JRC project: System Dynamics for System Innovation

Introduction and project update

Dimitrios PONTIKAKIS

JRC B7, Innovation Policies and Economic Impact, European Commission

joint work with:

George PAPACHRISTOS (JRC), Michal MIEDZINSKI (JRC), Tauno OJALA (JRC), Niels MEYER (JRC), Pål Davidsen (U. of Bergen), Jose Luis Torres (U. of Malaga), Igor Oliveira (Millennium Institute), Matthijs Janssen (U. Utrecht), Hedvig Norlén (Urbanstat), Michele Cincera (ULB), Eva Sevigne (OREKAN)

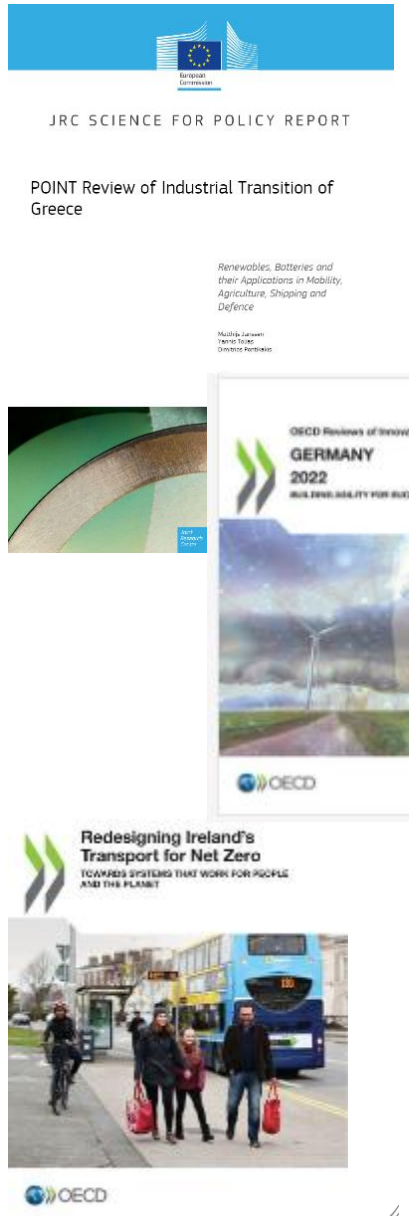
European Commission

Outline

- **Why**? *Policy challenges*
- **What**? *Objectives*
- **How**? *Ongoing work and future plans*

Policy challenges vs tools

- **Multiple and compounding crises**: "*transform or be transformed*"
- **Systemic** and **structural** roots and impacts, yet policy remains compartmentalized
- Unmet need to **evaluate potential gains from coordination between policies** (domains, sectors, portfolios, levels) to amplify and accelerate desirable social, economic and environmental impacts
- **Systems thinking** can help diagnose, identify and quantify leverage points to **focus public policies** and **enhance policy coordination**
- **Systems modelling and quantification could lend legitimacy** to more coherent and perhaps more (less?) ambitious policy packages
- *RRF case in point*: an opportunity for system innovation that caught us unprepared



How can we align, synchronise and/or sequence demand-side with supply-side policies?

Europe's problem: **production** capability failure (c.f. Draghi)

Governance mismatch at the spotlight

Dimension	Production capability accumulation process	Governance and Policy in EU countries
Time horizon	Long-term (one or more decades)	Short- to medium-term time horizons (policy cycle ~ electoral cycle)
Scope of change	Systemic: macro-economic / socio-technical	Fragmented across ministries/departments, levels of governance (EU, national, regional/local)
Direction of causality	Typically demand-led (c.f. economic history) which is also *predictable* Rare occasions of supply-led change (e.g. emergence of a general purpose technology) are *unpredictable*	Industrial policies typically focused mostly (or exclusively) on the supply-side (R&D/innovation, investment, skills, …) Typically uncoordinated with demand-side policies (handled by sectoral ministries/departments such as energy, agric., mobility, waste, health) Rare to plan sequences of interventions or tailor interventions according to stage (compare and contrast: China)

What? Objectives

Aim

Develop knowledge base for the *conceptualisation*, *measurement*, *modelling* and *evaluation* of **system innovation**

Objectives

- To construct a bespoke **quantitative model of system innovation** capable of simulating policy synergies and sequences across domains and levels of governance and evaluating their impacts
- To develop **suitable metrics** and a **data infrastructure** for the cost-effective empirical calibration of the model to distinct policy applications
- To develop a matching **participatory system dynamics modelling (PSDM) methodology** to engage with stakeholders, develop understanding, enhance the relevance of the model to real-world public policy, and nurture capacities for system innovation policy

Timeline

- 2024: *Exploratory phase*: developed experimental model of system innovation in renewables showcasing key ideas: https://publications.jrc.ec.europa.eu/repository/handle/JRC143019
- 2025-26: *Development phase (2025-26)* focus on the construction of a general macro-historical simulation model of productive transformations called **POLYTRoPOS** (*POLYvalent model for the evaluation of TRansformative POlicy Scenarios*), on its empirical calibration and on its validation with experts.

