POLYTRoPOS

Policy uses of the POLYTRoPOS framework

Matthijs Janssen (UU) / Michal Miedzinski (JRC B7)

Content

- Policy uses of POLYTRoPOS
- Desk-research based approaches for policy scenario development
- Illustrations of how to apply the desk-research based approaches
- Participatory modelling and capacity building
- Some conclusions

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Policy uses of POLYTRoPOS: Ex post

Policy needs from an evaluation perspective (**ex durante / ex post**):

- System additionality (Haddad et al., 2020)
- Acknowledging configurational, conjunctural and sequential causality (Geels, 2020)
- Pinpointing the role of policy in complex causal web of transition dynamics, policy and non-policy (Meelen et al., 2025)

→ Combinations and sequences of instruments in POLYTRoPOS

Policy uses of POLYTRoPOS: Ex ante

Policy needs from a policy planning perspective (**ex ante**):

- Understanding direct and indirect effects of policies (causality)
- Understanding immediate and ultimate effects of policies (time)
- Understanding combined effects of policies
- …
- Comparative impact assessment: scenarios (types, magnitudes, combinations, timing, etc.)

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Policy scenario development: Approaches

1. **Archetypical scenarios (scenario features)**, e.g.:
   - Development vs. phasing out / disinvestment
   - Push (technology) vs. Pull (challenge-led)
2. **Research-based scenarios**: theoretical & empirical literature
   - Literature on net-zero transitions
3. **Real-life scenarios:** revealed & stated policies
   - Historical cases: most details on e.g. policy types, scope and budgets
   - Plans, e.g. National Climate and Energy Plans, Net-Zero strategies
   - Visions/Scenarios: possibly plural

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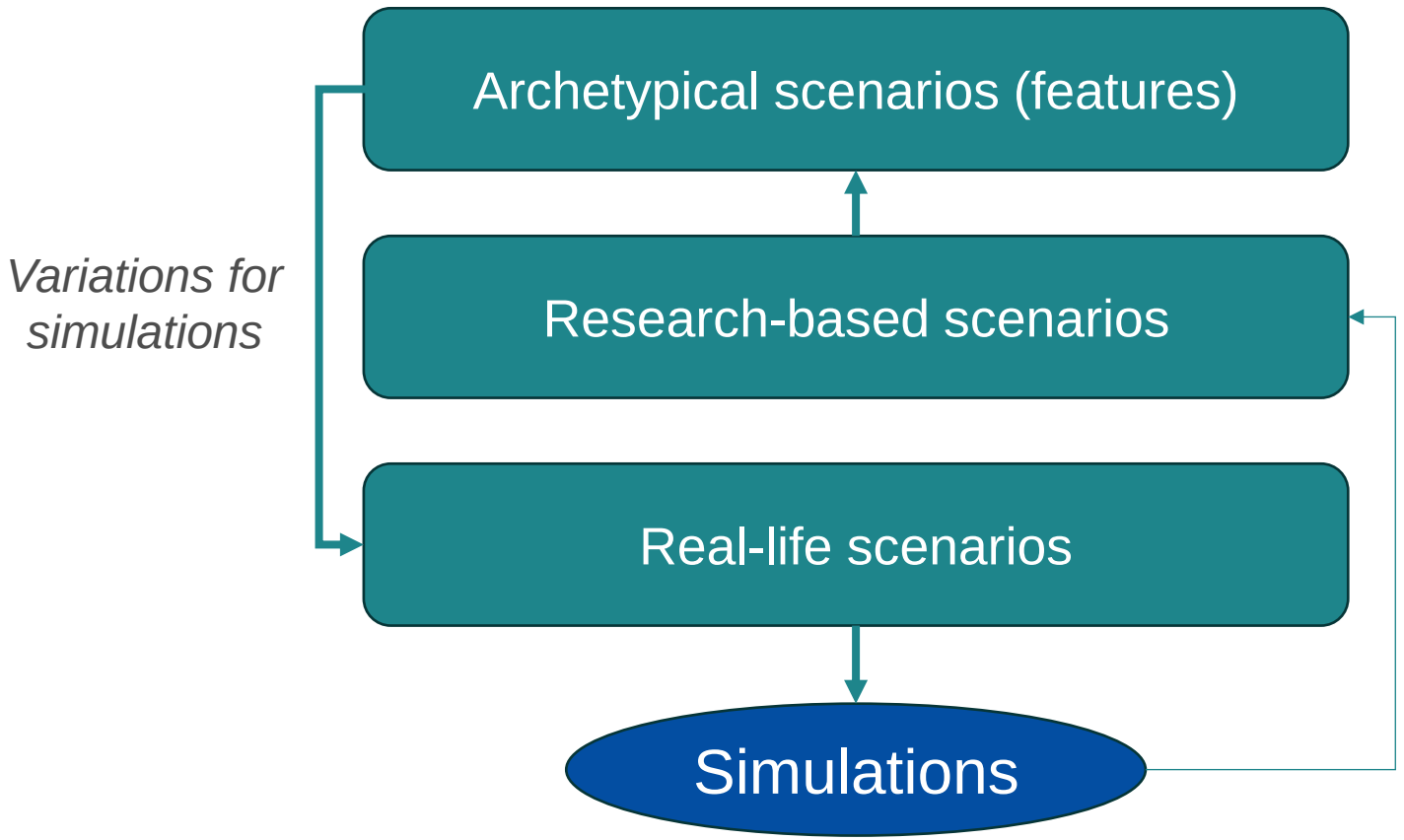
Policy scenario development: Approaches



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Scenarios = Policies * Model variables

Archetypical scenarios (features) | Research-based scenarios | Real-life scenarios

MODEL

	Mix?	Single	Single	Single	Single	Single	Combo	Combo
	Level	EU	EU	Country	Country	Region	Country	Country
	Field	Field A	Field B	Field A	Field B	Field A	Field A	Field A
	Policy	**P1**	**P2**	**P3**	**P4**	**P5**	**P1*P4**	**P1*P5**
Generic	**V1**							
Generic	**V2**							
Generic	**V3**							
Generic	**V4**							
Specific	**V5**							
Specific	**V6**							

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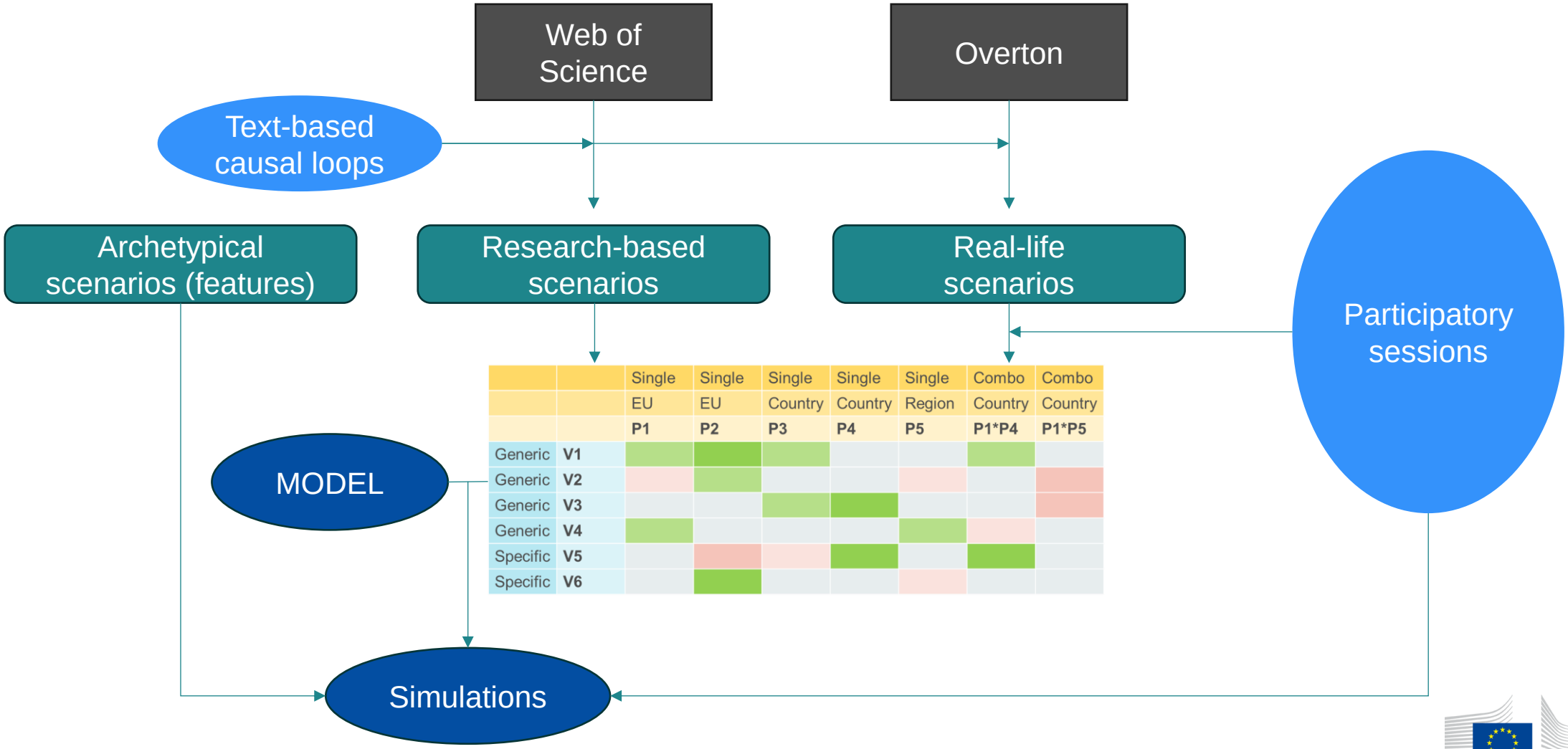
Scenario creation process



