Exploring the Viability of the Updated World3 Model for Examining the Impact of Computing on Planetary Boundaries

Limits'2025

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Context

Training AI models now demands increasing numbers of hyperscale data centers, and these facilities already nudge global CO_2, water use, and mineral extraction upward.

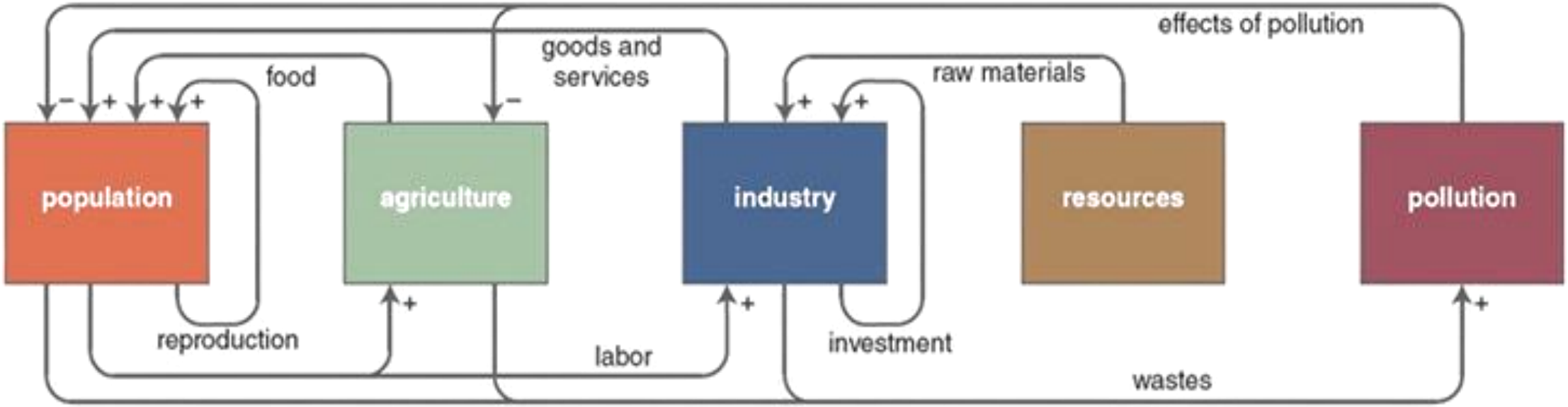
The paper explores whether the effect of growing AI on patterns of world development, particularly environmental outcomes, can be quantified using the World3-03 model.

We revisit the limits to growth concept that grounded the conception of Computing within Limits.

Is the Limits to Growth World3-03 model a viable method for exploring the impact of computing on planetary boundaries today?

World3-03 Model

The World3 model is an application of a **system dynamics-based approach** to explore the interplay of population, industry, resources, agriculture, and pollution over long periods under resource constraints.



Key World3-03 Scenarios

Scenario	Description
Business-as Usual (BAU) Standard Run	• Food production, industrial output, and population expand exponentially until the sharp depletion of resources eventually curtails industrial growth. • Collapse is eventually caused by natural resource depletion.
Business-as Usual 2 (BAU2)– High Resources	• Rapid population growth raises death rates and lowers food production, leaving resources severely depleted despite an initial doubling. • Collapse is caused by pollution.
Comprehensive Technology (CT)– Tech Fix	• The technology delays the onset of limits significantly. • Rising costs for technology eventually cause declines such as in industrial output, but no collapse.
Stabilized World (SW)	• The result of sustainability related policies would be population stabilization, as human welfare is on a high level. • In this scenario, collapse is not expected.

AI Dynamics in World3-03

- Adding new variables
- Refining technology parameters
- Updating model assumption
- Reconstructing AI Industry as a separate component