How? Activities

Conceptualising

- System innovation as an episode of transformation (creative destruction)
- Multi-scalar transformation and role of multi-level policy

Modelling

- Good theory (literature-backed setup)
- System of equations (general macroeconomic model)
- Simulation model programmed in software, GUIs

Measuring

- Statistical delineation of activities pertaining to specific episodes
- Data Workbench

Engaging and Understanding

- Qualitative research: PReliminary Innovation Systems Mapping (PRISM) reports
  - Policy document analysis
  - Interviews
- Participatory System Dynamics Modelling (PSDM)

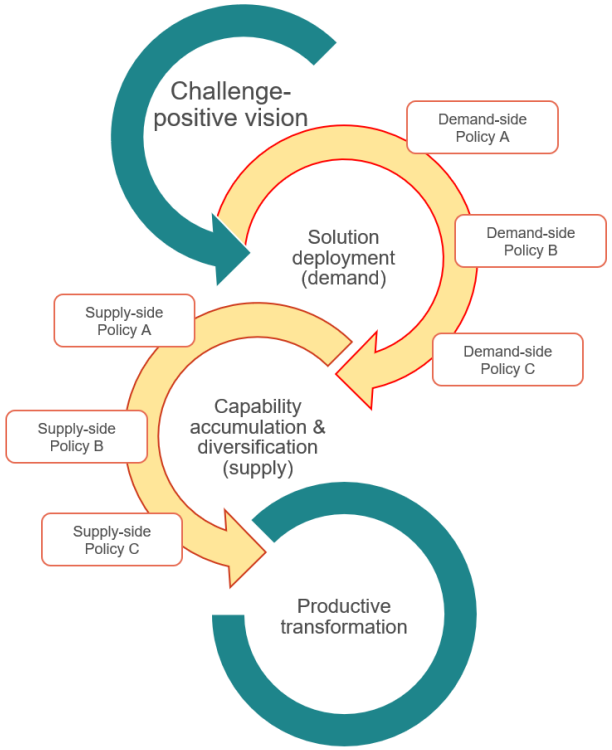
A policy-relevant model of system innovation based on a critical reading of literature

Characteristic of system innovation	Model and policy design features
Multiple values: economy, society, environment	Broad framing and systemic view
Infeasibility of many preferred outcomes	Rigorous framework for feasibility assessment
Dominance of diffusion and path dependency	Focus on what is predictable and important
Distributed agency	Facilitate interest alignment, coordinated action
Overwhelming importance of structure	Getting the ‘architecture’ right early on
Long time frames	Lengthened planning horizons
Enormous resource needs	Leveraging policy combinations and cascades
Unequal say and ownership	Redistributive policies, participatory governance

The model: POLYTRoPOS

ΠΟΛΥΤΡΟΠΟΣ = (adj.) literally "of many turns" (loops!) or "of many ways" an epithet used to describe Ulysses (Odysseus) in the opening verse of the Odyssey, loosely interpreted as: "resourceful" or "**versatile**"

POLY*valent model for the evaluation of* **TR***ansformative* **PO***licy* **S***cenarios*



A general model of the economy operating in symbiosis with the natural environment and societal wellbeing that can be readily applied to cases, or '*episodes*', of productive capability development and/or transition (e.g. energy, mobility, defence)

Key features

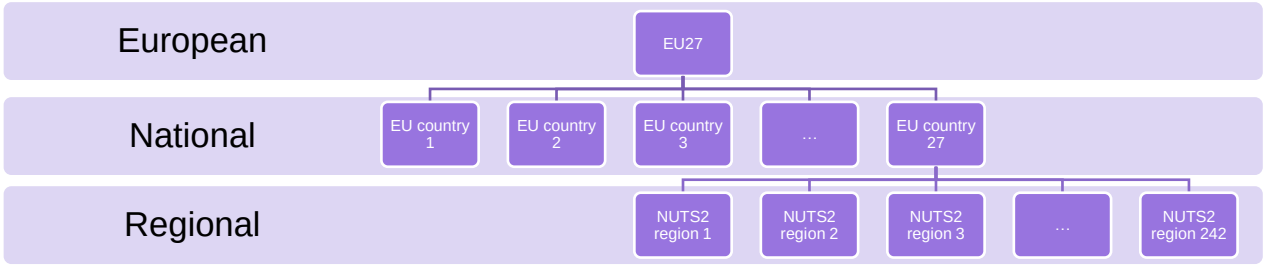
(1) Challenge-oriented (demand-led transitions)

(2) Production-focused (+ innovation/diversification)

(3) Evaluate policy-bundles (multi-ministry /-level) on *deployment*, *production* and *wellbeing*

Design considerations

- ✓ Drawing on rigorous theory and empirical regularities
- ✓ Time dimension & dynamic feedback
- ✓ Transitions set-up & *large-scale* change
- ✓ Multi-country, multi-level architecture
- ✓ Cost-effective empirical calibration (Data workbench)
- ✓ Communication-friendly, allowing participatory modelling
- ✓ Integrating multiple evidence bases & other EC models
- ✓ Capable of evaluating policy synergies and sequences