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Illustrations of the 3 scenario approaches

- Archetypical policy scenarios
- Literature-based policy scenarios
- Real-life policy scenarios

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Archetypical scenarios

- Focus on **adoption** vs focus on **capability development**.
- Full **import vs full autarky** (doing everything with resources in the system). Also relevant in current debates on OSA.
- **Fragmented vs coordinated investments**. To show the difference between 'every country/sector by itself' vs a more holistic approach
- **Small vs big investments**. What is the elasticity; which investments generate disproportionate returns?
- **Time-concentrated vs spread investments**: does it pay off to move slow / wait, or rather to face the pain early?
- …

Archetypical scenarios

Table 1
Key strategies for increasing complementarities across instruments.

	Explanation	Relevant literature
Interactions		
One-way	Two or more instruments achieve a uni-directional interaction whereby one instrument facilitates or accelerates the implementation, function or outcomes of another.	Taeihagh et al. [25], Dijk et al [6], Givoni [22], Howlett and Rayner [21], Sorrell et al. [11]
Two-way	Two or more instruments interact mutually. In the case that feedback effects and a symbiotic relationship are created, 'synergy' can arise as the combined effect of both instruments surpasses the sum of each.	Duguma et al. [31], Freeman and Farber [30], Matt et al. [34], Taeihagh et al. [25], Dijk et al [6], Givoni [22]
Relationships (often involving interactions)[a]		
Functional overlap	Instruments perform similar or overlapping functions. This overlap may or may not target the same technology/artefact or stakeholder.	Anderies et al. [35], Howlett et al. [36], Ring and Barton [37]
Coverage calibration	The scope of various instruments is calibrated or widened so that the mix as a whole achieves a desirable coverage of the targeted sector. Coverage may concern type of technology or infrastructure, type of stakeholder and lifecycle stage.	Cunningham et al. [27], Flanagan et al. [10], Schmidt and Sewerin [5], Van der Heijden [3]
Temporal calibration	Various instruments are calibrated to mandate or incentivise differing actions at differing points in time. This calibration may or may not target the same technology/artefact or stakeholder.	Cunningham et al. [27], Flanagan et al. [10], Gunningham and Grabosky [12], Kern et al. [38], Oikonomou and Jepma [29], Sorrell et al. [11], Van der Heijden et al. [39]

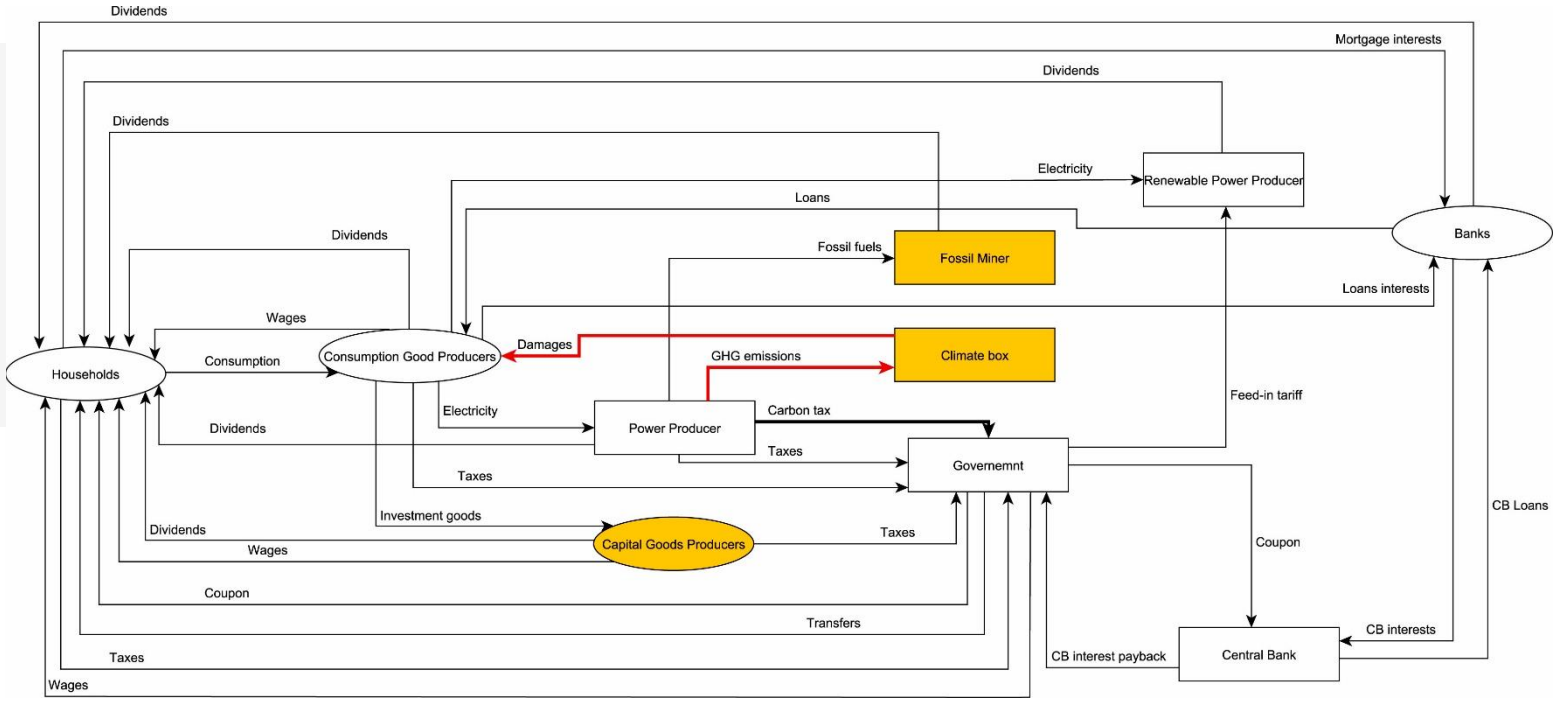
[a] Although these 'relationships' often involve a direct one- or two-way interaction across instruments, they can also be achieved without interactions.

Instrument interactions and relationships in policy mixes_ Achieving complementarity in building energy efficiency policies in New York, Sydney and Tokyo

Literature based scenario: Possible examples

Highlights

- A feed-in tariff policy and a carbon tax, isolated and combined, are examined.
- Feed-in tariff outperforms the carbon tax on climate/economy indicators together.
- The combined policy approach generally outperforms its individual components.



[Nieddu et al (2024) *Energy Policy*. Evaluating policy mix strategies for the energy transition using an agent-based macroeconomic model - ScienceDirect]

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Literature based scenario: Possible examples

Highlights

- Process eco-innovations can address global warming.
- Environmental and general innovation instruments can incentivize eco-innovations.
- The combination of these instruments determines a cross-instrumental policy mix (CIPM).
- CIPM outperforms general innovation instruments both in the short and long run.
- CIPM is as effective as environmental innovation instruments in both time horizons.

