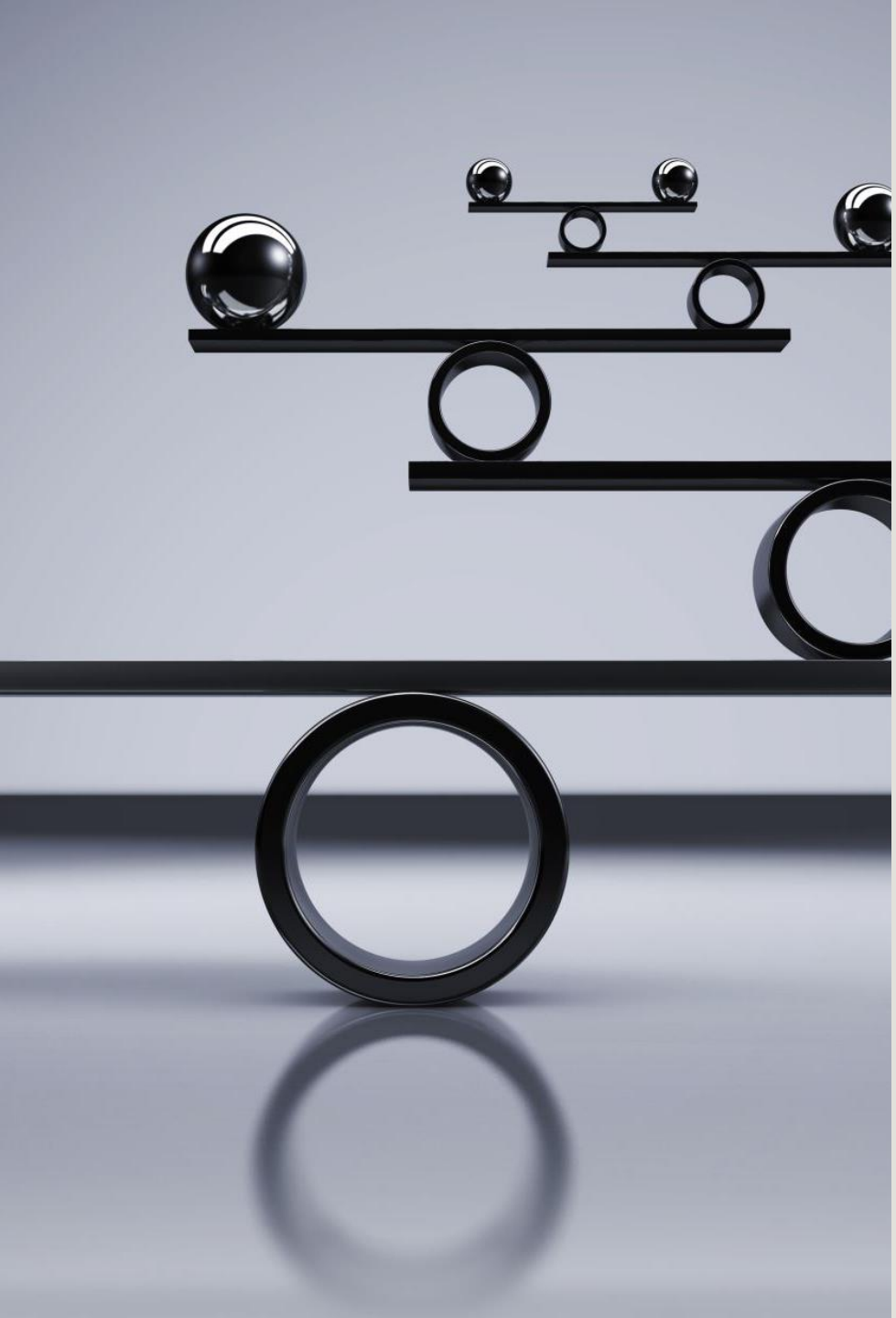

Balancing Energy Security and Decarbonisation: A Comparative Analysis of Carbon Pricing

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The Critical Challenge

The Dual Goal:

Achieve EU climate neutrality by 2050.

Maintain a secure, reliable energy supply.

The Policy Dilemma:

Multiple instruments are available.

Which is most effective for a rapid transition?

Core Question:

Carbon Tax (CT) vs. **Emissions Trading Scheme (ETS)** – which drives faster decarbonisation?