A model of transition episodes

- A general model of the economy in symbiosis with environmental and societal wellbeing meant to study **transitionary episodes of productive capability development**.
- Features bespoke design for this purpose, among others:
  - *demand-led causality* with *production feedback* in keeping with lessons from literature: Schmookler (1966); Mokyr (1992); Amsden (2001); Bell (2009); Andreoni & Scazzieri (2014)
  - endogenous *transition delays and tipping points* (e.g. from technology diffusion, uneven factor accumulation across primary-intermediate-final production, demand-supply-demand bottlenecks, etc.): Forrester (1961); Sterman (2001); Papachristos (2019); Lenton et al. (2023)
  - feedback between *innovation* and *productivity/diversification* (+ global *cost/performance* of macro-solution): Romer (1992); Hausmann and Rodrik (2003); Boschma et al. (2017)
  - broadest possible set of policy variables and concern for multiple impacts (economy, society, environment): Schott and Steinmueller (2018); Haddad et al. (2022)
  - multi-level architecture suitable for evaluating coherence of policies within & between levels: Kivimaa and Kern (2016); Pontikakis et al. (2020); Miedzinski et al. (2021)
- Implementation combines macroeconomic theory + SD = a disequilibrium macro-historical model
- *Many* possible outcomes: **oscillation**, **explosive growth**, **collapse**, **equilibrium?**

https://publications.jrc.ec.europa.eu/repository/handle/JRC139240

https://publications.jrc.ec.europa.eu/repository/handle/JRC143019

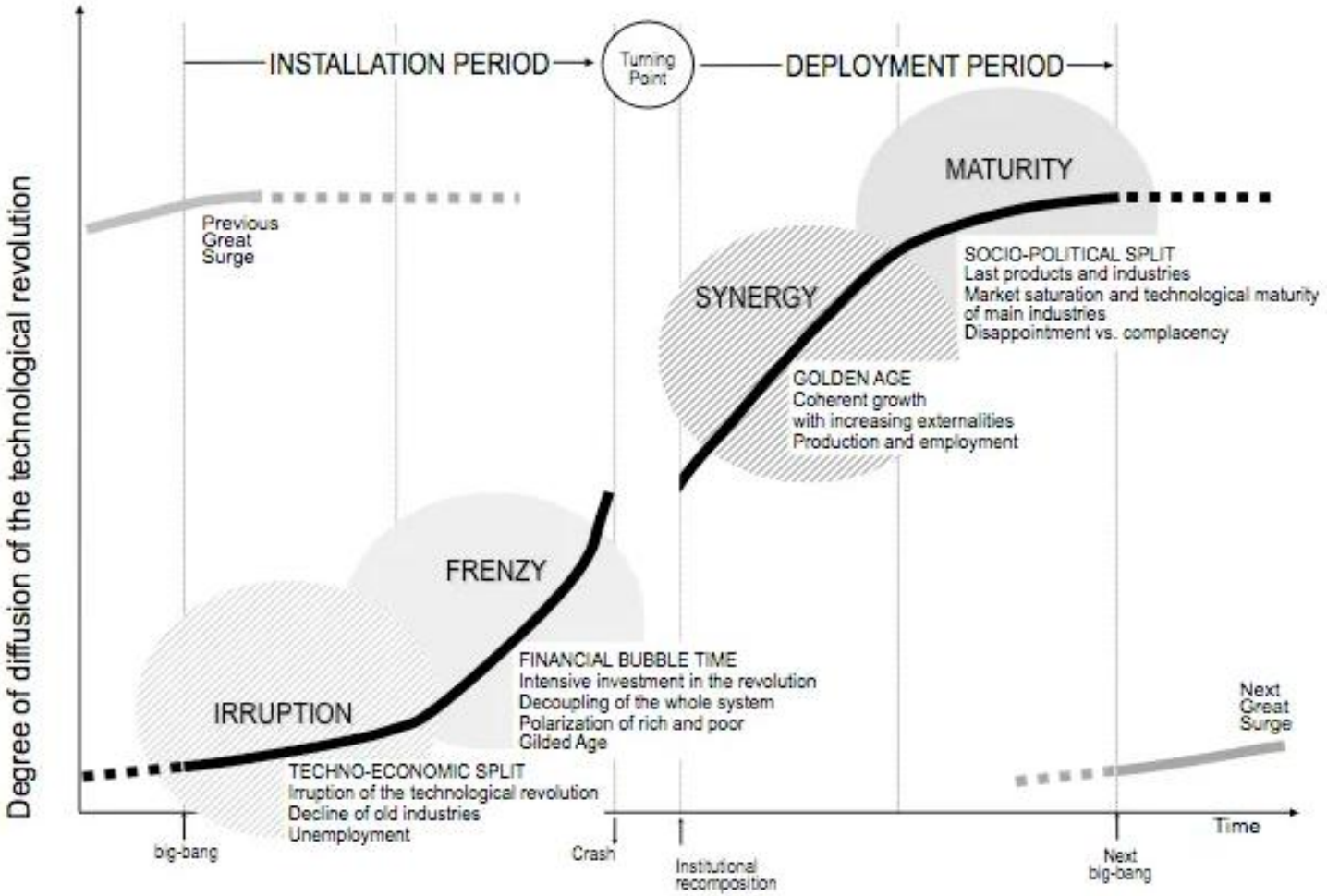
What is a transition episode? Examples from economic history

