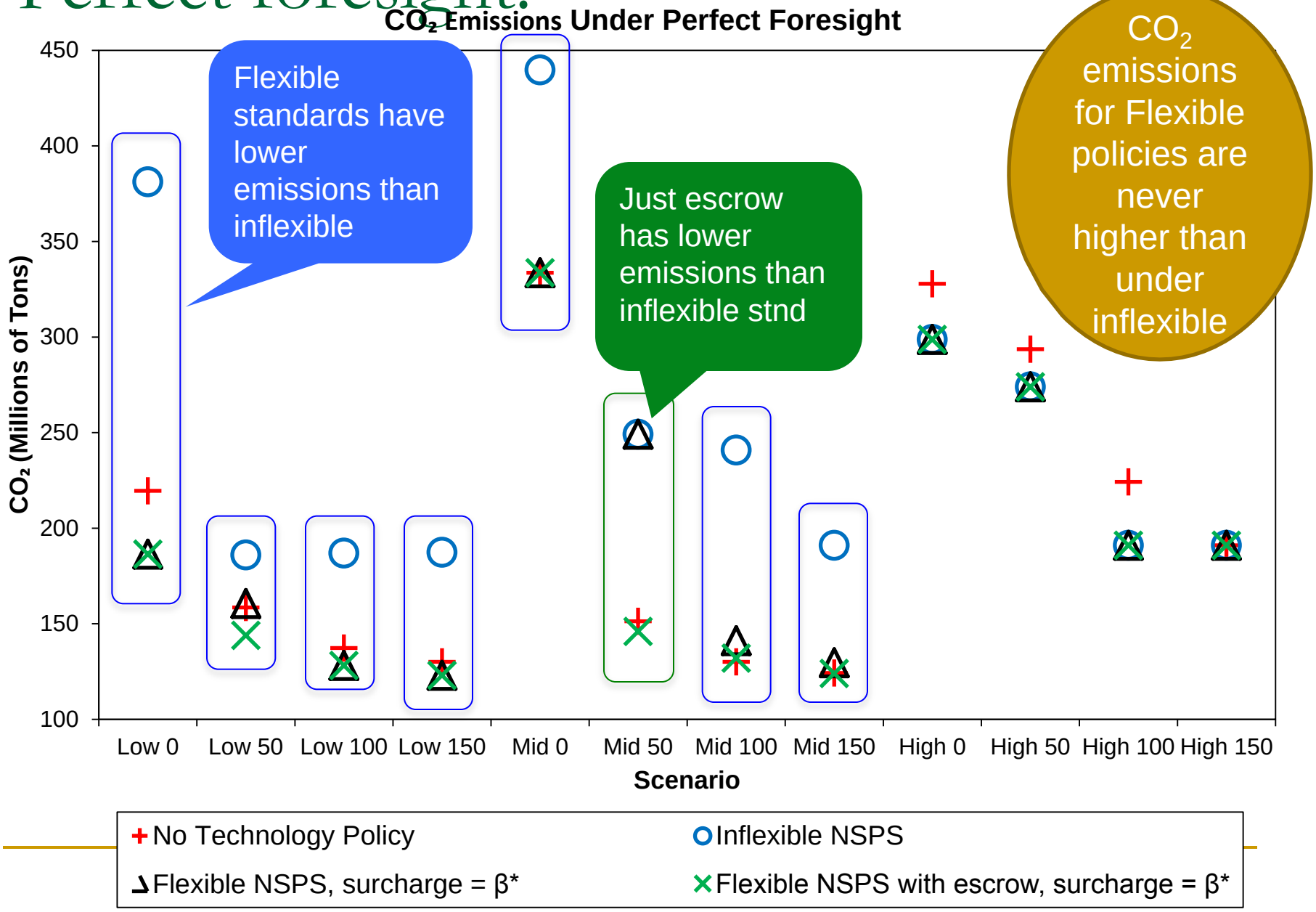
Flexible Standard

Flexible Standard with Escrow

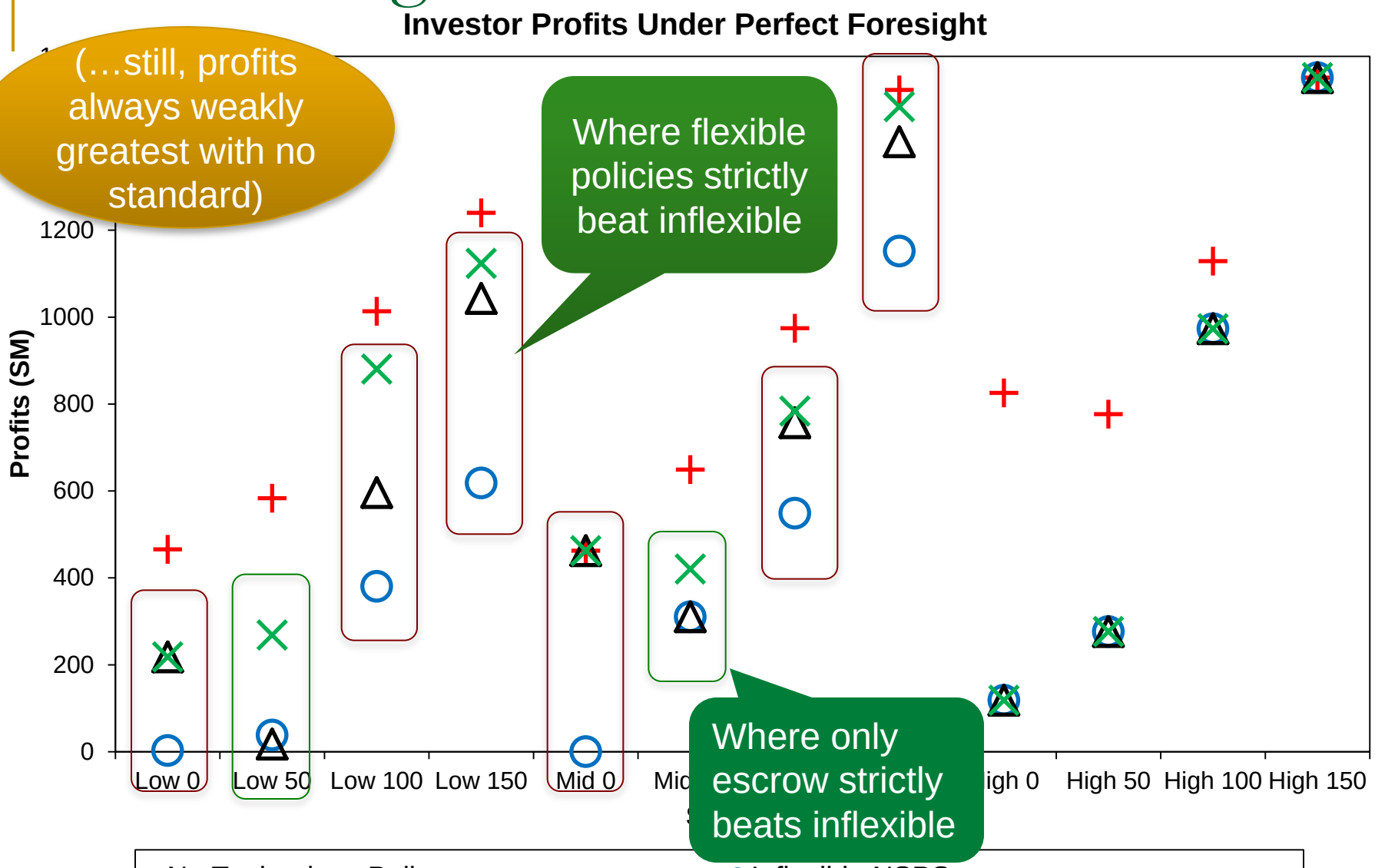


- Both policies accelerate investment compared to inflexible standard.
- Escrow leads to slightly earlier investment in generation and CCS
- Escrow requires lower ACP for some scenarios
- Low0 – investor reverts to wholesale power market in 2045 before installing IGCC w/CCS

Perfect foresight:



Perfect foresight:



Optimization model - **Uncertainty**

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

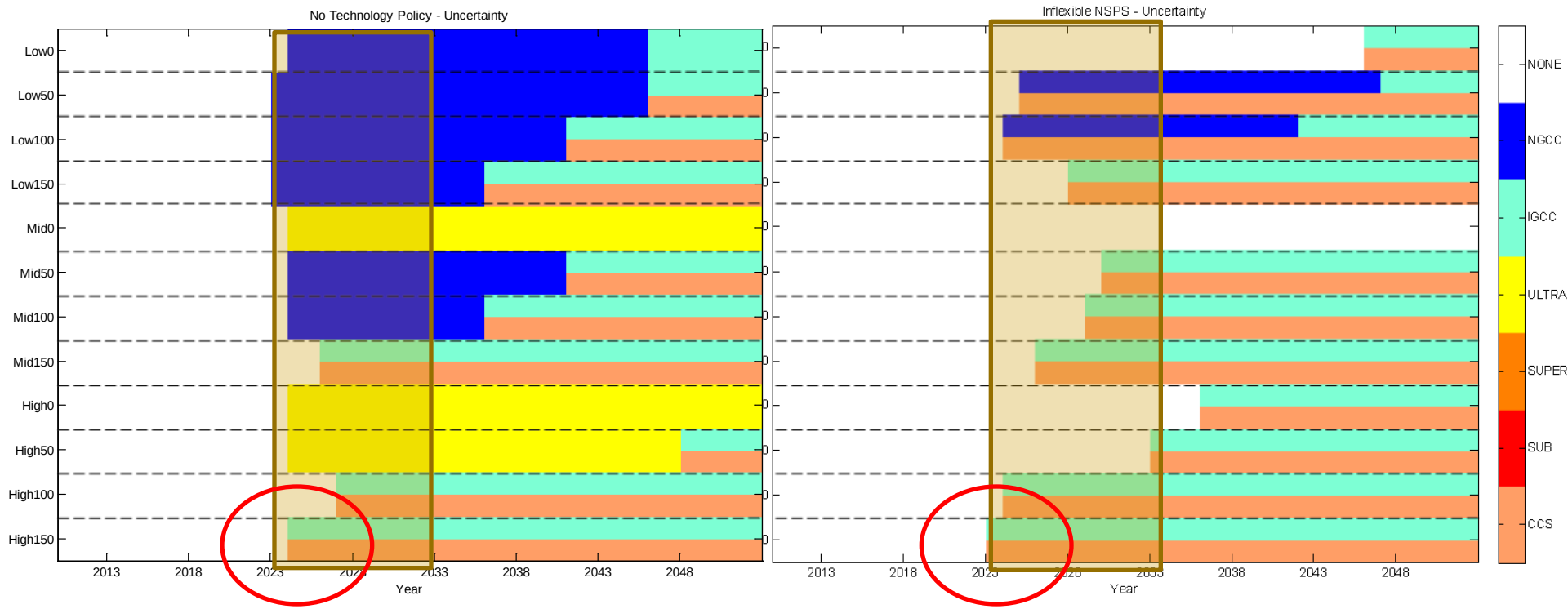
For example, for year t=1:

- 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

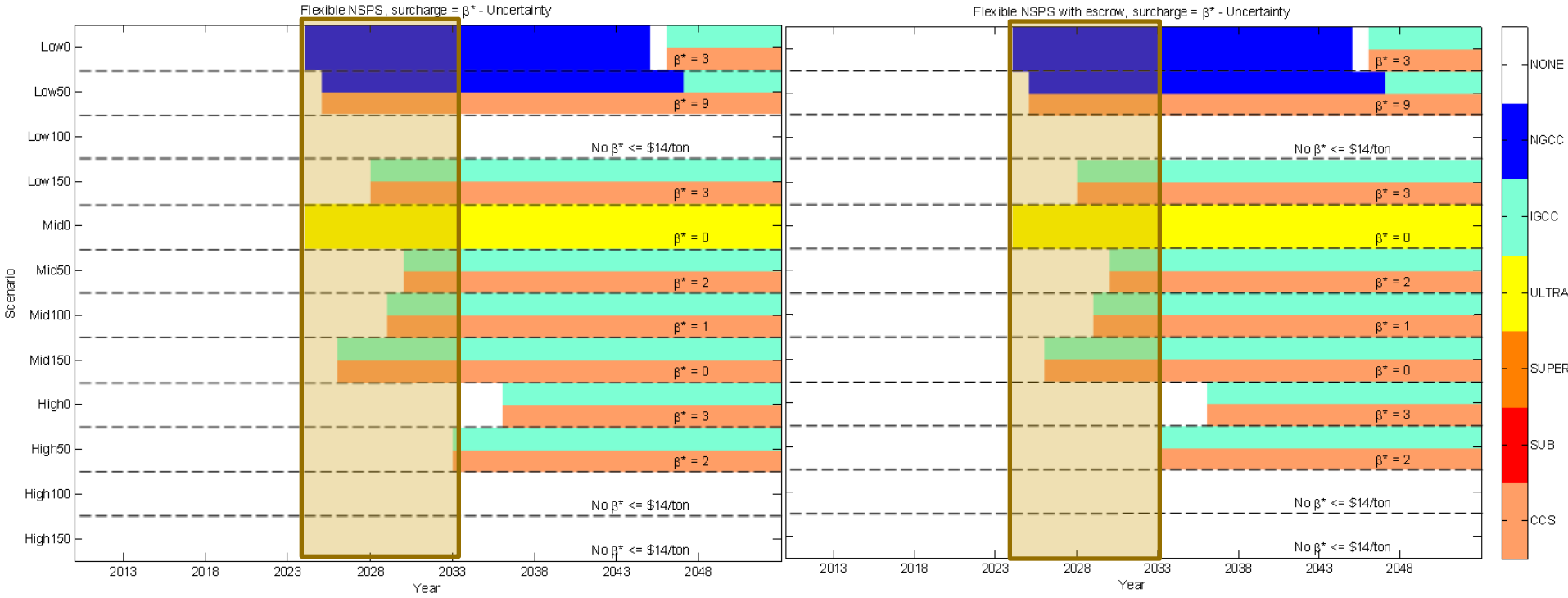


- Note uncertainty delays investment: *value of waiting*
- Again, inflexible NSPS delays investments in almost every case, but effect is not as great as under perfect foresight
- One exception: High 150, where policy removes value of waiting!