Methodology: A One-Way Integration

A Hybrid Framework:

- Combines two complementary models.

pymedeas2 (System Dynamics Model):

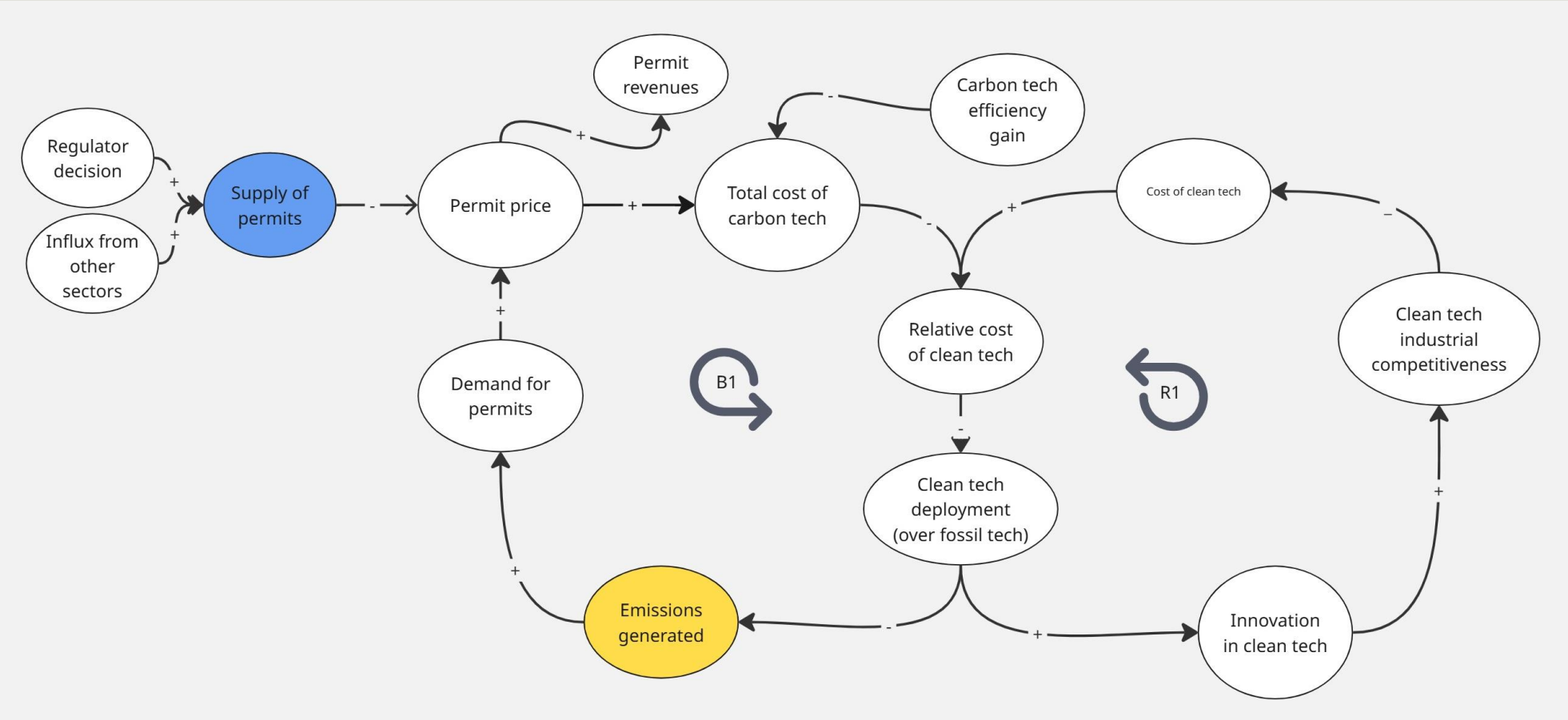
- Simulates the **macro-level** EU energy system.
- Embeds **biophysical constraints** (land, resources).