Edquist, 2013; Crespi et al., 2015). Policy mixes can arise from both the combination of different policy instruments that belong to the same policy area (e.g. environmental regulation and environmental taxes) or those that belong to different policy areas (e.g. environmental taxes and R&D subsidies). As suggested by Bouma et al. (2019), the interaction between different instruments may lead to positive, negative or neutral effects. Indeed, a policy mix can become a 'policy mess' (Sorrell, 2003) when the mix of instruments lacks an overall coherence (i.e. when different instruments with different goals are not coordinated properly) (Beise and Rennings, 2005; Crespi et al., 2015; Kemp and Pontoglio, 2011; Rennings, 2000). Therefore, an evaluation of policy mix effects is pivotal to understanding whether policies are welfare-enhancing (Bouma et al., 2019). However, such an evaluation is complex (Bouma et al., 2019; Goulder and Parry, 2008), and empirical research on the topic is scarce (Trencher and van der Heijden, 2019). Furthermore, very few articles have analysed policy mix within the realm of environmental policy (e.g. Costantini et al., 2017; Crespi et al., 2015; Haščič, 2012). Moreover, to the best of our knowledge, no previous study has empirically analysed the effectiveness of a policy mix including two policy areas – environmental policy and innovation policy – for innovation activities in general (i.e. not necessarily EI).

In this study, we will refer to this particular type of policy mix as a *cross-instrumental policy mix*. The lack of empirical studies on a cross-instrumental policy mix constitutes a remarkable gap since many countries have various policy instruments to sustain 'general' innovation and EI. Still, they are not coordinated, and their combined effect on the actual development of EI remains largely unverified. Furthermore, there is a lack of evidence on the temporal effects, that is, whether the theorised positive impact of a cross-instrumental policy mix on EI occurs in the short term only or if it persists in the long term as well. Therefore, the two research questions explored in this study are: *Is the*

Greco et al. (2022) *Technovation.* Policy mix or policy mess? Effects of cross-instrumental policy mix on eco-innovation in German firms - ScienceDirect

Real-life scenario: Possible examples

- **OECD reports**
  - Net Zero+: The OECD Horizontal Project on Climate and Economic Resilience | OECD
  - Mission-Oriented Innovation Policies for Net Zero | OECD

- **IEA documentation on net-zero strategies,**
  - https://www.iea.org/reports/net-zero-by-2050

Real-life scenario: Possible examples

- **EU Green Deal Industrial Plan**
  - **EU Net-Zero Industry Act (NZIA)**
  - (policy from other pillars)

- **EU National energy and climate plans**
  - Sweden - Final updated NECP 2021-2030 (submitted in 2024) - European Commission

Policy-based scenario: EU GD Industrial Plan

Predictable and simplified regulatory environment

Faster access to funding

Enhancing skills

Open trade for resilient supply chains

Net-Zero Industry Act

Identifying goals for net-zero industrial capacity and provide a regulatory framework suited for its quick deployment

Critical Raw Materials Act

Ensuring sufficient access to those materials, like rare earths, that are vital for manufacturing key technologies

Reform of electricity market design

Helping consumers benefit from the lower costs of renewables

The Green Deal Industrial Plan - European Commission

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Policy-based scenario: EU NZIA

The Net-Zero Industry Act explained

The Net-Zero Industry Act is an initiative stemming from the Green Deal Industrial Plan which aims to scale up the manufacturing of clean technologies in the EU. This means increasing the EU's manufacturing capacity of technologies that support the clean energy transition and release extremely low, zero or negative greenhouse gas emissions when they operate.

This Act will attract investments and create better conditions and market access for clean tech in the EU. The aim is that the Union's overall strategic net-zero technologies manufacturing capacity approaches or reaches at least 40% of annual deployment needs by 2030. This will accelerate the progress towards the EU's 2030 climate and energy targets and the transition to climate neutrality by 2050. It will also boost the competitiveness of EU industry, create quality jobs, and support the EU's efforts to become energy independent.

Net-Zero Industry Act - European Commission

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Policy-based scenario: EU NZIA pillars/actions

To stimulate investment into net-zero technologies, the Act proposes:

- **Net-zero Strategic Projects**: identifying priority projects essential for reinforcing the resilience and competitiveness of the EU net-zero industry
- **Cutting red tape and accelerated permitting**: lowering administrative burden for developing net-zero manufacturing projects and simpler and faster permitting procedures. This is particularly for strategic projects which will benefit from even faster permitting, to increase planning and investment certainty.
- **CO2 injection capacity**: supporting carbon capture and storage projects, notably by enhancing the availability of CO2 storage sites
- **Attracting investment**: attracting investment through the Net-Zero Europe Platform and the European Hydrogen Bank
- **Facilitating access to markets**: boosting demand for renewables by implementing sustainability and resilience criteria in procurement procedures and auctions
- **Innovation**: establishing regulatory sandboxes to help develop and test innovative net-zero technologies and create a level-playing field for innovation
- **Enhancing skills**: setting up Net-Zero Industry Academies, with the support and oversight by the Net-Zero Europe Platform. These will provide training and education on net-zero technologies, and lead to quality jobs creation.

[Net-Zero Industry Act - European Commission]

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EU NZIA – Headline benchmarks (Targets)

- **Overall:** “by 2030, manufacturing capacity in the Union of the strategic net-zero technologies listed in the Annex approaches or reaches a benchmark of at least 40% of the Union’s annual deployment needs for the corresponding technologies necessary to achieve the Union’s 2030 climate and energy targets”
  - **Solar PV**: the European Solar PV Industry Alliance (supported by the EU’s Solar Energy Strategy) aims to reach at least 30 GW of operational solar PV manufacturing capacity by 2030 across its supply chain, […]. This translates into a share of around 45% of the EU’s annual installation or deployment needs by 2030. → **24 GW** / 53 GW installed capacity
  - **Batteries**: The European Battery Alliance (EBA) has the political objective of making sure that European manufacturers produce 90% of the EU’s annual battery deployment needs in 2030. → from 75 GWh in 2022 to **885 GWh** in 2030 (lithium-ion batteries)
  - **Electrolysers**: 100% of EU’s deployment needs for this technology → installed electrolyser capacity of around **105-140 GW**
  - [Wind and heat pump technologies: 80% and 60% of deployment needs]

EU NZIA – Finance

Regarding financing, no new money or funding instrument is provided in NZIA, but the latter provides for support for the coordination of financing . As the Commission's recent investment needs analysis showed,[114] €92 billion cumulative over 2022-2030 are needed to ramp up EU's manufacturing capacity to meet the industry-led technology-specific objectives put forward in NZIA's recital 17. Out of these, around €16-18 billion could be required from the public purse, and in this respect several existing EU instruments, directly managed by the European Commission or with Member States (like InvestEU, Innovation Fund, RRF, Modernisation Fund, as well as cohesion policy instruments), can be better geared to contribute to the achievement of NZIA objectives and partly cover these public funding needs.[115] This support can create an important pull factor for net zero innovation demonstration projects developed under the Horizon Europe programme below technological readiness level 8. In addition, the Commission will aim at ensuring that NZIA priorities and to support net-zero strategic projects is factored in relevant EU programs, as appropriate.

By establishing definitions of economic activities that can be considered environmentally sustainable, the EU Taxonomy will help direct investments to economic sectors where they are most needed to reach the objectives of the European Green Deal and enable the net-zero transition. The first Climate delegated act covering climate change mitigation and adaptation objectives (116) applies

In this context it is worth highlighting that the Commission has now, via its Temporary Crisis and Transition Framework of 9 March 2023, provided Member States with a possibility to implement State aid measures that facilitate new investments in production facilities within specific sectors that are strategic for the transition to a net-zero economy. These measures may be granted in various forms, including tax advantages. The permitted aid amount and intensity may be increased where the investment takes place in an assisted area (as per the applicable regional aid map), to contribute to the goal of convergence between Member States and regions. In exceptional cases, the TCTF allows Member States to provide higher support to individual companies, where there is a real risk

EU NZIA – CO2 Injection Capacity

neutrality will not be reached if CCS capacities are used to remove emissions from sectors that can and must decarbonise.

As such by requiring sectorial contributions from the oil and gas companies to the establishment of the front-runner storage projects, a reliable quantity of storage services supply will become available and recognised as Net Zero Strategic Projects, provided by market participants that where anyway expected to be at the forefront of this development. This in turn will increase certainty to underpin investment decisions for the development of CO_2 capture projects in hard-to-abate industries.

The proposed EU target of annually 50 million tonnes of CO_2 injection capacity builds on the fact that several CO_2 storage projects are currently in different stages of the exploration and permitting process in the EEA, though no certainty exists on when they will become operational. These projects need to become operational by 2030 to allow industries to capture CO_2 instead of emitting it. The target is in line with the market expectations of the storage operators, as well as with the estimation of the CCUS Forum industry coalition of 80 Mtpa by 2030 in the EEA. The vast majority of the current storage projects are in the North Sea region.