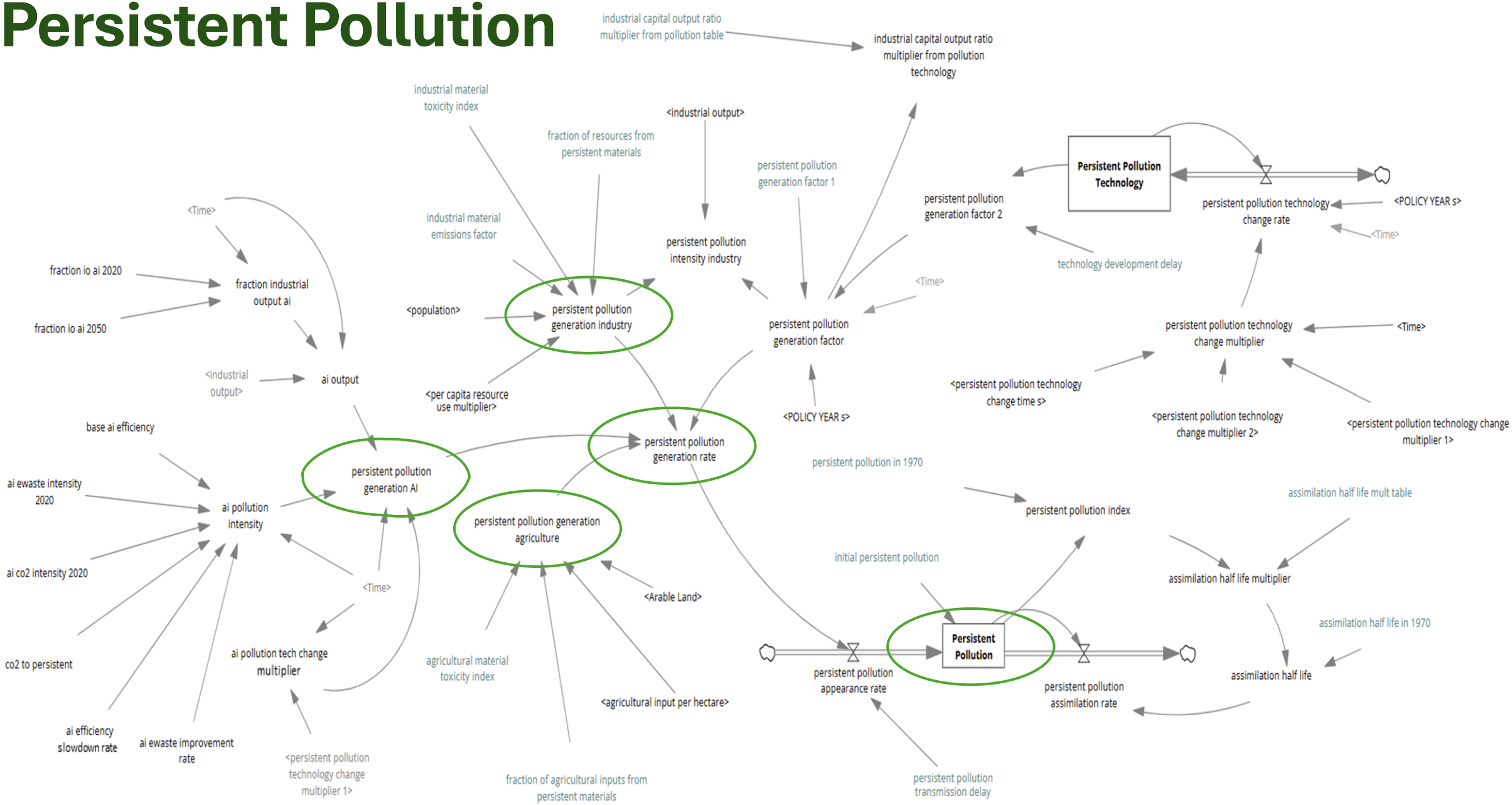
Method

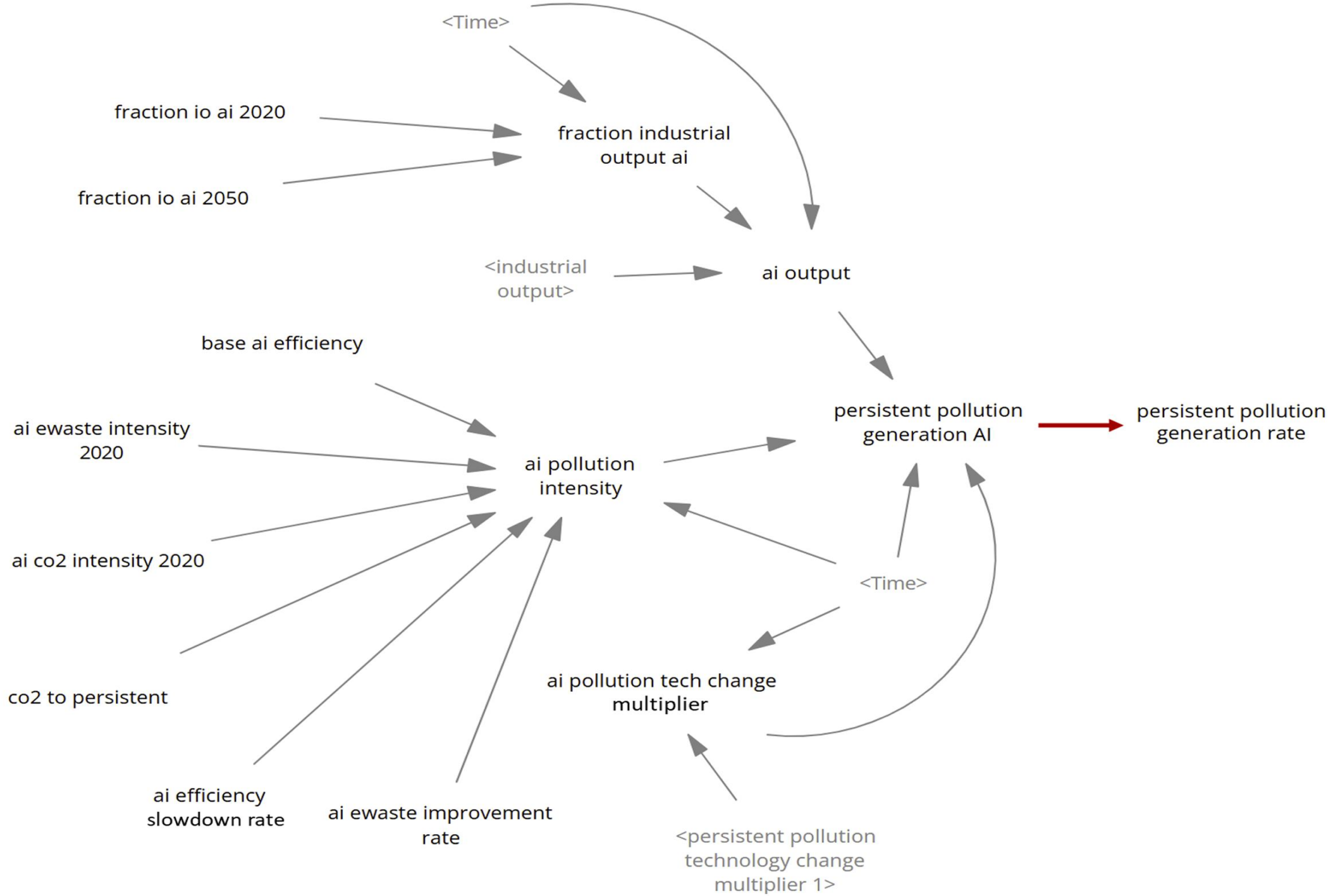
We used Vensim PLE 10.3.2 to update the Persistent Pollution sector of the World3-03 model.

The sector was modeled to reflect AI-related emission from data center materials and operations.

Recent studies and available data on AI's carbon impact made this integration both relevant and feasible.