Historical Examples:

- Steam engines
- Steel, electricity, heavy engineering
- Oil, automobile, mass production
- Information and telecommunications

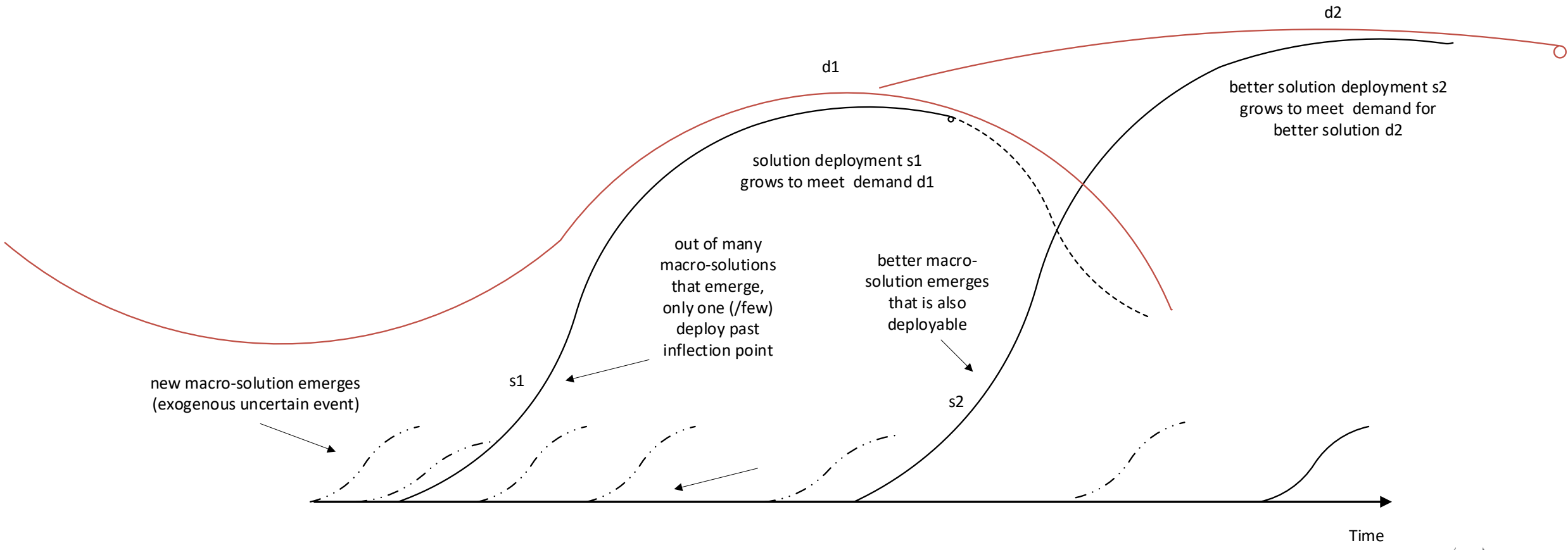
…Green industrial revolution?

Recurring stages of technological revolutions



Source: Perez, C. (2002), *Technological Revolutions and Financial Capital, The Dynamics of Bubbles and Golden Ages*, Edward Elgar, Cheltenham