TaxvsETS (Agent-Based Model):

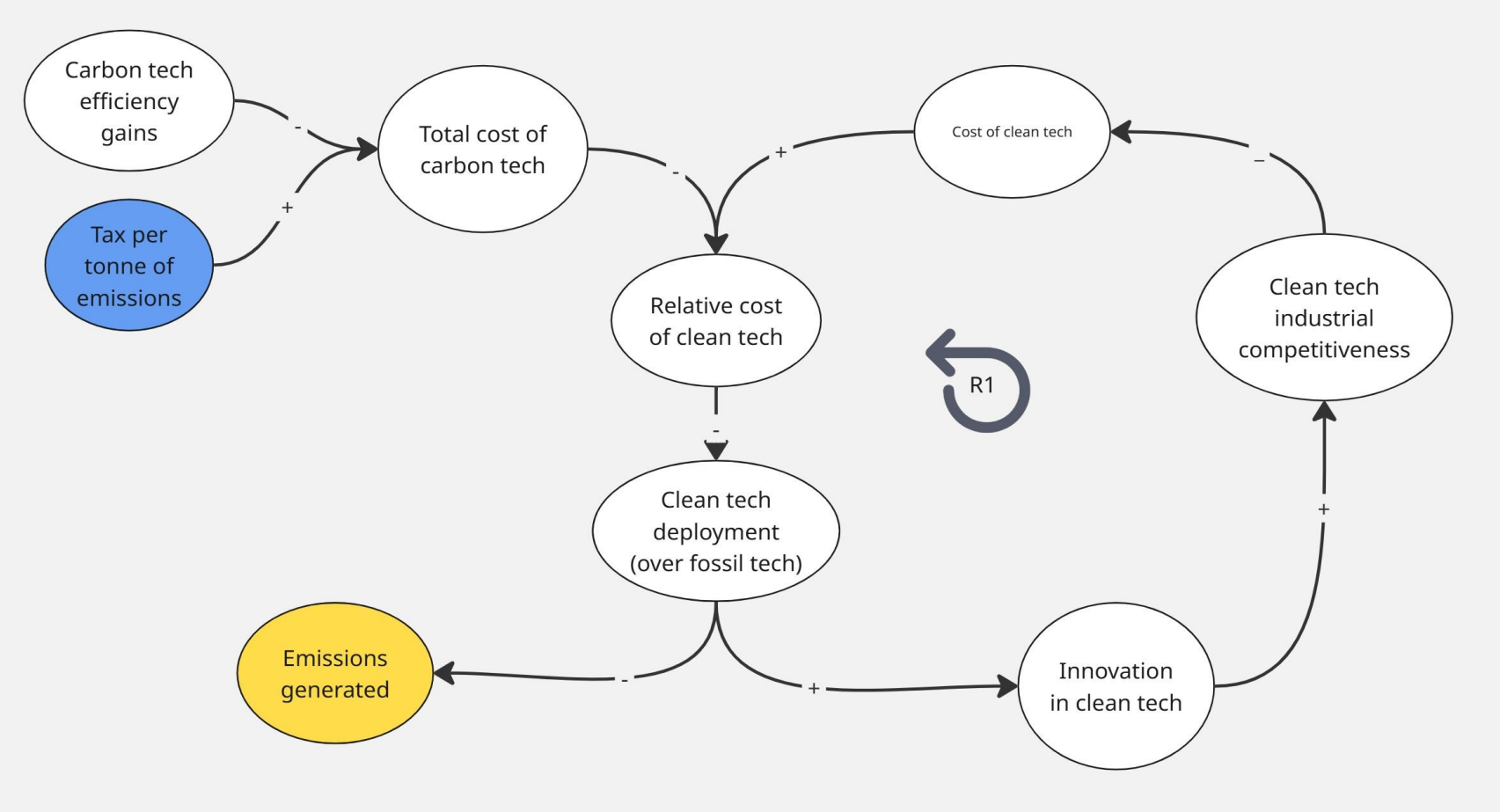
- Simulates **company-level** investment decisions of energy firms.

One-Way Integration: System constraints from pymedeas2 inform the rules within which firms operate in the ABM.

Methodology: ETS



Methodology: Carbon Tax



Scenario Setup

Goal: Compare CT and ETS under equivalent policy stringency.