Net Zero Strategic Projects will also be needed in southern and eastern EU Member States. The coordinated development of such storage projects across the EU, incentivising also companies with similar oil and gas activities in other regions, will create industrial scale capacity and learning effects that the storage sector can benefit from EU wide. The proportional contribution by oil and gas producers takes account of the medium and long-term revenue and growth potential for storage site operations. The 2030 target capacity will allow stable annual revenues during 15-20 years of operation. This will serve a growing demand for storage services, which the CCUS Forum stakeholder

Policy-based scenario: NCEP Sweden

Cross-sectoral	Energy supply	Housing and services	Industry	Transport	Waste	Agriculture	Forestry
Energy and Carbon Tax	Energy and Carbon Tax	Energy and Carbon Tax	Energy and Carbon Tax	Energy and Carbon Tax	Ban on dumping flammable and organic waste	**CAP**	The Forestry Act
EU ETS	Waste Incineration Tax	**Ecodesign Directive**	**EU ETS**	**Emission requirements for new vehicles**	Collection of measurement data from dumps	Rural Development Programme	Land drainage rules under the Environmental Code
Klimatkliv (Climate	**EU ETS**	**Energy Labelling Regulation**	*Industrikliv* (Industrial	Reduction obligation	Waste tax	The Rural Development Network	Forest and land protection under the Environmental Code and nature conservation agreements
Stride) funding	Electricity certificates system	Building regulations	Stride) funding	Bonus-malus system	Producer responsibility	Advice	
initiative	Wind power initiative	Energy and Climate Advisory Service	initiative *Energisteg*	CO_2-based vehicle tax	Municipal waste planning	Support for biogas from manure	National Forest Programme
Environmental Code	Support for solar energy	Energy declarations	(Energy Step) funding	Lower taxable value for vehicles with environmental technology	**EU waste package**	Biogas support	Advice and education
Planning and Building Act		Education programme for low-energy buildings	programme	Pump Act			**CAP**
Fossil-Free Sweden			Requirements and support for energy mapping	Environmental information about fuels			
Communication		Client groups and networks	Energy and climate coaches	Climate incentive payment			
Energy and Climate Advisory Service			Energy-efficiency network	Urban Environment Agreement			
Regional energy and climate plans			Environmental Code	Infrastructure planning			
The European Regional Development Fund			**F-Gas Regulation and BREF**	Eco-bonus system for shipping			
Research and demonstration				Procurement rules			
Procurement rules				Tax on air travel			
				EU ETS (flights)			

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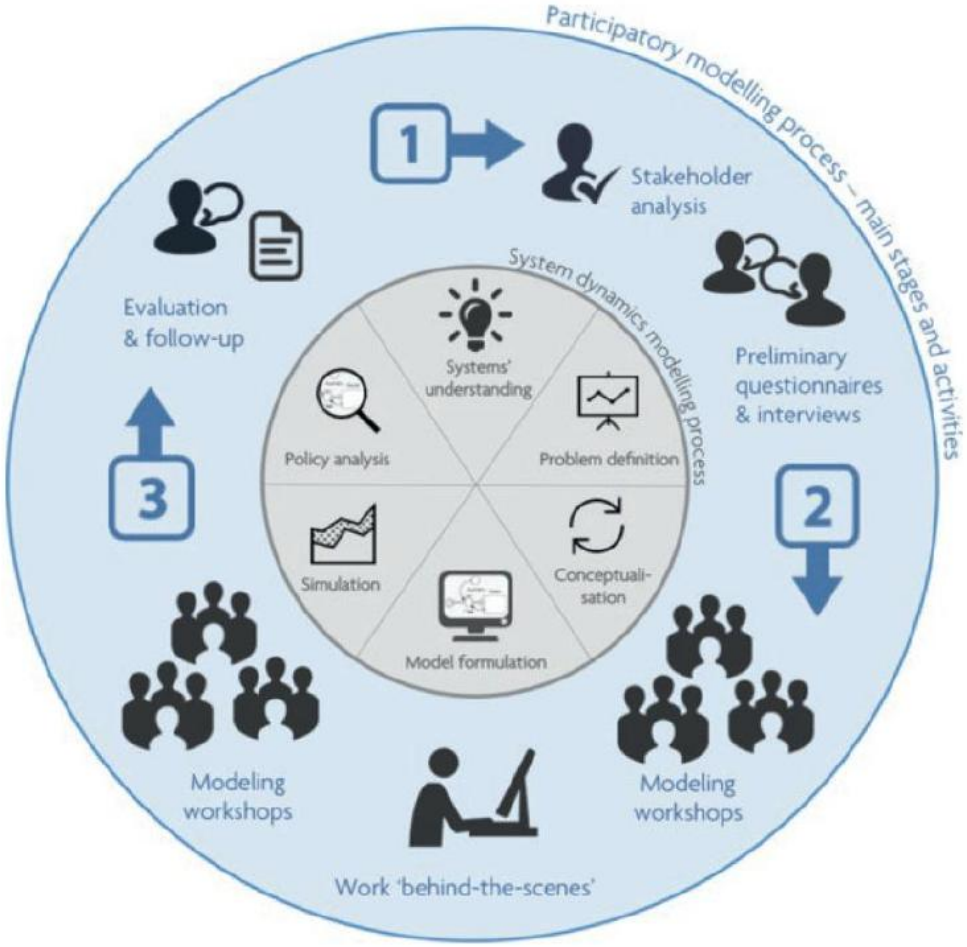
Participatory System Dynamics Modelling

Modeling with “problem-owners” is one of the defining features of system dynamics.

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

A useful model can enable an understanding of the dynamic complexity of socio-ecological problems.



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

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Participatory System Dynamics Modelling

- *Increase resolution and improve policy relevance*: Build **place-based adaptations and extensions** of our general (theory-based) model
- *Construct a policy-user interface*: Construct **policy/decision layers** at the national, regional and EU levels
- *Broadening the frame*: engage with stakeholders within the **broad system-level (or system of systems)** boundaries of our model to change perspectives
- *The model as a common language*: Work with stakeholders to co-create **original scenarios of bundles/sequences of policies /stakeholder actions** that aim for system-level additionality and are currently very difficult to envisage by other means

→ When our general model is ready, we should be able to even **cost and evaluate the approximate impact of policy scenarios** ex ante which allows further meaningful deliberations with stakeholders and quick policy scenario iteration.

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Participatory System Dynamics Modelling

PSDM can be relevant to transformative innovation policy in many ways:

- Constructing a commonly understood ‘theory of change’
- Capacity building for system innovation
- Permitting policy making in interaction
- Continuous monitoring, formative evaluation and iterative adaptations of directionality
- Setting the basis for new interactions and better coordination
- Reflexive learning etc.

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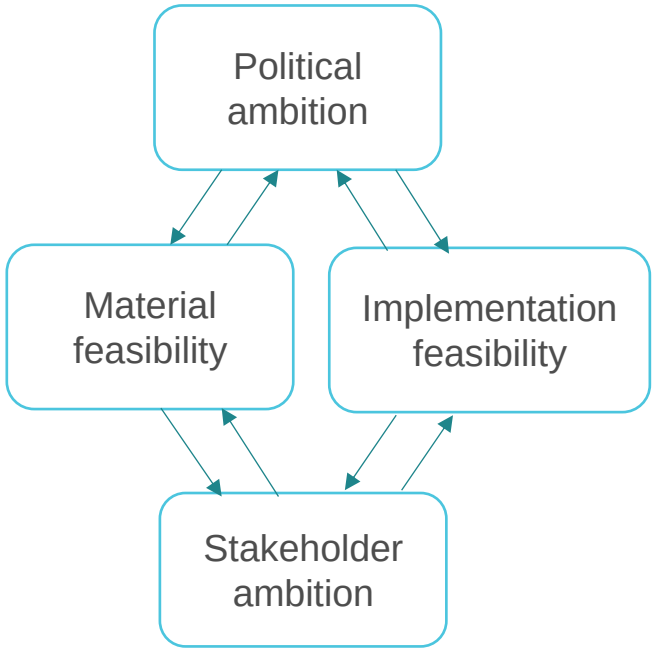
Combining PSDM with a rigorous quantitative model (POLYTRoPOS)

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

e.g. consider three possible situations

- Situation 1. High ambition, insufficient policies: Model simulations suggest that current policies will fail to meet current political ambition. → *CHANGE*: New/re-designed policies (or new combinations/sequences). PSDM to ensure only feasible policies are proposed.
- Situation 2. Low ambition due to lack of belief in material feasibility: (e.g. resource constraints, capability constraints): Model simulations may identify combinations and sequences of policies that produce material impacts no-one thought possible. *CHANGE*: Political ambition rises, policies are designed via PSDM, monitored and adjusted in real-time
- Situation 3. High material feasibility, low ambition due to powerful incumbent interests: PSDM-generated simulations can build **legitimacy** for outcomes that co-opt incumbents, raise ambition