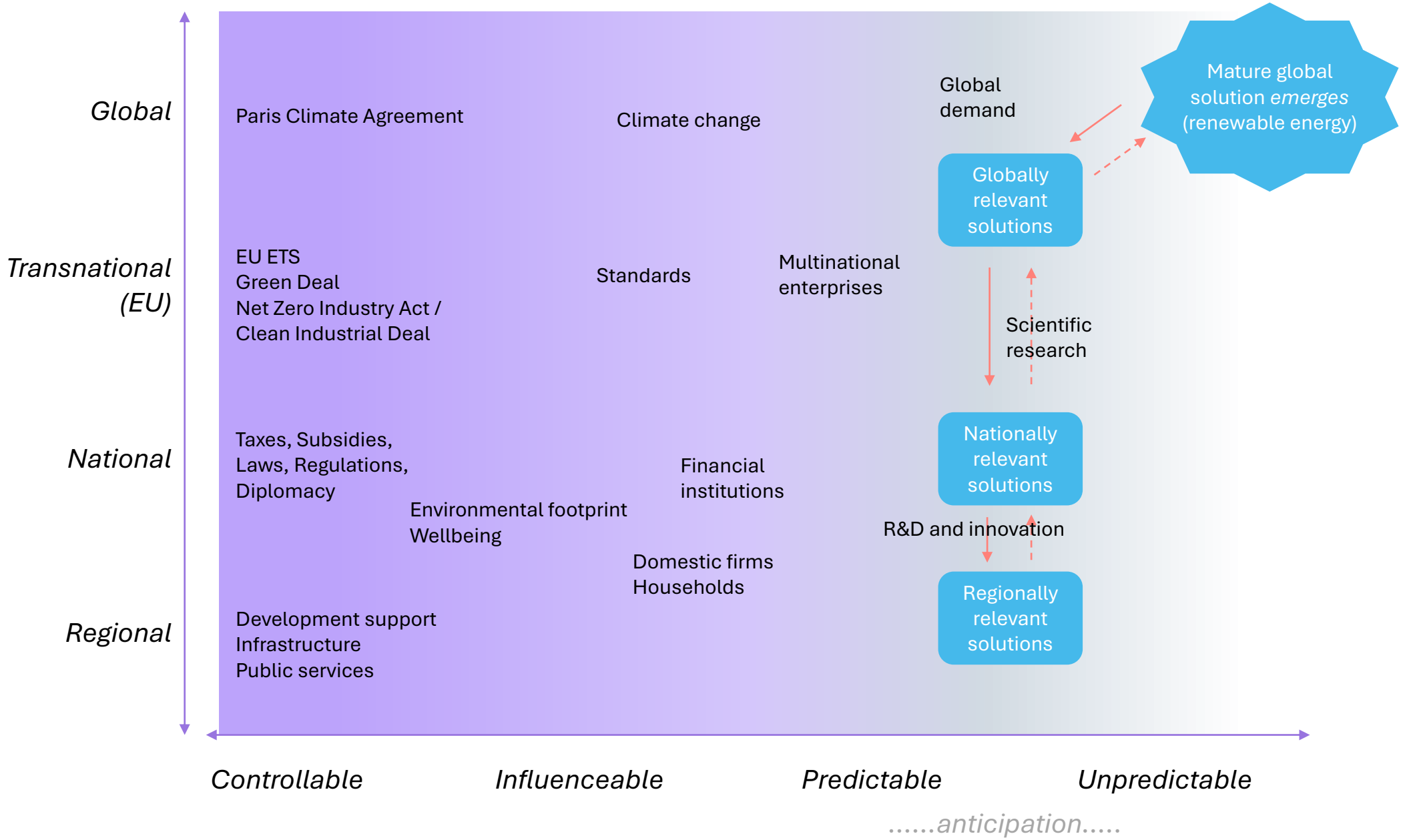
Macro-historical demand-supply trajectories and *series* of episodes