Persistent Pollution




<Time>
fraction io ai 2020
fraction industrial output ai
fraction io ai 2050
<industrial output>
ai output
base ai efficiency
ai ewaste intensity 2020
ai pollution intensity
persistent pollution generation AI
persistent pollution generation rate
ai co2 intensity 2020
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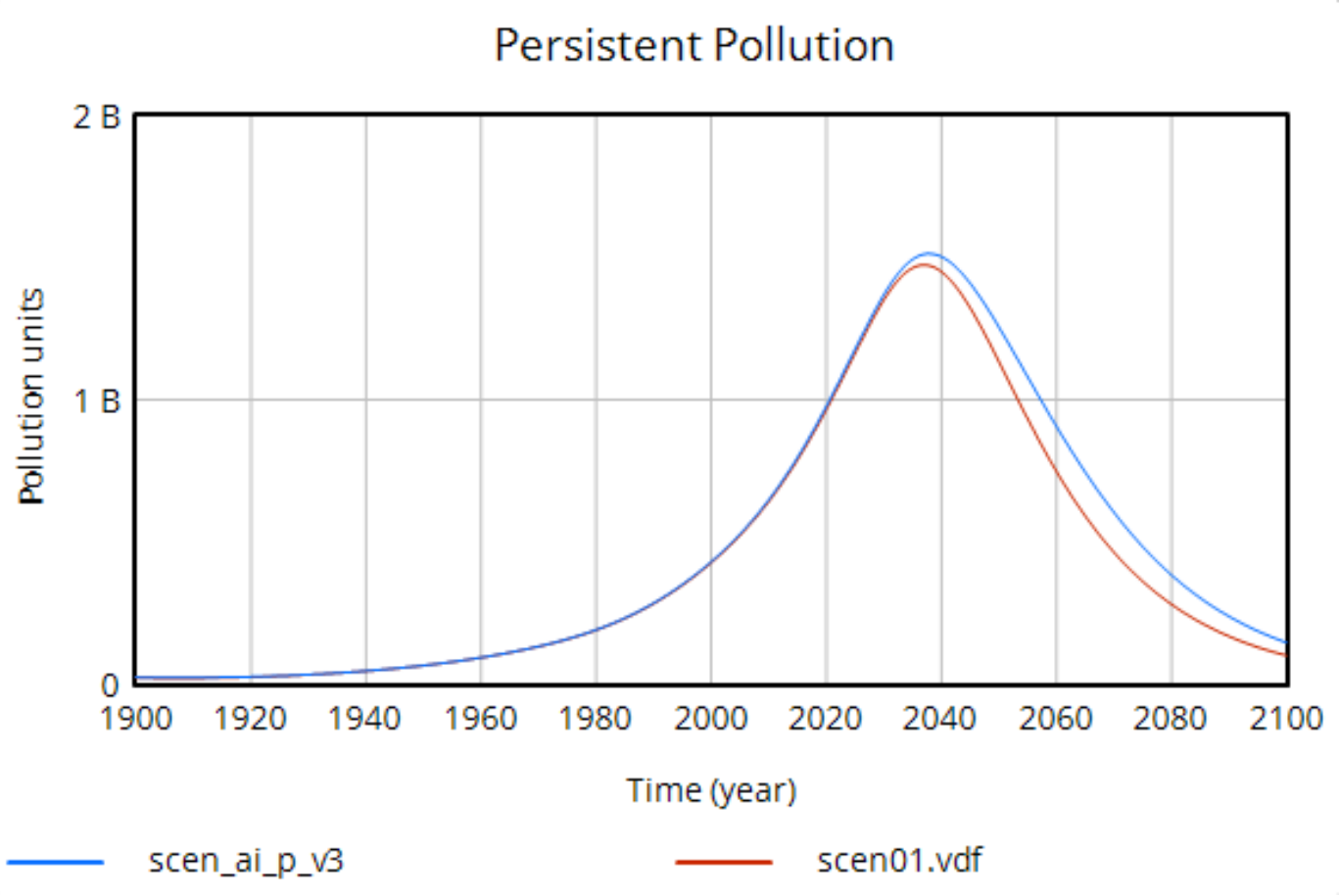
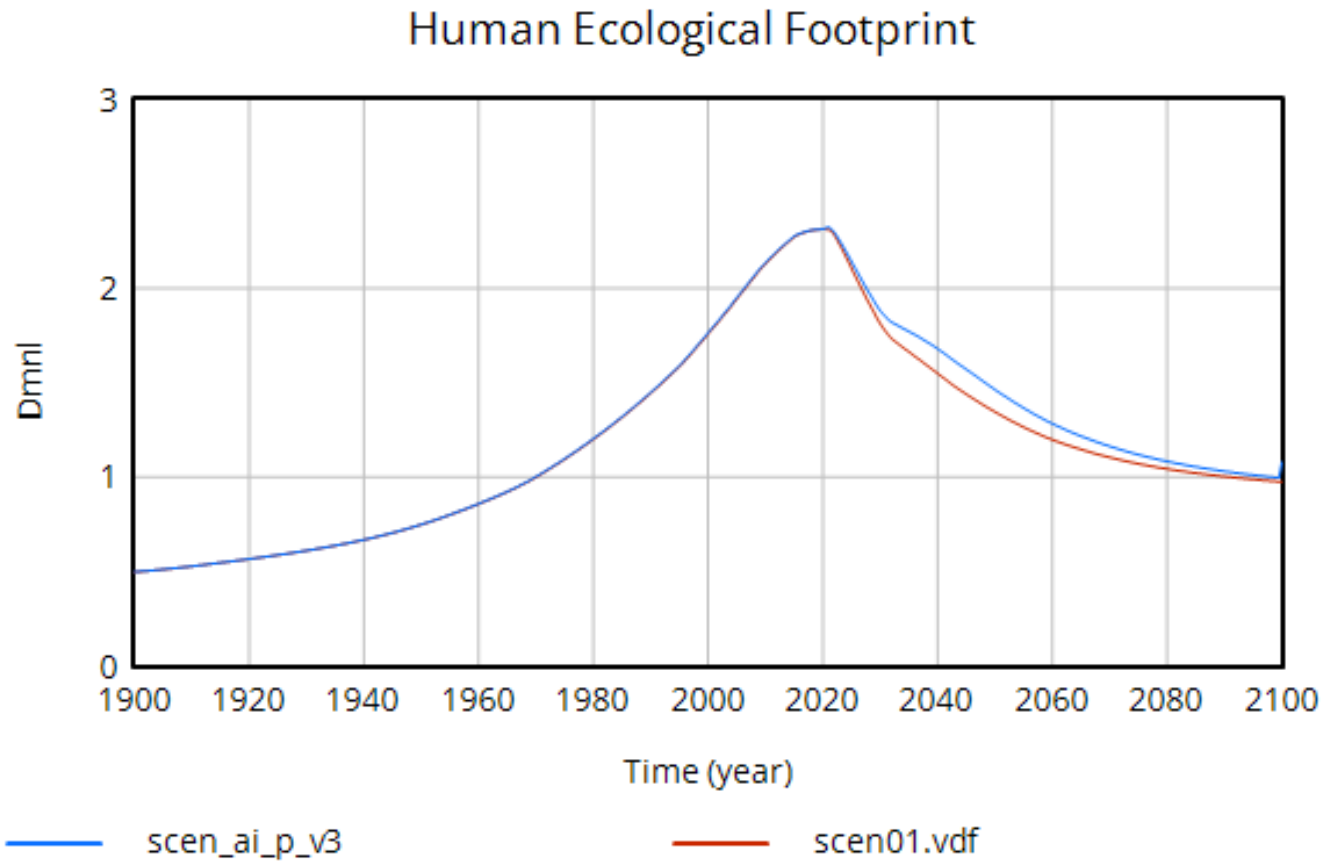
co2 to persistent
ai pollution tech change multiplier
ai efficiency slowdown rate
ai ewaste improvement rate
<persistent pollution technology change multiplier 1>