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From data to participation (and back): PRISM

Purpose of “PReliminary Innovation System Mapping” (PRISM):

A preliminary assessment tool regarding *delineation/status of system* and *focus for system change*. Useful to identify needs of further evidence gathering and analysis

Specifications:

- Assessment: policy contributions within territorial boundaries (governance), systemic scope (space) and transformative change (time)
- Drawing on limited number of ‘situational’ metrics (same for all territories) and system stakeholder / expert consultations
- Must be inexpensive to implement and produce preliminary assessments quickly
- Preliminary assessment reports highly visual and preferably around 10-15 pages

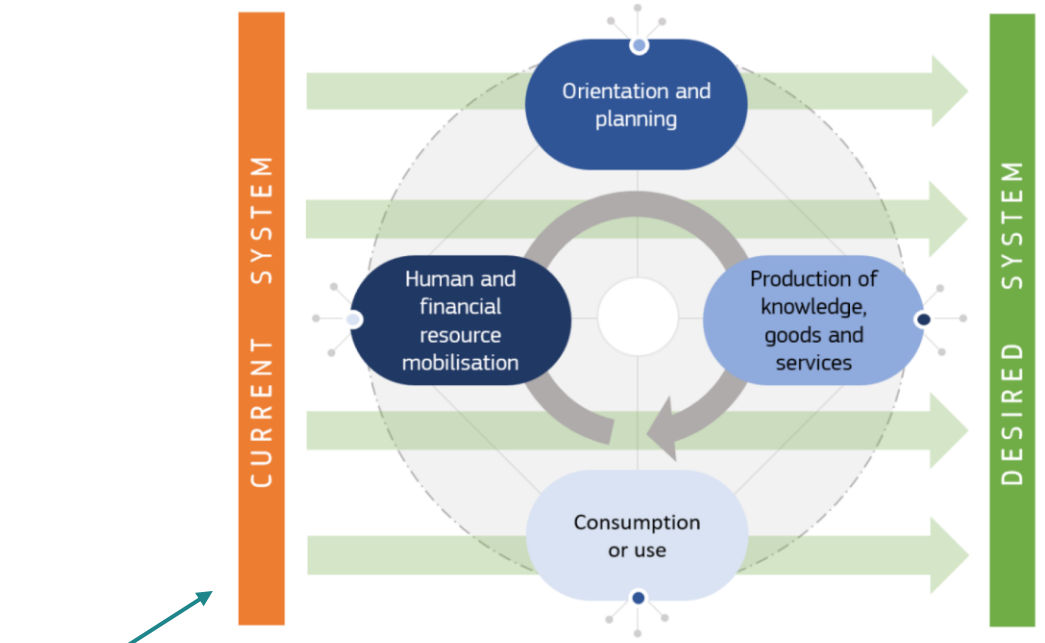
PRISM methodology: functions +CLDs

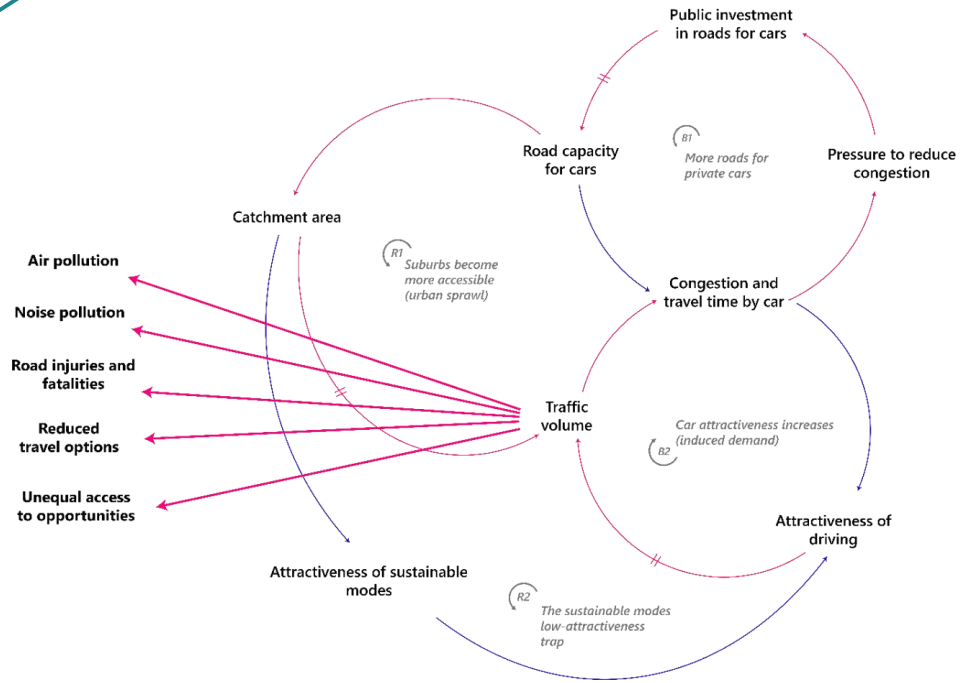
The functional perspective on systems

- Hekkert et al., Bergek et al.: Suggest the use of functional perspective as an alternative to the actor-based perspective in evaluations of innovation systems
- Barre et al (2013) - define macro-functions, but focused on research and innovation system
- Pontikakis et al (2020) – apply framework through the lens of system innovation and adapt **four** macro-functions

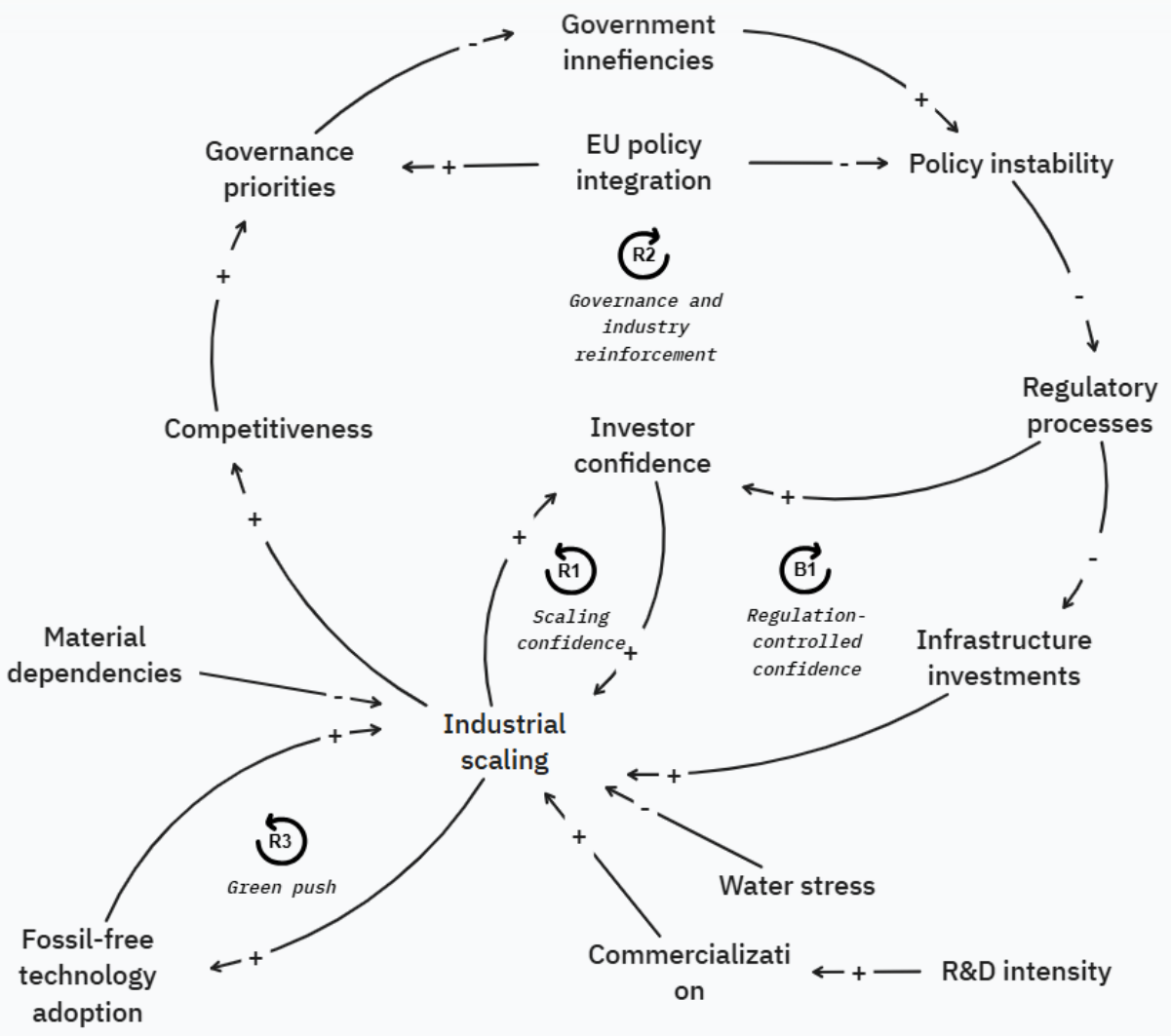
Causal loop diagrams as evaluation tools