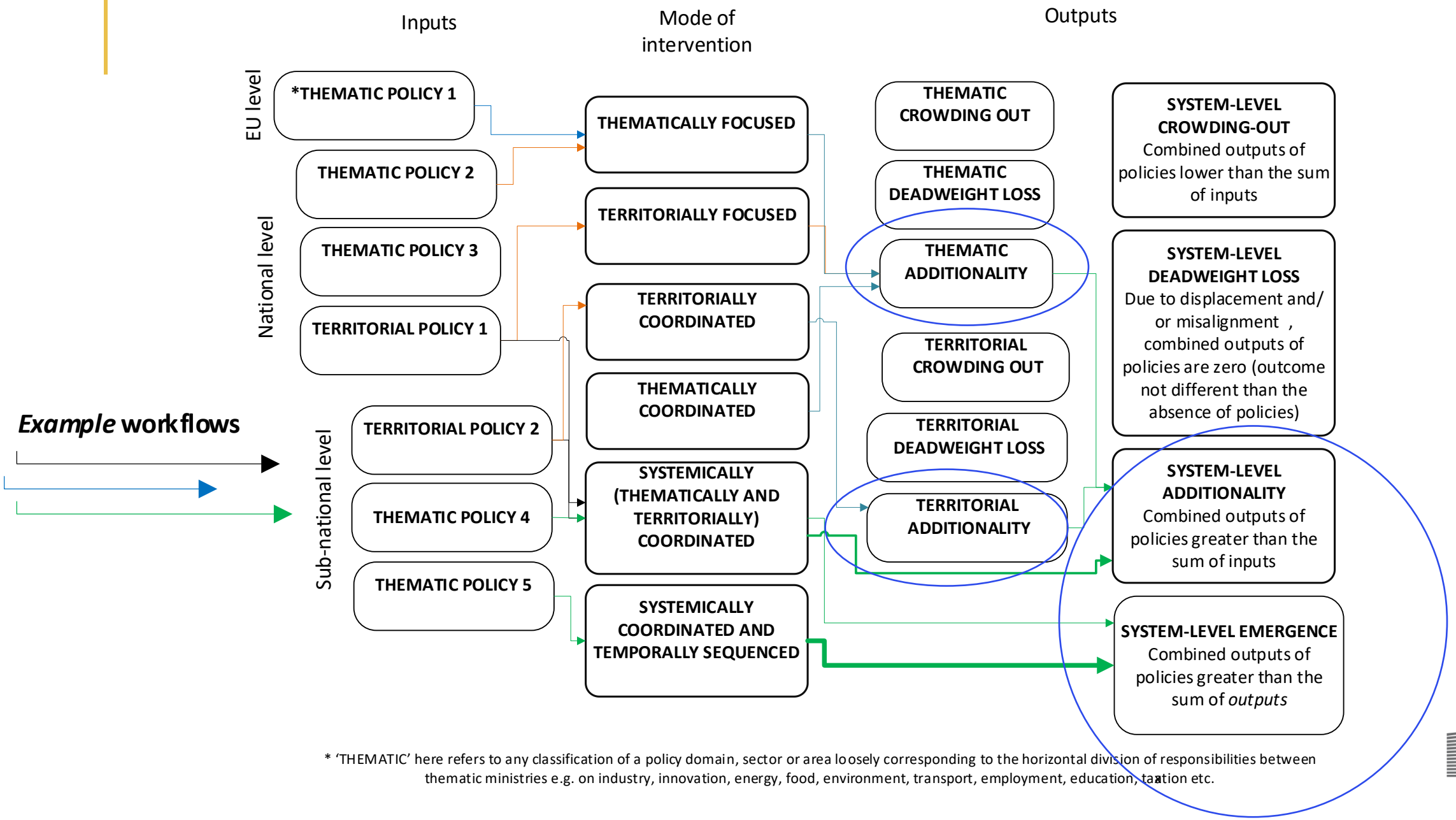
EPISODE 1

EPISODE 2

Multi-scalar change and public policy: areas of *control*, *influence*, *anticipation*



How does public policy influence a transition episode?



* 'THEMATIC' here refers to any classification of a policy domain, sector or area loosely corresponding to the horizontal division of responsibilities between thematic ministries e.g. on industry, innovation, energy, food, environment, transport, employment, education, taxation etc.

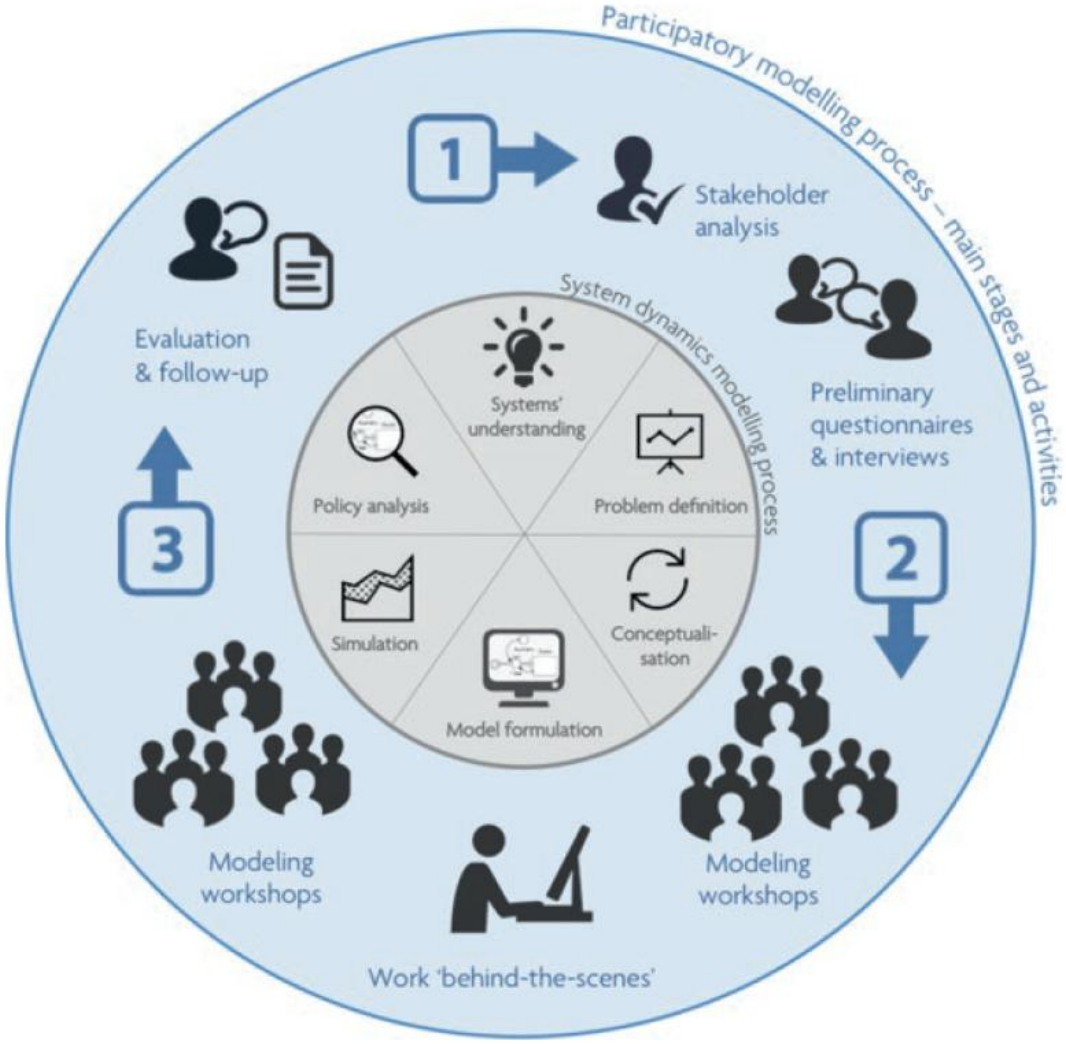
Participatory System Dynamics Modelling (PSDM)

Participatory system dynamics modeling involves stakeholders in the conceptualisation, specification, and synthesis of knowledge and experience into a model