Findings



YEAR	CHANGE FROM BAU
2020	0.94 %
2040	3.77 %
2060	21.69 %
2080	37.31 %
2100	45.35 %

Findings



YEAR	CHANGE FROM BAU
2020	0.01%
2040	8.40%
2060	7.09%
2080	3.83 %
2100	10.71%

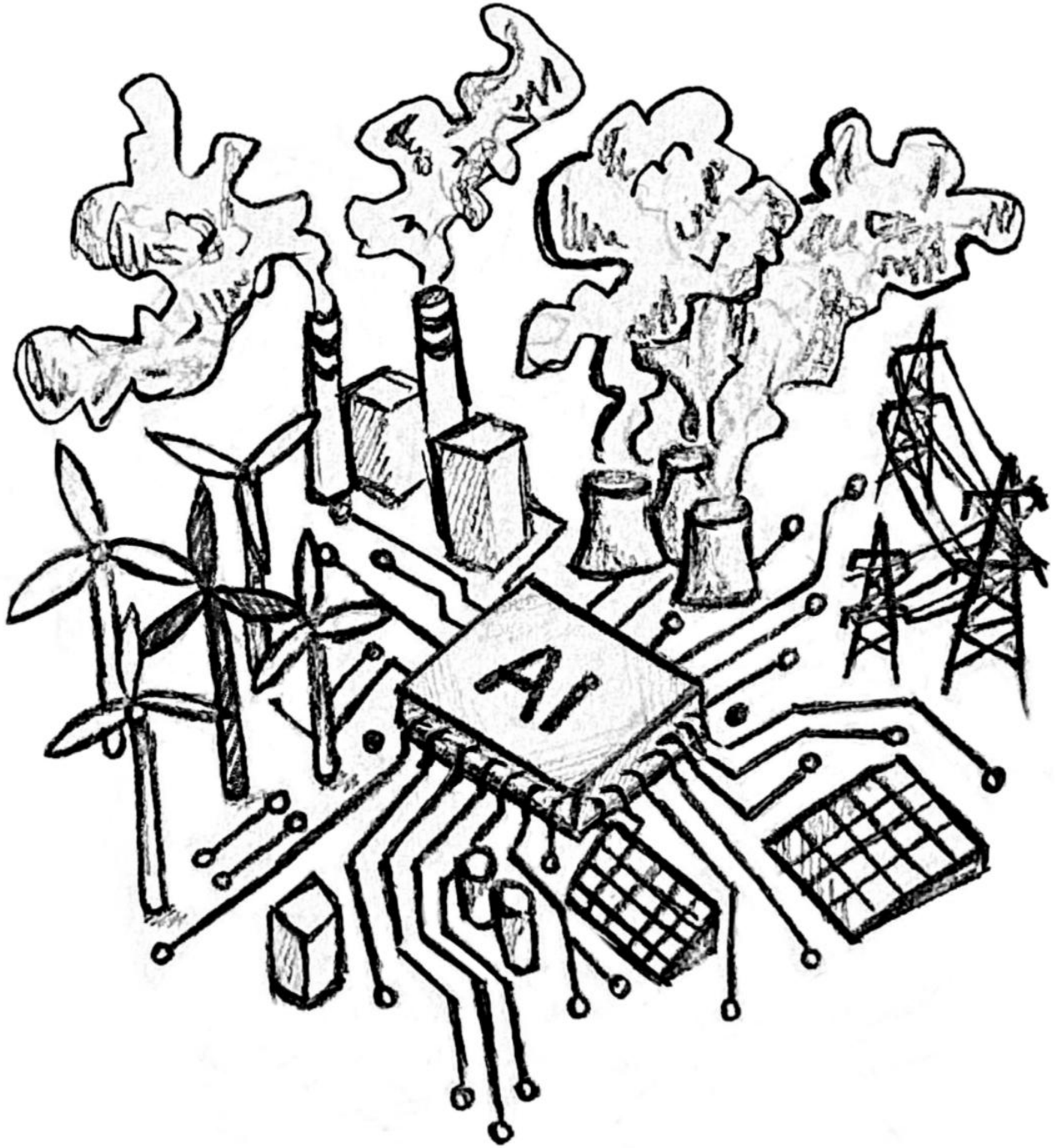
Takeaways

This is a proof of concept: by modifying persistent pollution, the results show that our added variables do in fact enable us to modify World3-03 and obtain the expected consequences.

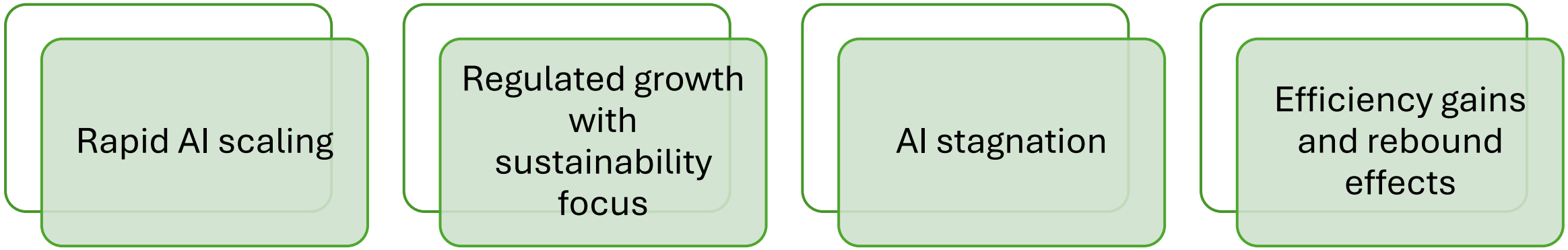
Our results integrating AI-related impacts into the World3-03 model suggest that this approach holds significant potential for quantifying the ecological consequences of large-scale computing trends.