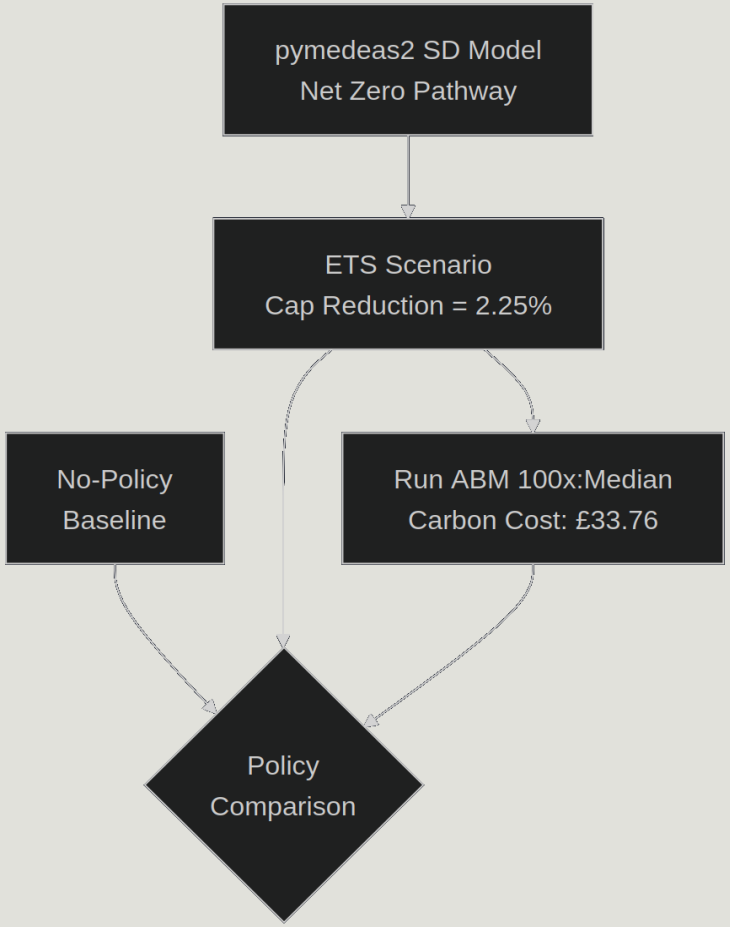
Step 1: Set the ETS Cap from pymedeas2 model

- pymedeas2 output gave an average annual emissions reduction of **2.25%**.
- This was used as the annual cap reduction in the ABM.

Step 2: Calibrate the Carbon Tax from the ETS

- Ran the ETS scenario 100 times.
- Calculated the median total cost of carbon for firms.
- Set the Carbon Tax at this value: **£33.76 per tonne**.

Scenarios Run: ETS, CT, and a No-Policy baseline.



Key Result 1: Speed of Decarbonisation

Time to Zero Emissions (Median)		
48 years (No Policy)	**15 years** (ETS)	**6 years** (Carbon Tax)

Takeaway: The Carbon Tax leads to a **much faster** transition, achieving zero emissions in less than half the time of the ETS.

Key Result 2: Cumulative Emissions & Prices

- The CT results in **~70% lower cumulative emissions** than the ETS.
- The CT leads to **slightly higher but stable electricity prices**, reflecting the stronger investment signal.

Scenario	Cumulative Emissions Reduction	Energy Price [£/MWh] (Median)
No Policy	Reference	21.79
ETS	-91.7%	49.41
Carbon Tax	**-97.4%**	**53.41**

Discussion: Performance vs. Practicality

Analytical Performance (Our Model):

- **Carbon Tax is superior:** Faster, deeper cuts, more efficient.
- **Interpretation of results:** Model outcomes indicate relative differences between scenarios, **not precise forecasts**.

Political Economy (The Real World):

- **ETS:**
  - *Pro:* More politically acceptable to industry ("flexibility").
  - *Con:* Can be regressive ("pay to pollute") advantage for large firms.
- **Carbon Tax:**
  - *Pro:* Transparent, revenues can be recycled to protect vulnerable groups.
  - *Con:* Faces strong political opposition, vulnerable to lobbying.

Conclusions

Methodological Contribution: A novel hybrid (SD + ABM) framework for climate policy assessment.

Core Finding: Under equivalent stringency, a **Carbon Tax outperforms an ETS** in driving rapid decarbonisation of the electricity sector.

Policy Implication: For speed and effectiveness, a CT is superior, but its implementation requires navigating complex political economy and equity concerns.

Hybrid modelling is a powerful tool for designing robust climate policy in complex socio-technical systems.

Thank You for your attention!

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Code & Models:

https://github.com/Earth-and-Energy-Systems-Lab/pymedeas2

https://www.comses.net/codebases/003518b1-a9e5-4fe8-b76d-97d81d0be6b6/releases/1.0.0

QUESTIONS?