- CLDs: If *reinforcing* loop driving system closer to desired state= function OK; If *balancing loop* and far from desired state= function NOT OK, need policy intervention
- e.g. OECD (2022) *Redesigning Ireland's Transport for Net Zero*





JRC case study: Sweden



'Episode' under study: "System transformation in the nexus of energy, mobility and energy-intensive industries".

Partner: VINNOVA

Steps

- Desktop research (PRISM methodology: functional approach, AI document tagging, CLD-based preliminary evaluation)
- Interviews
- PSDM: Workshop (10/6/25, Stockholm)
- POLYTRoPOS-Sweden fork of model
- Follow up PSDM workshop(s) to develop more feasible, ambitious and resilient policy bundles

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Conclusions

Policy use in terms of policy scenario development / assessment:

- Different approaches possible, also in combination
- Doubts regarding whether to start from the model, or from policy literature / practice. → PRISM
- Challenging to link some policy types to model variables (e.g. regulatory sandbox): participatory methods might help to contextualize
- Participatory modelling: translating mental models to simulation model, *and vice versa*

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Thank you

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Appendix

Conceptual building blocks:

- Policy inputs & goals
- Policy mix concepts
- Policy mix figures

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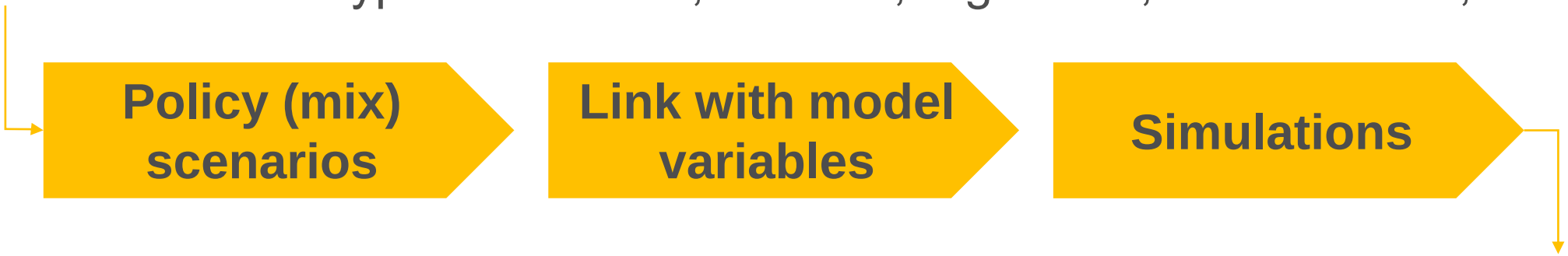
Building blocks: Policy inputs & goals

- **Policy inputs**. Can be characterized on various dimensions, e.g.:
  - Intervention types: carrots, sticks, sermons
  - Instrument types: subsidies, taxation, regulation, infrastructure, …



- **Policy goals** / Performance indicators
  - Economic growth (jobs; added value; GDP/capita), Competitiveness
  - Sustainability (emissions, material use, …)
  - (Independence / autonomy / sovereignty?)

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Building blocks: Policy mix - CONCEPTS

- **Policy mix components:** strategies & instruments
- **Policy mix dimensions**: governance level; sector; territory
- **Policy mix interactions**: incl. complementarities & synergies
- **Policy mix quality:** comprehensiveness, coherence, consistency
- **Policy mix delineation:** top-down vs bottom-up
- **Policy mix temporality**: the order of interventions matters
- **Policy feedback loops:** responsive and coalescing policy
  → policies can influence adjacent sectors
- **Policy mix agency:** influencing characteristics rather than elements

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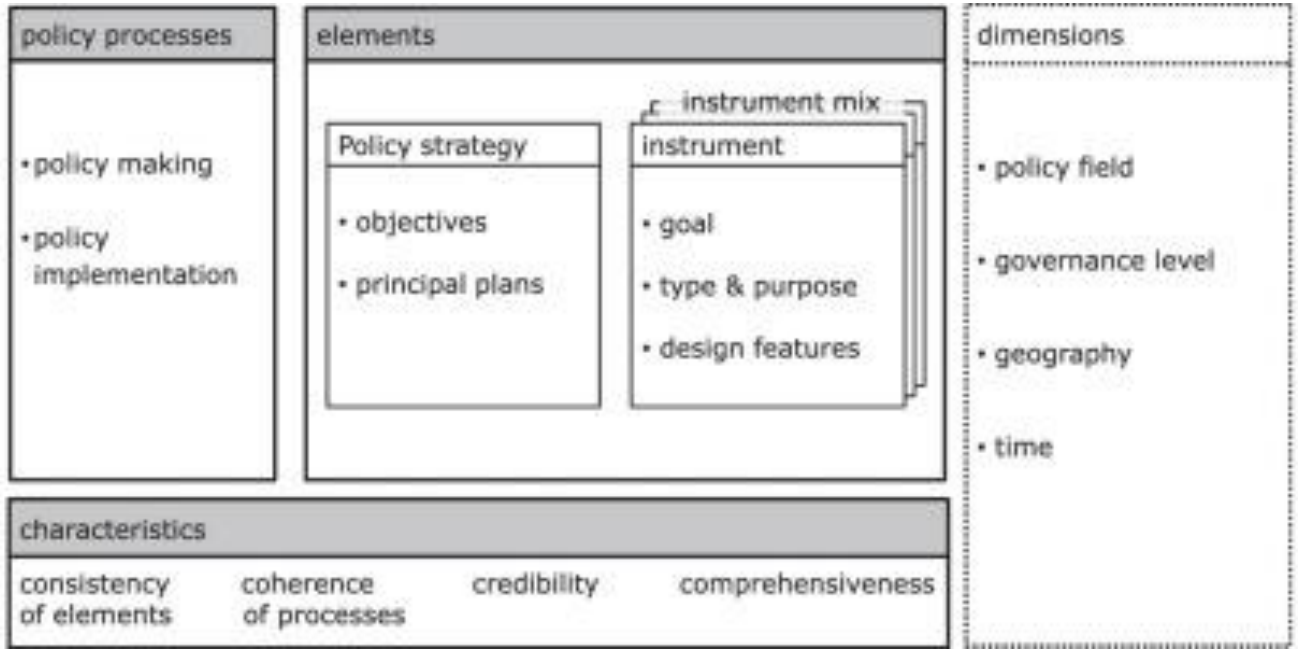
Building blocks: Policy mix - FIGURES



Rogge & Reichardt (2016) *Research Policy.* Policy mixes for sustainability transitions: An extended concept and framework for analysis - ScienceDirect