Generates context-specific **Causal Loop Diagrams (CLDs).** CLD synthesis can provide a stakeholder-derived '*Theory of Change*'

Provides *complementary evidence* & an *ideation space* for future **policy scenarios**

Progressively shapes/*changes mental models*, helps *build capacities* for **system innovation**



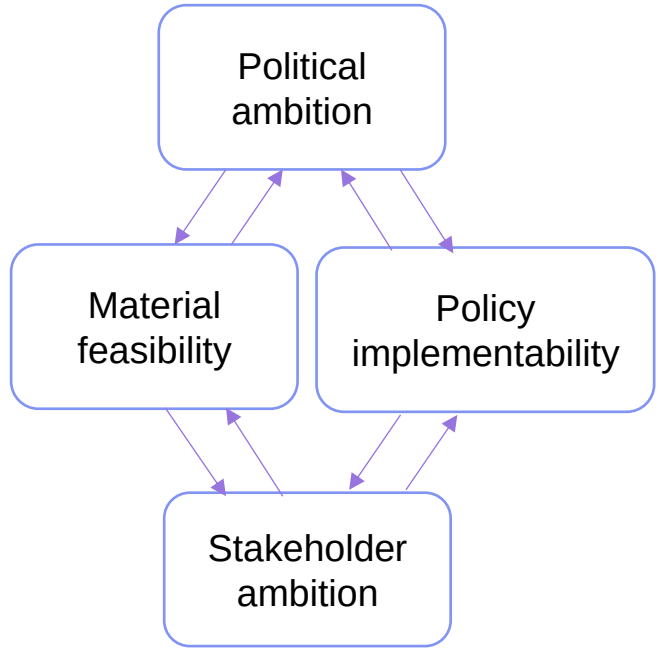
Source: Videira, N., Antunes, P., Santos, R. (2017). Engaging Stakeholders in Environmental and Sustainability Decisions with Participatory System Dynamics Modeling. In: Gray, S., Paolisso, M., Jordan, R., Gray, S. (eds) Environmental Modeling with Stakeholders. Springer, Cham. https://doi.org/10.1007/978-3-319-25053-3_12

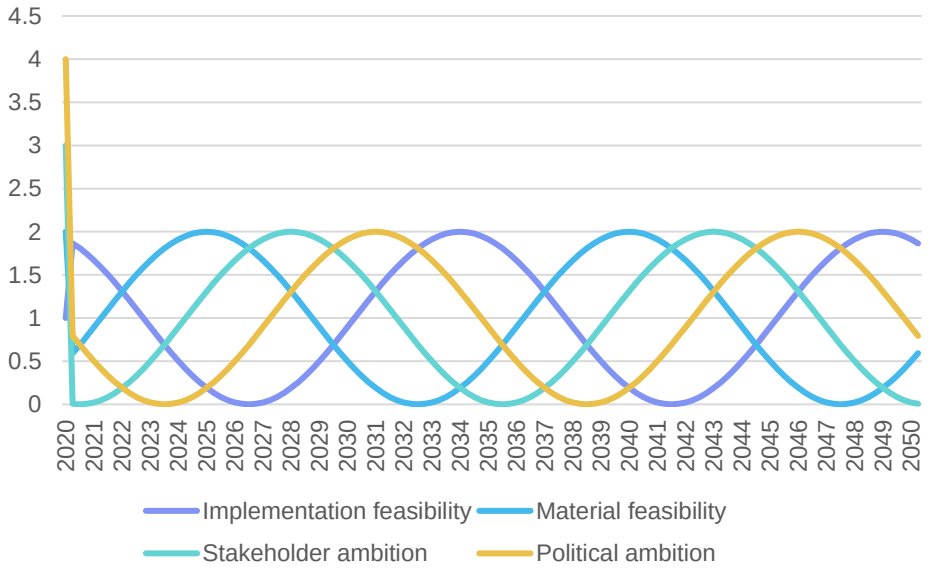
Combining PSDM with a rigorous quantitative model (POLYTRoPOS)

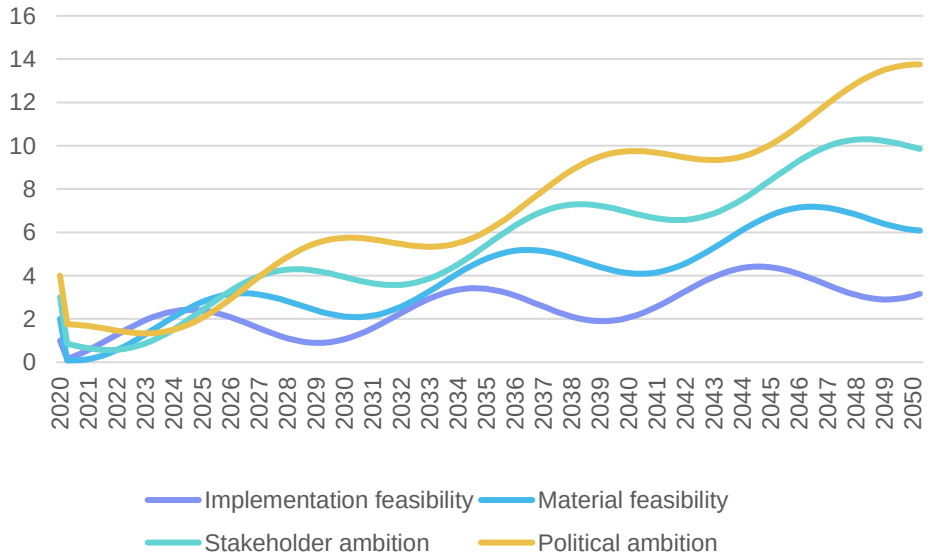
Combined framework could address need to **modulate** inter-alia: political ambition, material feasibility, implementation feasibility, stakeholder acceptance, e.g.:

Model demonstrates material (/economic) *feasibility* → *Transformative ambition* rises

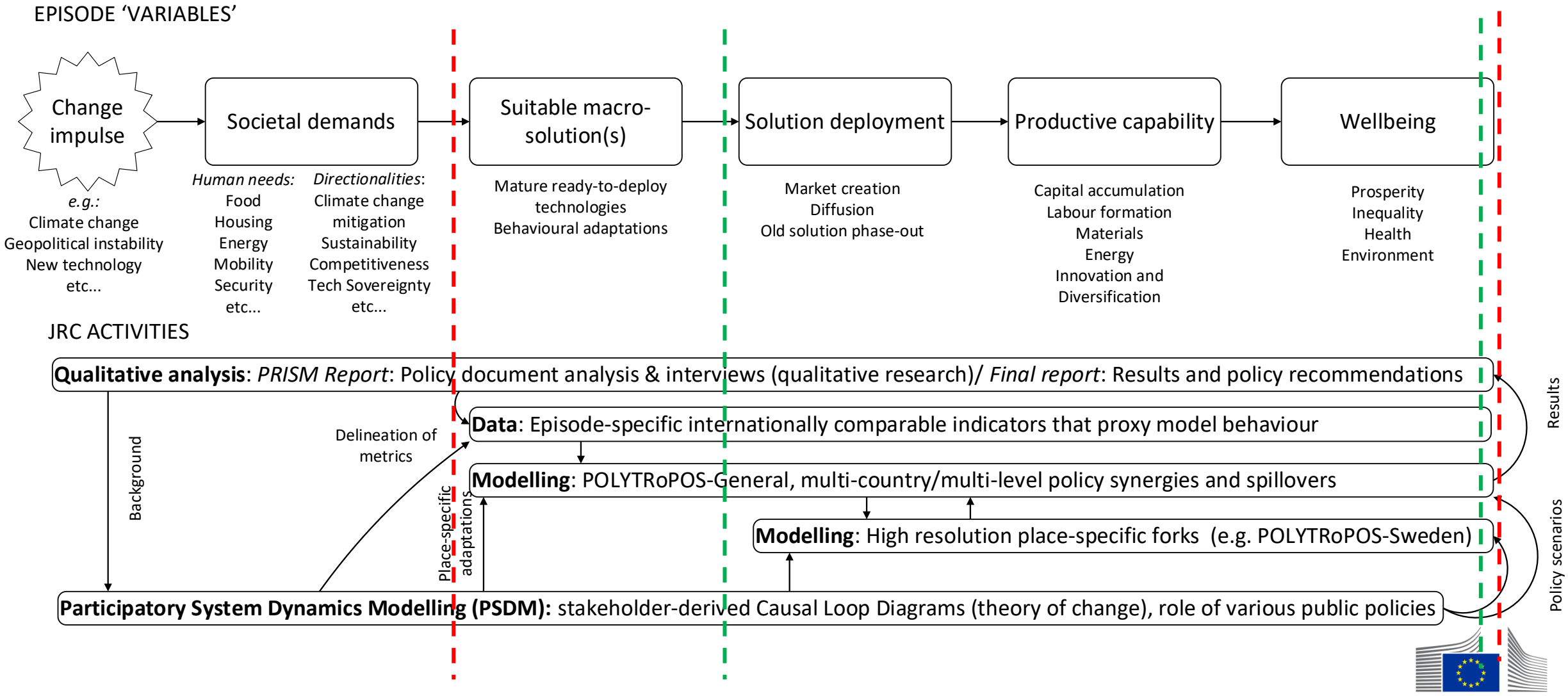
PSDM demonstrates policy *implementability* → stakeholder ambition, investment and therefore *material feasibility* rises







Case study protocol: episode vs activities



Future development: 2026-27

- Validate general model, define units and perform initial calibration
- Calibrate for all 27 EU member states (NUTS0) and rest of the world
- Develop place-specific, higher resolution forks for Sweden (national archetype) and Navarre (regional archetype)
- Implement multi-level (NUTS2 ←→ NUTS0) structure
- Use both deductive reasoning (political/policy theory) and inductive methods (PSDM, interviews) to develop and test regional, national and EU policy ‘layers’
- Nurture policy practitioner community of users, with PSDM workshops, training and study visits (building on our collaborations with Sweden, Navarre and others)

Thank you

dimitrios.pontikakis@ec.europa.eu