Investments with Uncertainty

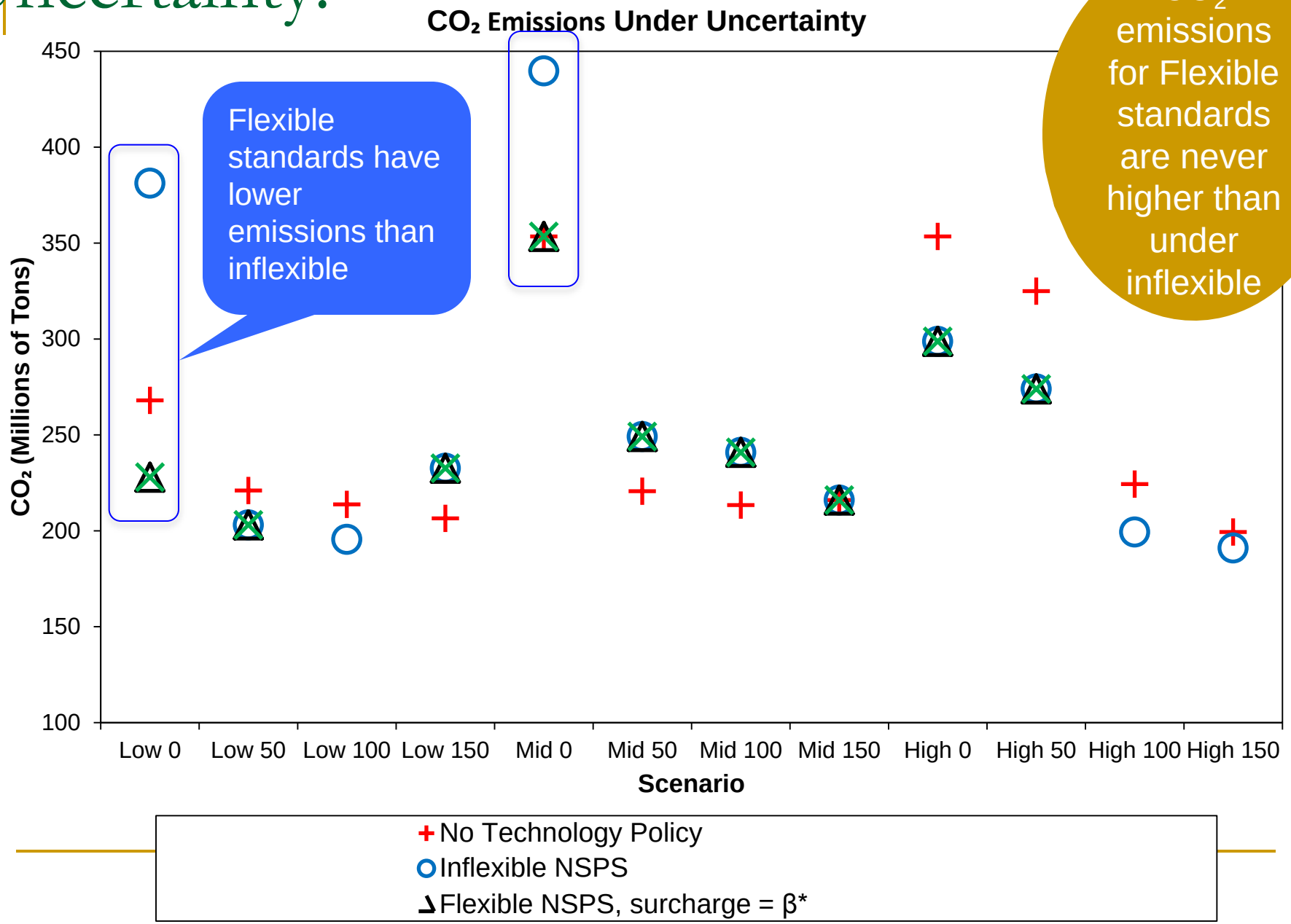
Flexible Policy

Flexible Policy with Escrow

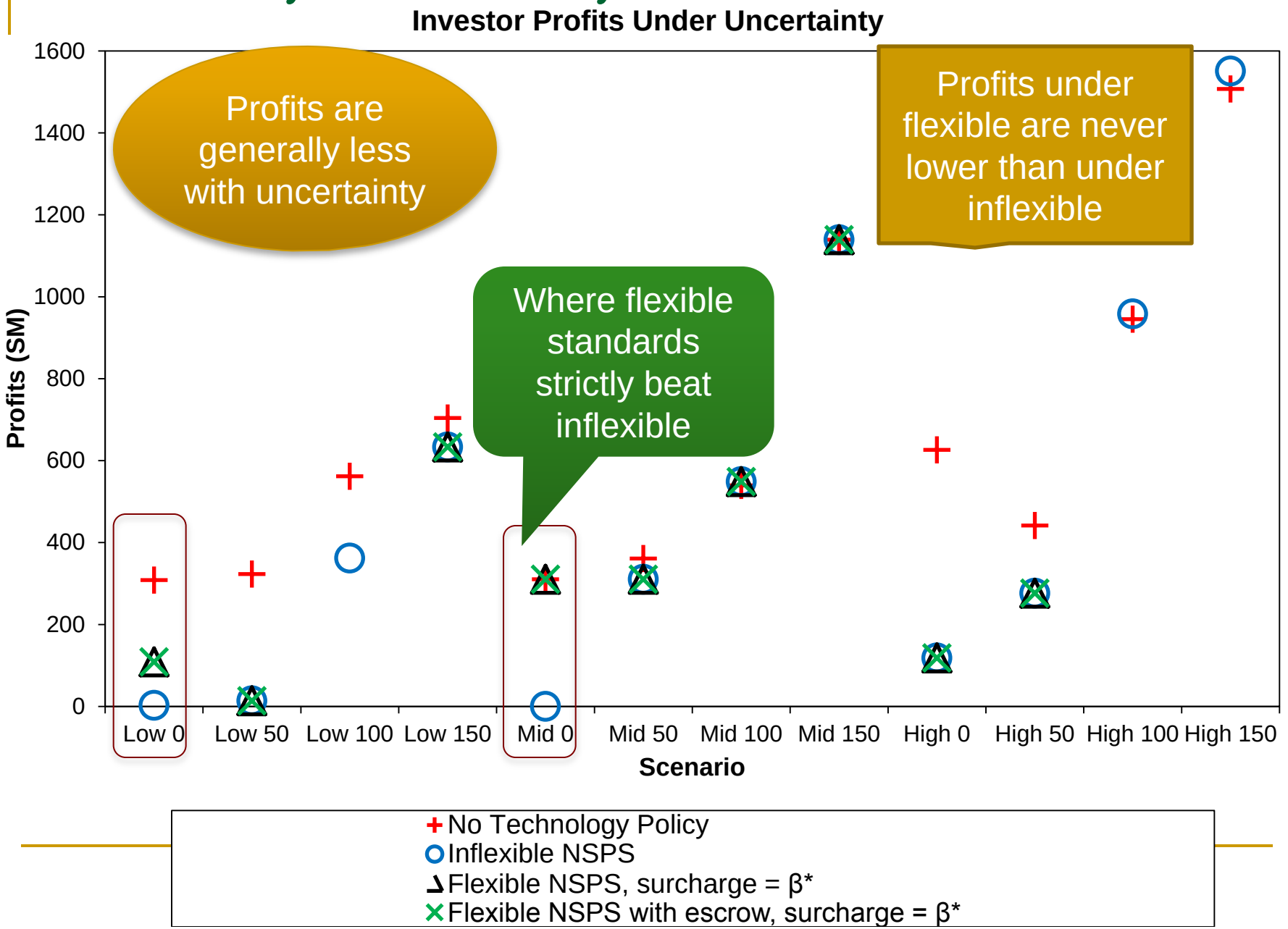


- Flexible policy – all investments except Low0 have CCS
- (Almost) no escrow funds accumulate - no difference with uncertainty

Uncertainty:



Uncertainty: flexibility



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?

Thank you!

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