Building blocks: Policy mix - FIGURES

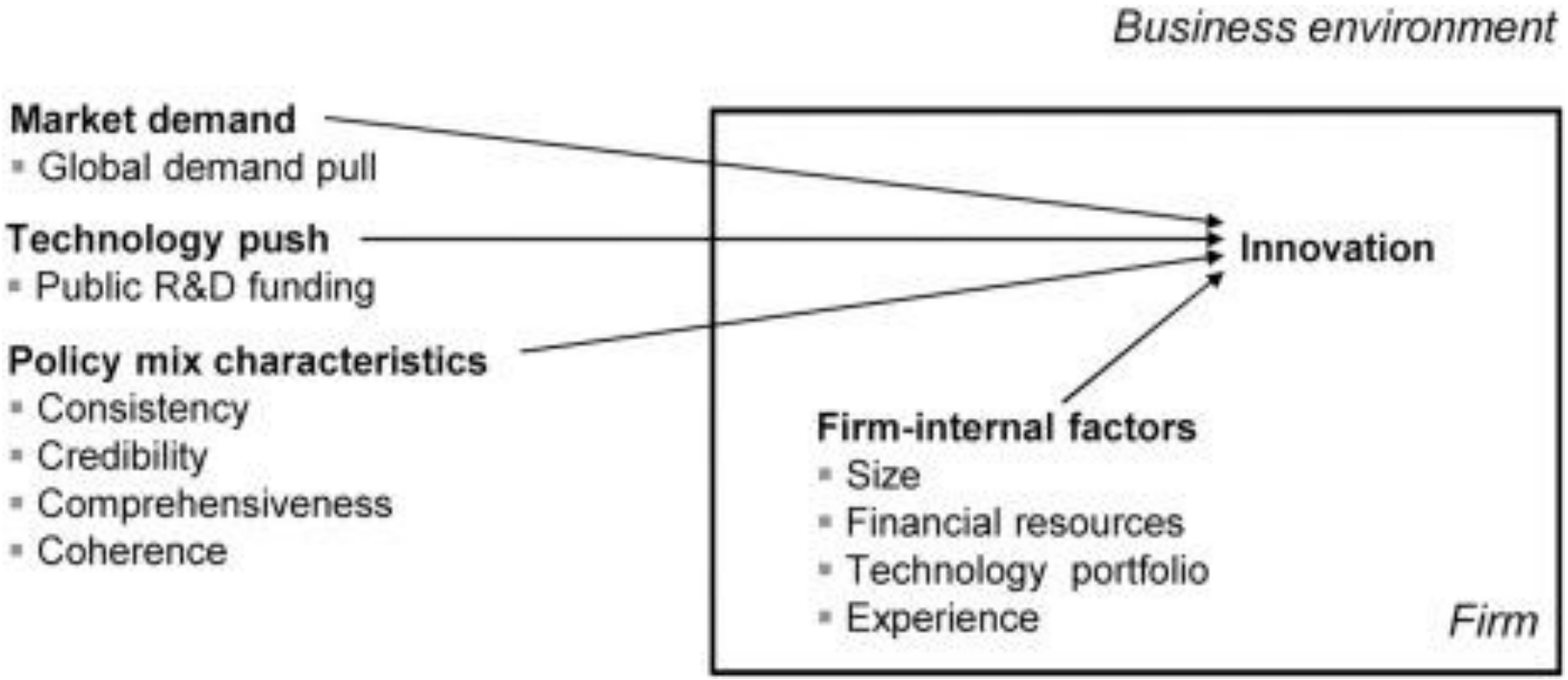
Dimensions in which interactions can occur
Across: Policy space Governance space Geographical space Time

Possible types of interaction
Between: 'different' instruments targeting the same actor/group (within/across dimensions) 'different' instruments targeting different actors/groups involved in the same process (within/across dimensions) 'different' instruments targeting different processes in a broader system (within/across dimensions)
Between: 'the same' instruments (across different dimensions)

Possible sources of tension between instruments in the policy mix
Conflicts between: policy rationales policy goals implementation approaches

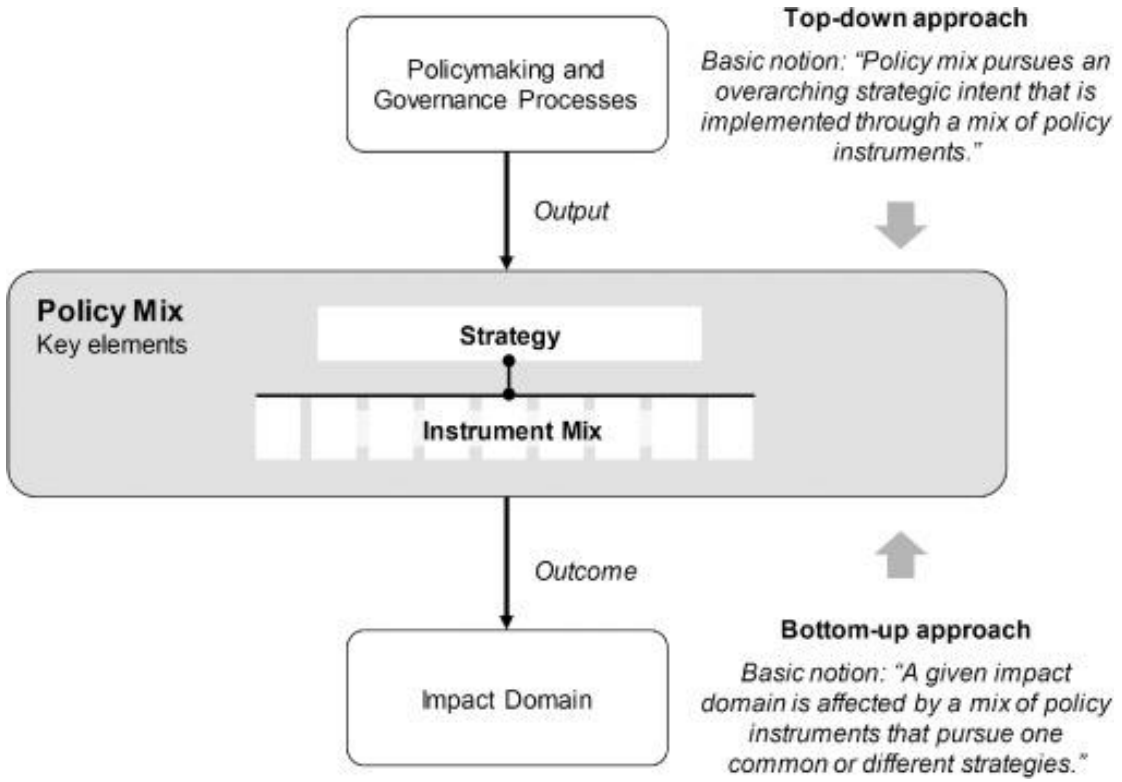
Flanagan et al. (2011) *Research Policy*. Reconceptualising the 'policy mix' for innovation - ScienceDirect

Building blocks: Policy mix - FIGURES



Rogge & Schleich (2018). *Research Policy*. Do policy mix characteristics matter for low-carbon innovation? A survey-based exploration of renewable power generation technologies in Germany

Building blocks: Policy mix - FIGURES



Ossenbrink et al. (2019) *Research Policy*. Delineating policy mixes: Contrasting top-down and bottom-up approaches to the case of energy-storage policy in California - ScienceDirect

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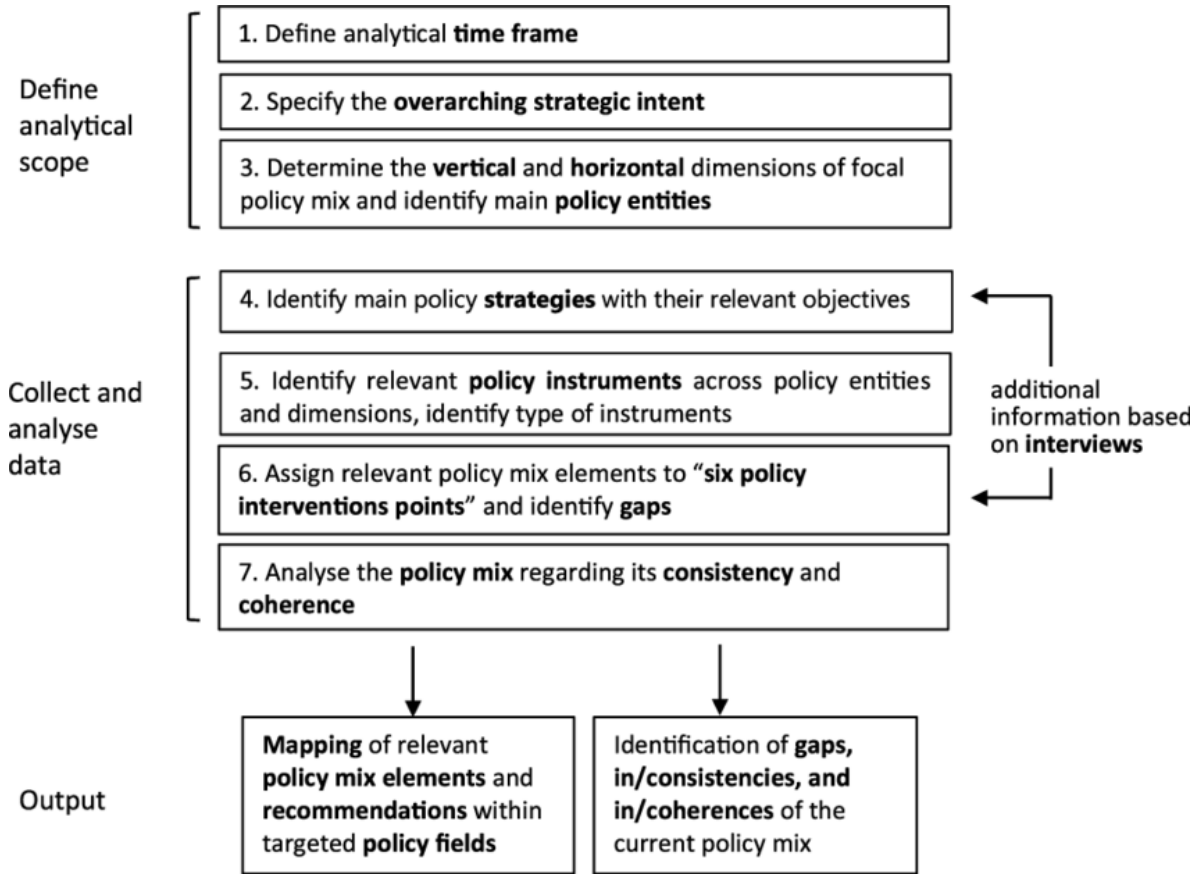
Building blocks: Policy mix - FIGURES