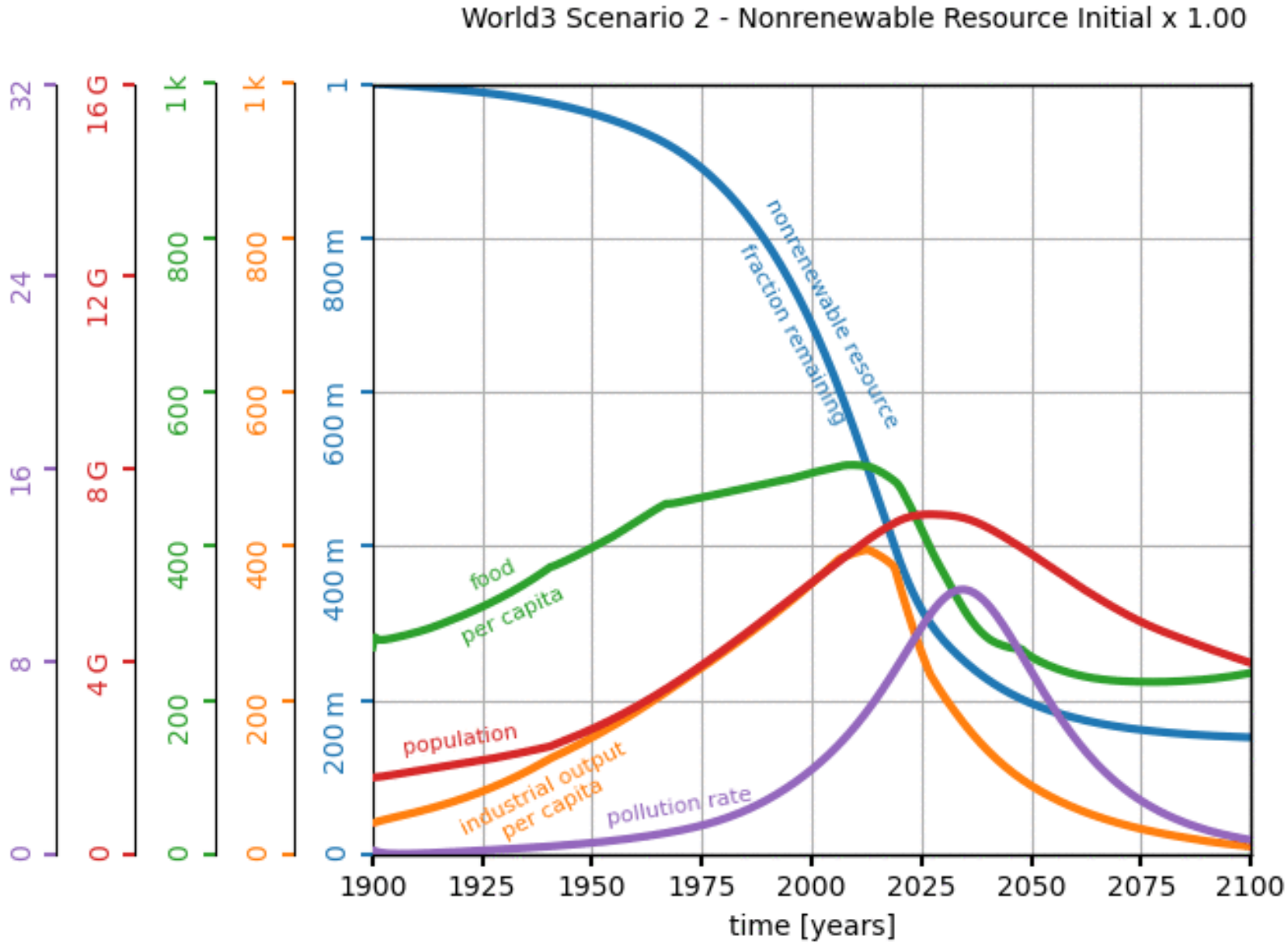
Research Opportunities

- Establishing scenarios for AI scaling
- Modifying different variables
- Adding new AI sector
- Simulating current AI projections
- Moving towards planetary boundaries and pathways



Research Opportunity: Scenarios for AI Scaling




World3 Scenario 2 - Nonrenewable Resource Initial x 1.00
nonrenewable resource fraction remaining
food per capita
population
industrial output per capita
pollution rate
time [years]
1900
1925
1950
1975
2000
2025
2050
2075
2100
0
200 m
400 m
600 m
800 m
1
0
200
400
600
800
1 k
0
4 G
8 G
12 G
16 G
0
8
16
24
32

Reverse Panel Questions

- What kinds of quantitative simulations of planetary-boundary pressures would be interesting to explore given (our) proof-of-concept of integrating AI within the World3 model?
- How would you like to build on this work (for example, to extend it, teach with it)?