•olicy mix for the sustainable protein transition in Austria - Addressing repercussions of - regime shifts as a prerequisite for acceleration - ScienceDirect

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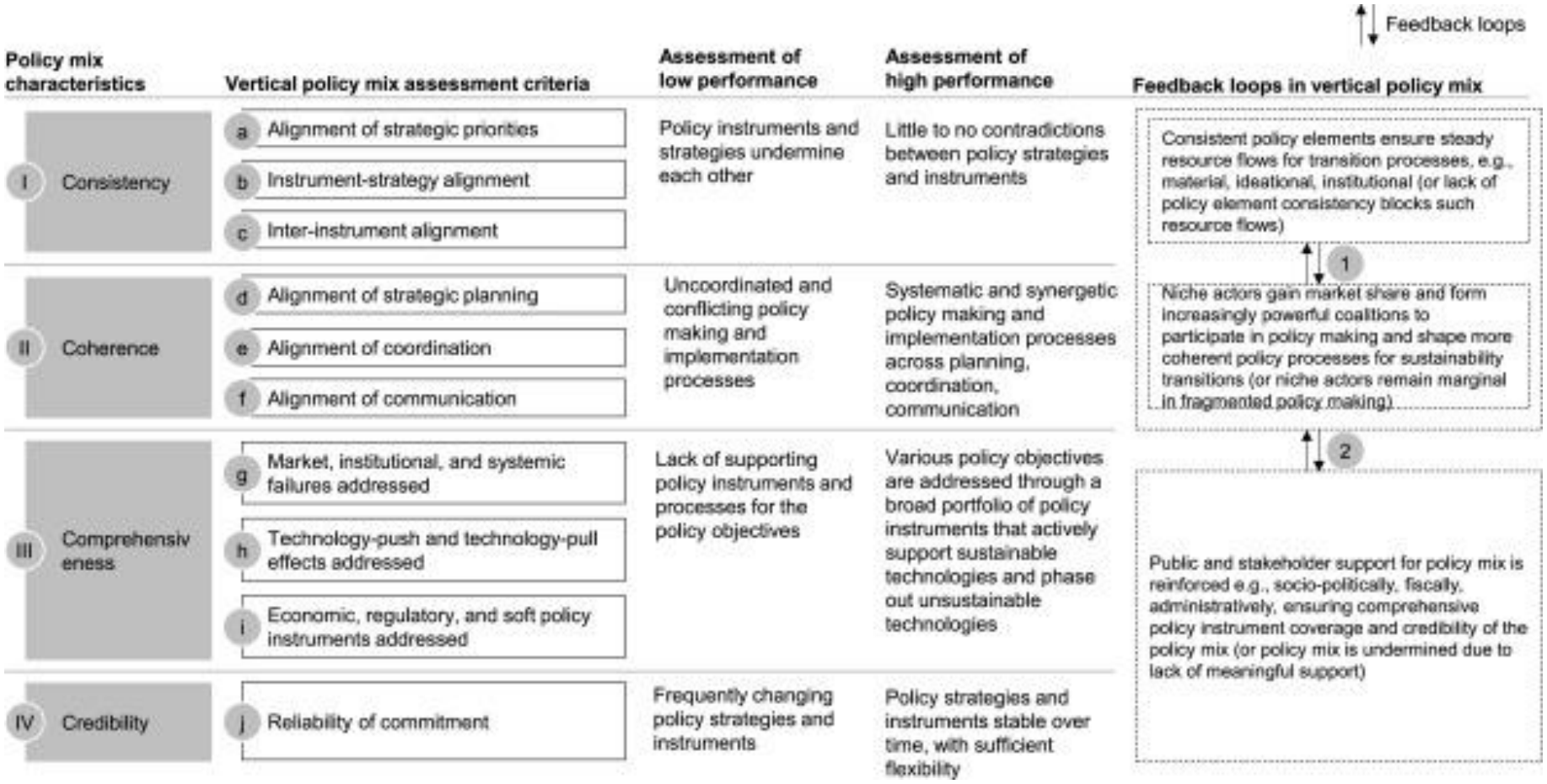

Zepa & Hoffmann (2023) *EIST*. Policy mixes across vertical levels of governance in the EU: The case of the sustainable energy transition in Latvia - ScienceDirect

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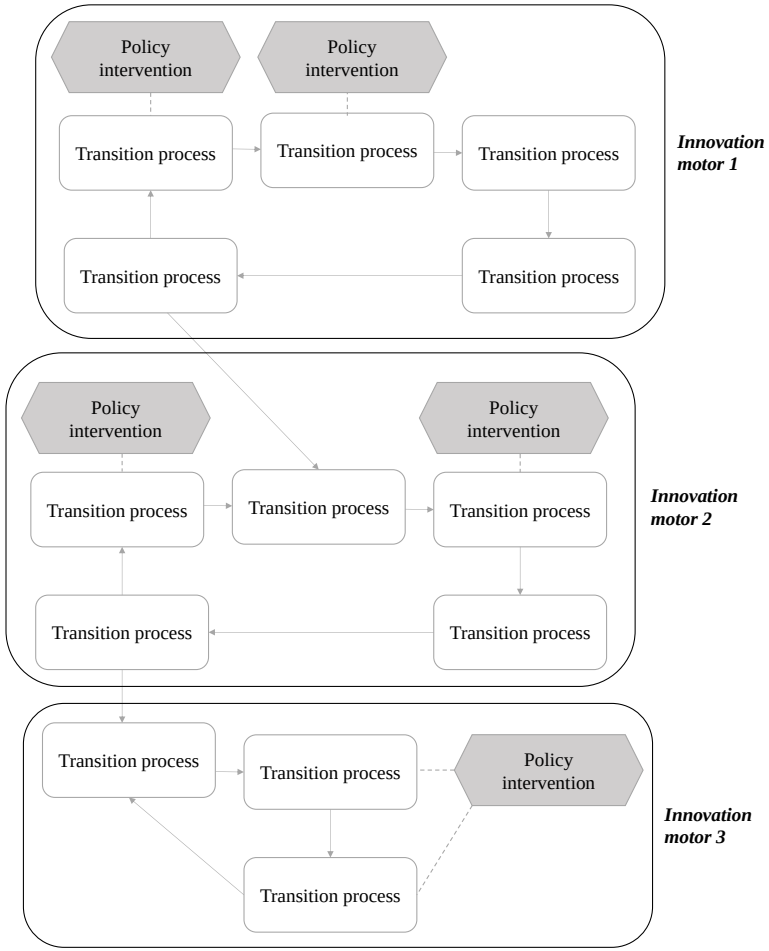

Theory: Policy-driven systemic change

- Policy evaluations based on TIS (or TO): **what system?**
  (Wise & Arnold 2022; Janssen 2019; Haddad & Bergek 2022; Gong & Hansen 2023)
- Interdependencies between policy mixes and innovation system development: **feedback loops!**
  (Reichardt et al. 2016; Edmondson et al. 2019)
- Geels (2022): untangling complex causal patterns
  - **conjunctural** causality (e.g. Pakizer et al. 2023)
  - **event-chain** causality (e.g. Tchorzewska et al. 2025)
  - Also needed: **configurational** causality (Geels 2022)

Kallenbach, Meelen & Janssen. Evaluating the role of policy in accelerating transitions: The success case of the electric bus in the Netherlands. Working paper.

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